DIAGNOSTIC TECHNOLOGIES FOR CULTURAL HERITAGE

Mariangela Cestelli Guidi

INFN - Laboratori Nazionali di Frascati

December 12, 2019

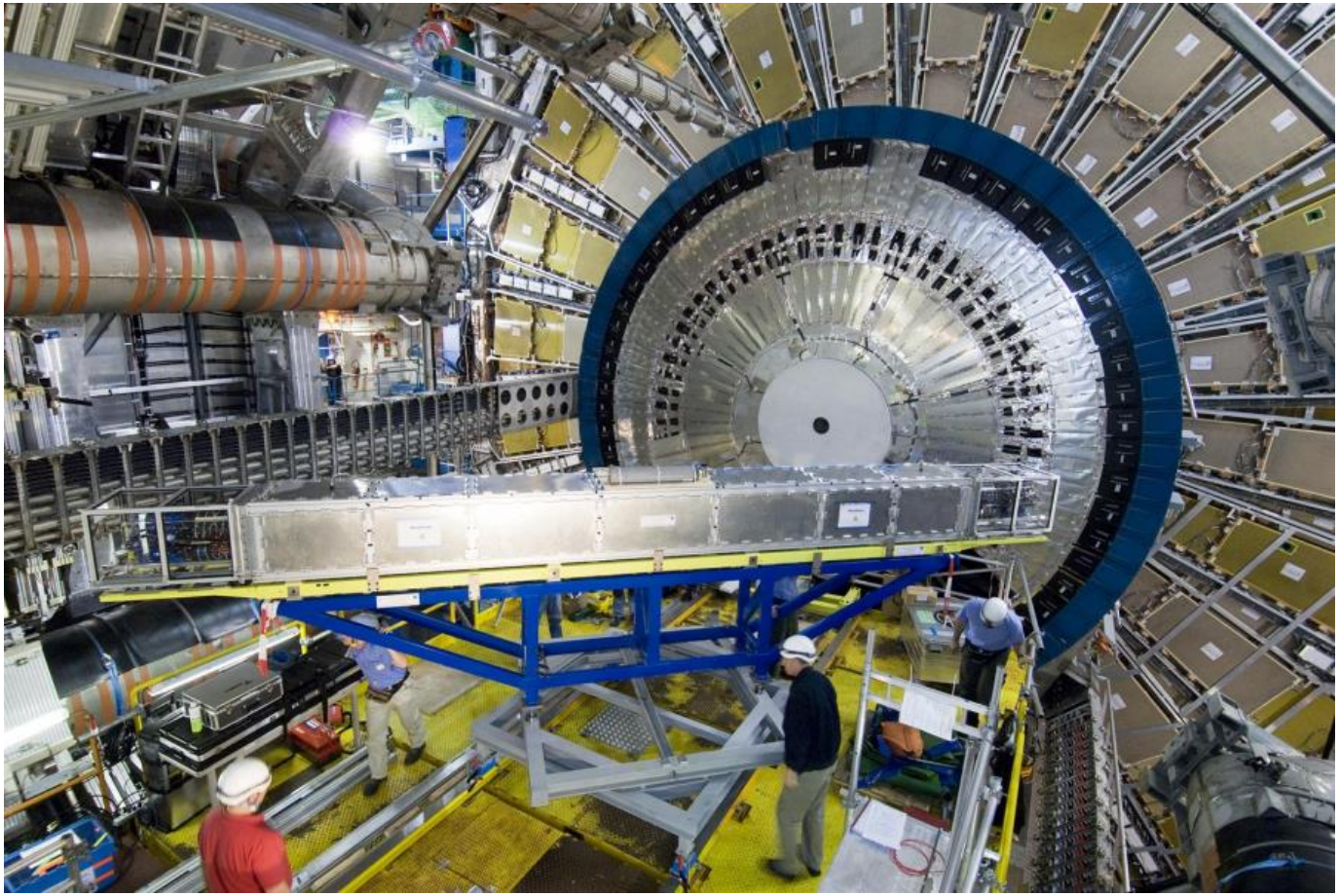
INFN CHNet
Istituto Nazionale di Fisica Nucleare
Cultural Heritage Network

Outline

- INFN and the Cultural Heritage Network CHNet
- Synchrotron radiation for the study of materials for cultural heritage
- Portable instruments for non invasive diagnostic technologies @ LNF and Tor Vergata research centers

INFN CHNet
Istituto Nazionale di Fisica Nucleare
Cultural Heritage Network

Istituto Nazionale di Fisica Nucleare (INFN)



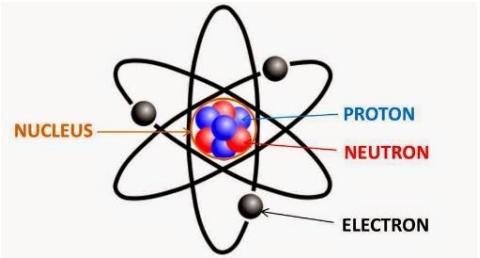
http://www.infn.it/it/

INFN and the National Frascati Laboratories

They are the largest laboratories in the INFN
The main feature is knowing how to build particle accelerators. This school began in **1957**, and continues until today.

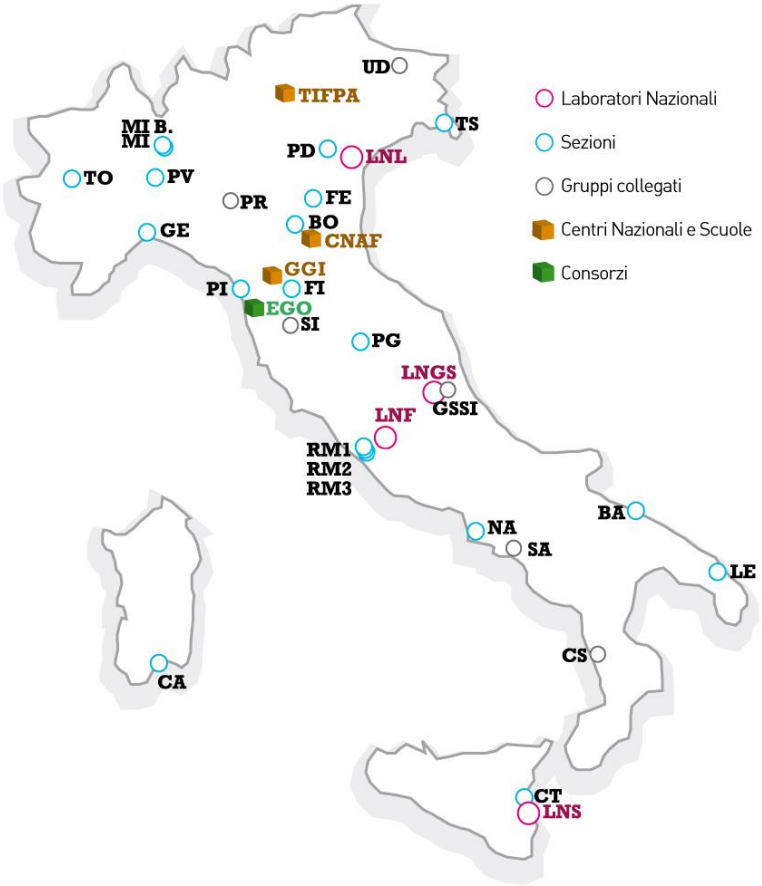
http://www.lnf.infn.it/edu/stagelnf/2009/relazioni_masterclass2009/milardi.pdf

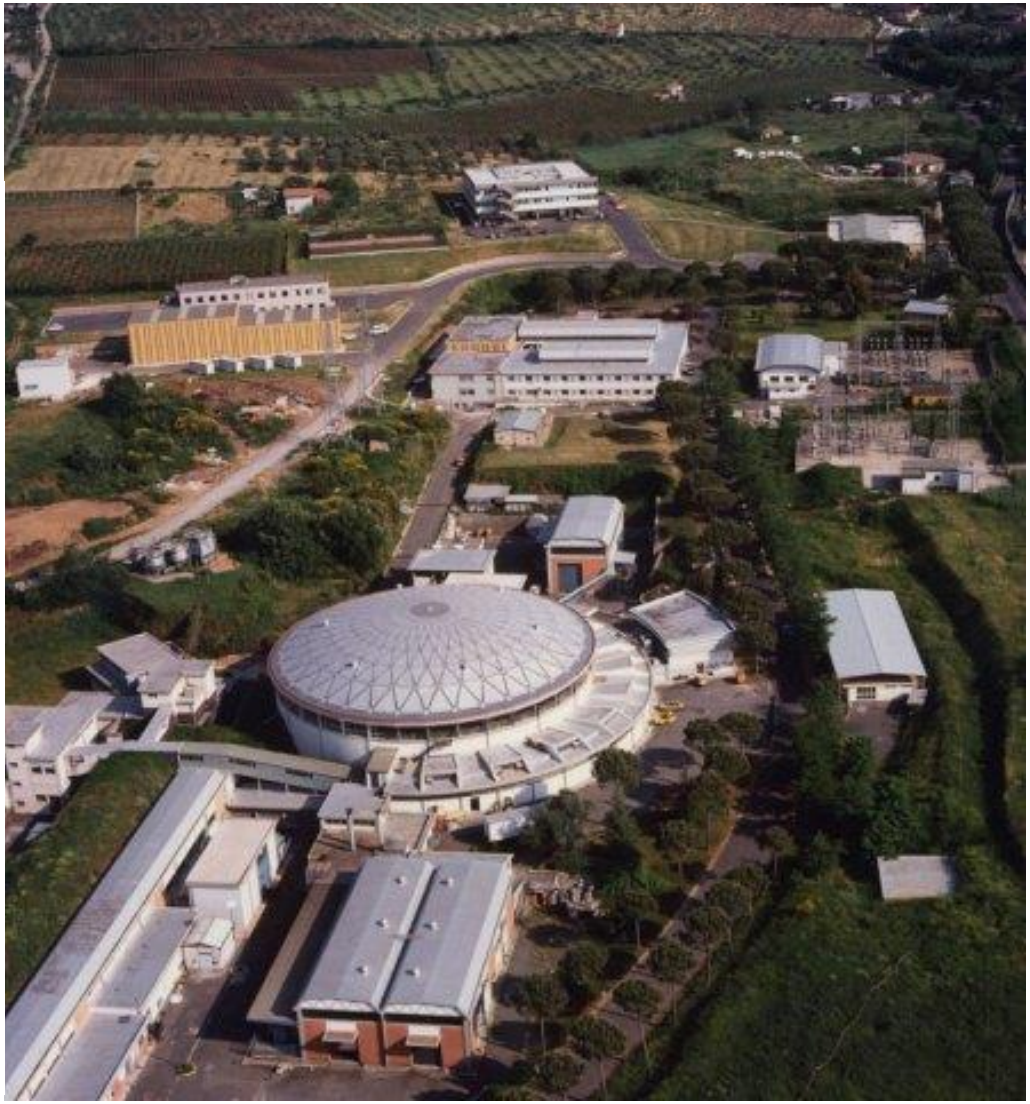
http://home.infn.it/immagini/picture.php?/552/tags/9-lnf



Particle accelerators were born to study the constituent elements of matter and the laws that regulate their interaction.

INFN - Frascati National Laboratories



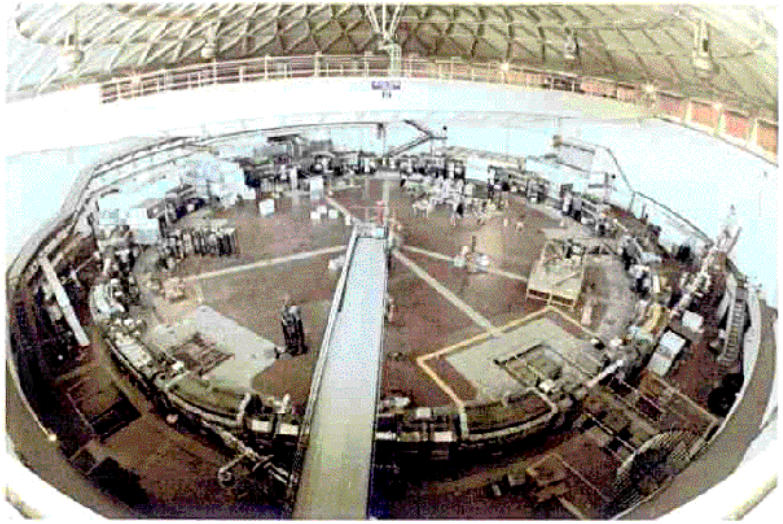


Frascati National Laboratories

The first Italian research facility for the study of nuclear and the subnuclear physics with accelerator machines.

Elettro sincrotrone (1959)

AdA (1961) primo acceleratore particelle-antiparticelle



ADONE The Big AdA (1969)

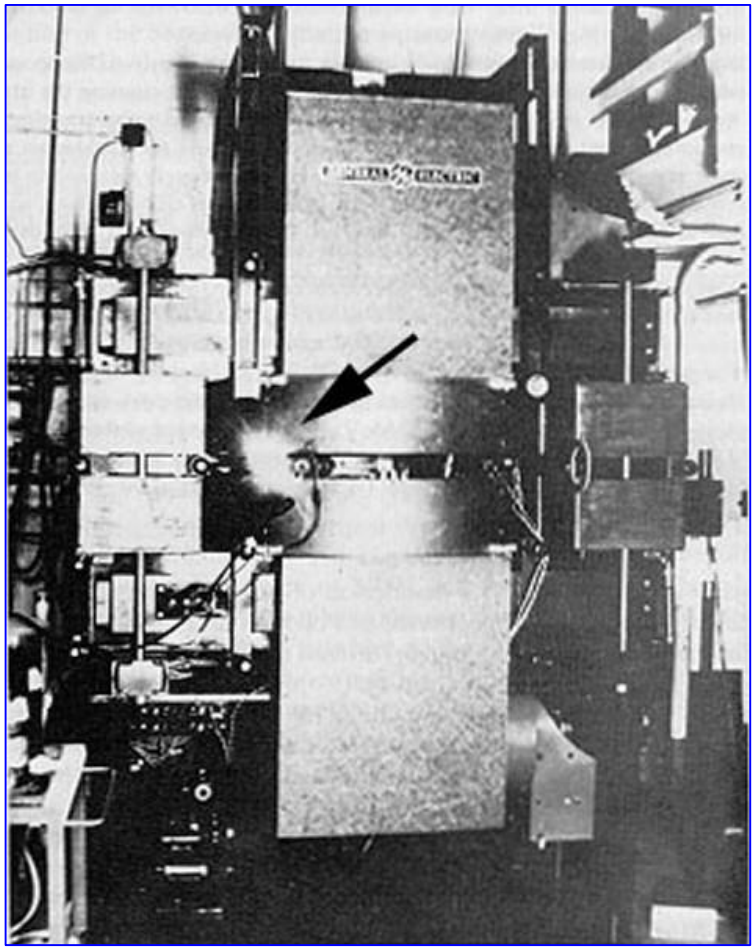
DAFNE (1995)

Light from accelerators

1887: Joseph Larmor and Alfred Lienard study the case of the radiation emitted by an electron in motion on a circular trajectory due to a centripetal acceleration.

1947: The visible part of the radiation emitted by an accelerated electron beam in the small 70 MeV synchrotron of the Schenectady Laboratory in New York is observed for the first time.

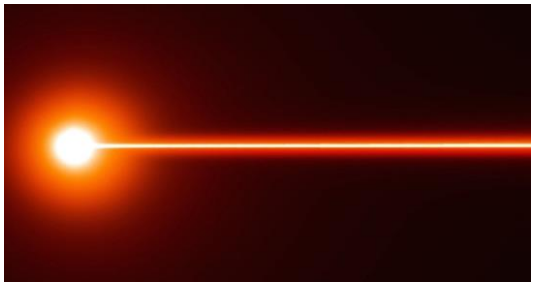
This radiation, for a long time, was considered as a disturbance for accelerating machines: the accelerated particles lost part of their energy in the form of radiation and this was then supplied to them.



1947 *General Electric Res. Lab.* - 70 MeV Electron Synchrotron – N.Y. USA

La Luce di Sincrotrone

In the second half of the 1950s, synchrotron radiation was used in a small number of laboratories around the world to conduct pioneering experiments



Today the situation has radically changed:

Synchrotron light becomes a truly unique radiation!

Thousands of researchers work in around 40 laboratories where accelerators are designed, built and optimized to produce synchrotron light.

ESRF, Grenoble - Francia 6 GeV, C = 844 m
aperta agli utenti nel 1994

Synchrotron Radiation Sources in the world

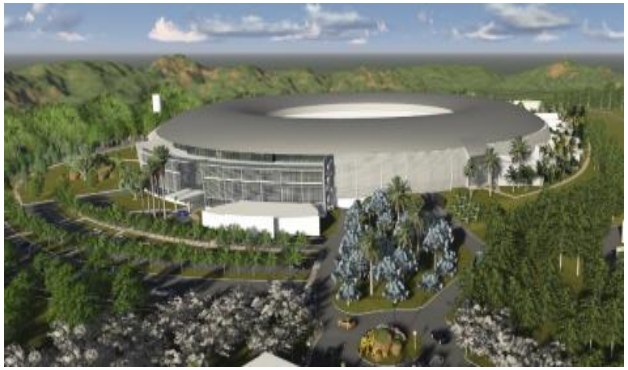
Elettra (2.4 GeV) - Trieste

DIAMOND (3 GeV) - UK

SESAME (2.5 GeV) - Jordan

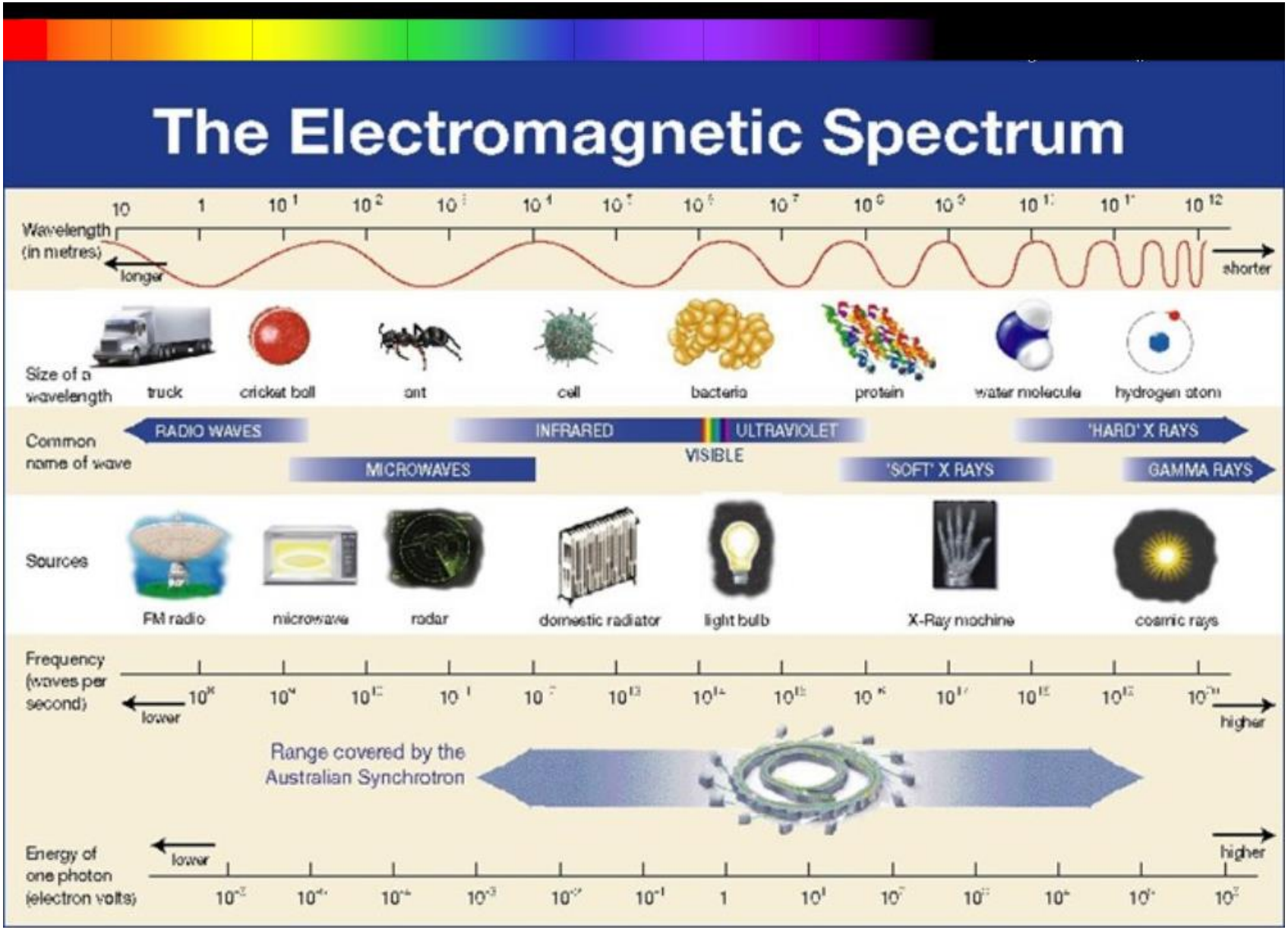
In construction – Ultimate SR facilities

Lund (3 GeV) - Svezia



Sirius (3 GeV) - Brasile

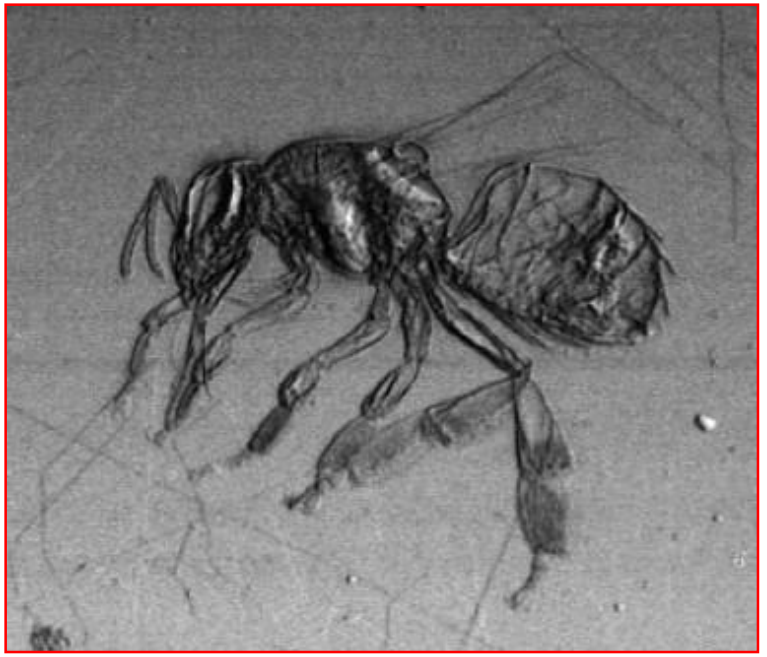
SSRF (3.5 GeV) Shanghai -Cina


The Electromagnetic Spectrum
Wavelength (in metres)
longer
shorter
Size of a wavelength
truck
cricket ball
ant
cell
bacteria
protein
water molecule
hydrogen atom
Common name of wave
RADIO WAVES
MICROWAVES
INFRARED
VISIBLE
ULTRAVIOLET
'SOFT' X RAYS
'HARD' X RAYS
GAMMA RAYS
Sources
FM radio
microwave
radar
domestic radiator
light bulb
X-Ray machine
cosmic rays
Frequency (waves per second)
lower
higher
Range covered by the Australian Synchrotron
Energy of one photon (electron volts)
lower
higher

Synchrotron radiation properties

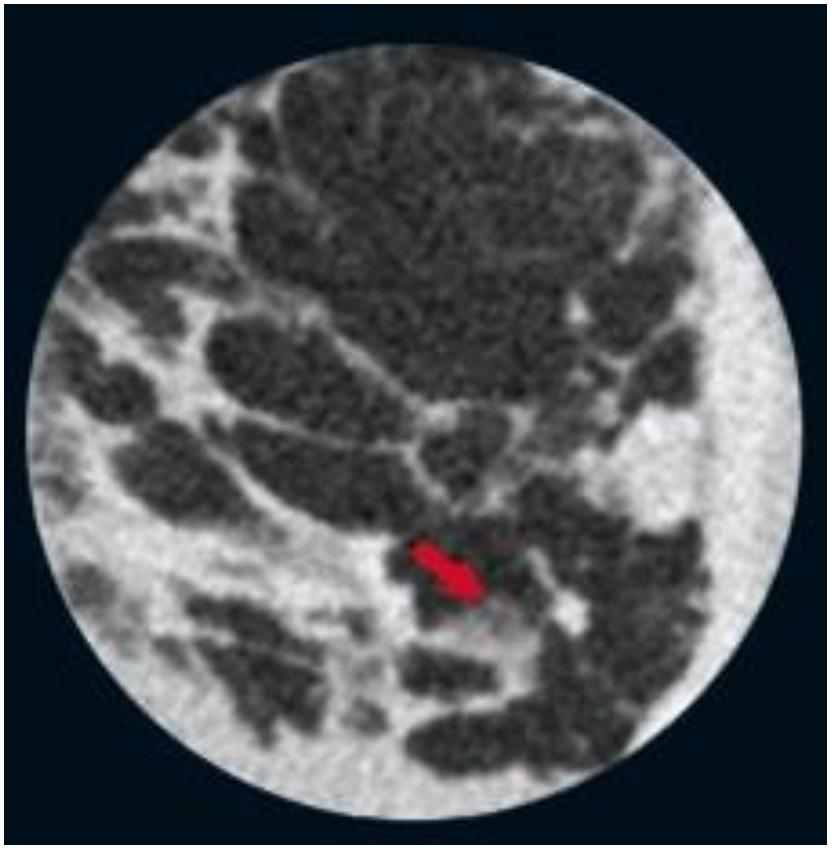
Better image quality, using radiation doses similar to or lower than those used in conventional radiography.

The comparison between the two images is clear:

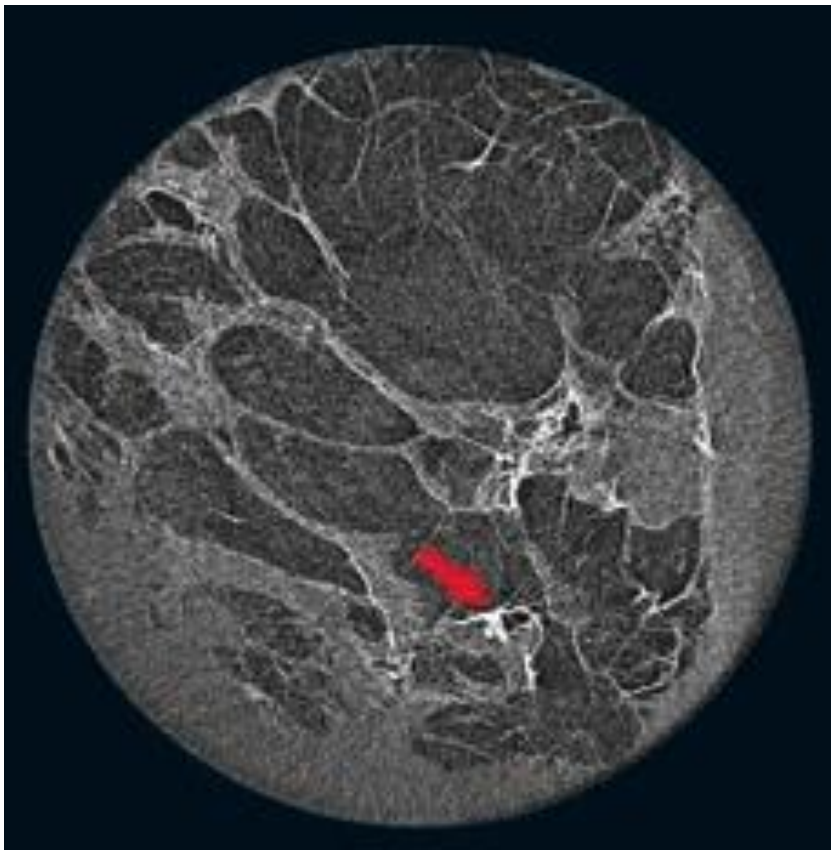


No other source of electromagnetic radiation presents, all together, the multiple and extraordinary characteristics of synchrotron light.

Medical applications



Esame senologico - TC Tomografia computerizzata convenzionale produce immagine 3D



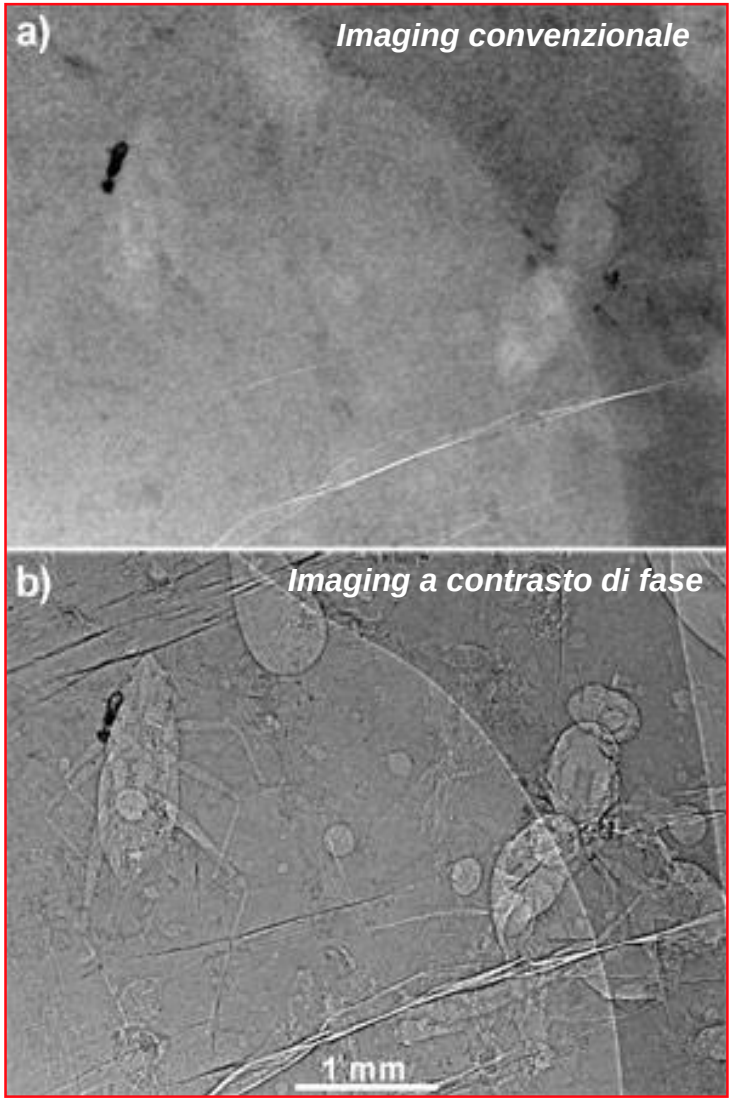
Esame senologico -ABI Analyser Based x-ray Imaging, 3D, risoluzione 7 volte migliore.

It guarantees much better resolutions. Micro calcifications, small deposits of minerals can clearly be observed, which can indicate the presence of tumors and their shape and margins can be more accurately defined.

La Luce di Sincrotrone in paleobiologia

Paleontologi dell' Università di Renne in Francia e ricercatori della facility di luce di sincrotrone ESRF a Grenoble hanno scoperto la presenza di 356 animaletti, inclusi in un pezzo (2 kg) di resina fossile di albero, completamente opaco, di 100 milioni di anni fa (periodo medio-Cretaceo)

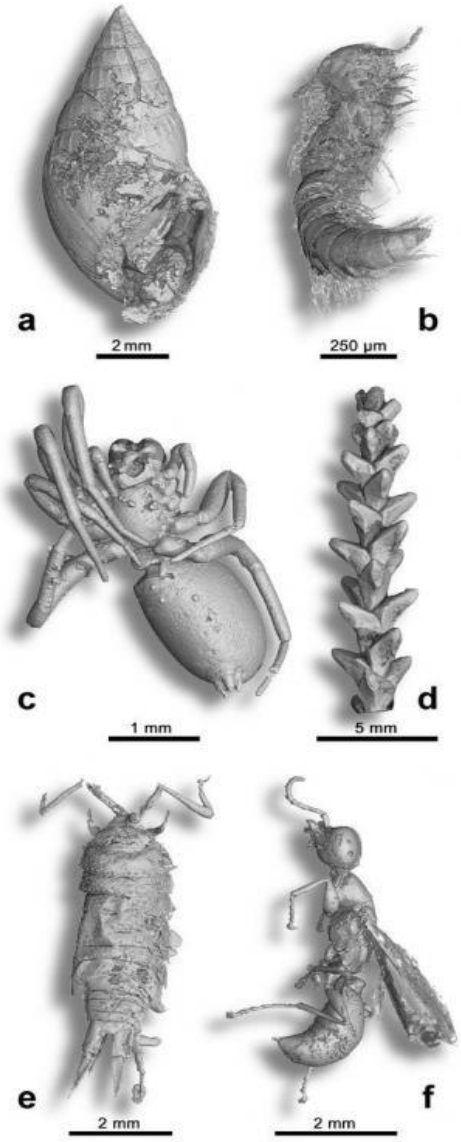
Ambra fossile opaca



M. Lak, D. Neraudeau, A. Nel, P. Cloetens, V. Perrichot and P. Tafforeau, Phase Contrast X-ray Synchrotron Imaging: Opening Access to Fossil Inclusions in Opaque Amber, **Microscopy and Microanalysis, (2008), 14:251-259**

La Luce di Sincrotrone in paleobiologia

Sempre ad ESRF usando la microtomografia X a contrasto di fase e' stato possibile effettuare una visualizzazione 3D dei microorganismi inclusi nel campione di resina fossile.



a) Gastropod Ellobiidae; b) Myriapod Polyxenidae; c) Arachnid; d) Conifer branch (Glenrosa); e) Isopod crustacean Ligia; f) Insect hymenopteran Falciformicidae.

M. Lak, D. Neraudeau, A. Nel, P. Cloetens, V. Perrichot and P. Tafforeau, Phase Contrast X-ray Synchrotron Imaging: Opening Access to Fossil Inclusions in Opaque Amber, Microscopy and Microanalysis, (2008)

Accelerators, Synchrotron radiation and Cultural Heritage

Fisica e Beni Culturali

The works of art are complex systems, made up of many different materials that tend to deteriorate with time and exposure to the environment.

Understanding what a work of art is composed of is essential for preserving it

We must imagine a work of art a bit like a "special" patient to whom an accurate diagnosis must be made before being able to perform “surgery”.

Quali domande ci poniamo davanti ad un'opera da analizzare?

- What are the materials used by the artist?
- What kind of technique did you use?
- Are there materials from later periods?
- Are there synthetic materials?
- Is there degradation?
- Is the cleaning method effective?
- Are the materials used compatible with the era or are we facing a fake?

Niccolo' Alunno: Madonna con Bambino e Santi (1499)

Madonna della seggiola
Dipinto su tavola, Raffello (1513)

To answer these questions there is a need for a team of scientists, each with different diagnostic techniques that work together

CHNet: the INFN network for cultural heritage

The interest for non destructive diagnostic techniques and conservation of the archeological and artistic heritage has enormously grown. **CHNet-Cultural Heritage Network** is the INFN competence network for the study and conservation of artworks, using technologies which are developed in the field of particle physics.

CHNet Coordinator: *Francesco Taccetti (ftaccetti@fi.infn.it)*

RESEARCH
TECH-TRANSFER
TEACHING
DIAGNOSTIC SERVICES

http://chnet.infn.it/it/chi-siamo-2/

CHNet: the INFN network for cultural heritage

The mission of INFN-CHNet is to become a reference point on the national and international scale, for the multidisciplinary community of public and private sectors that carry out their activities in the field of the study and diagnosis of cultural heritage.

For decades, the INFN laboratories have not only used the most modern technologies in this field, but, thanks to specific research projects, they are developing new ones looking for solutions to the problems posed by operators in the sector such as, for example, archaeologists, historians , restorers and conservators.

http://chnet.infn.it/it/home-2/

CHNet: the INFN network for cultural heritage

The different diagnostic techniques provide complementary information that can be useful for:

- restoration and conservation plans;
- study the materials used and the construction techniques;
- reconstruct the place of origin of the raw materials used for the construction of the artifacts (so as to be able to reconstruct the trade routes, or to use the original materials in the case of restoration and consolidation);
- dating artworks or archaeological sites;
- contribute to the authentication of the artworks.

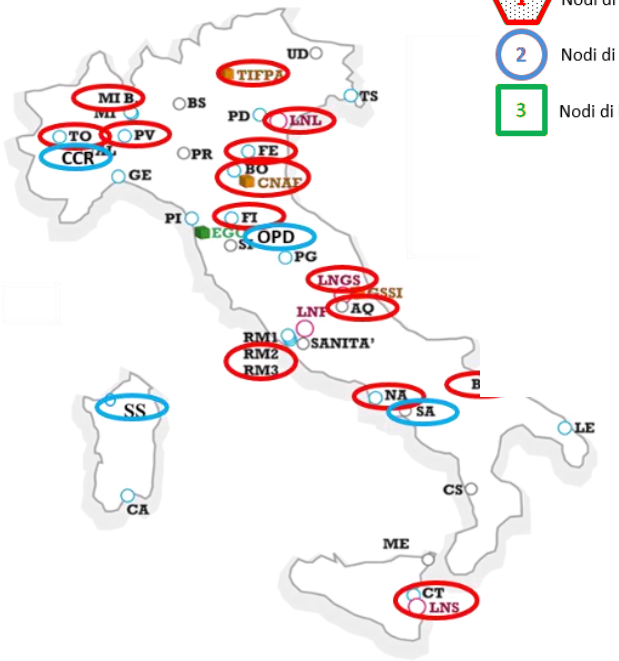
http://chnet.infn.it/it/home-2/

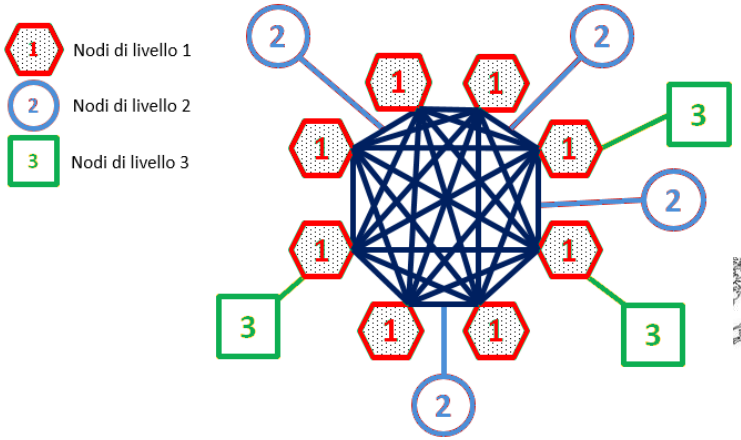
CHNet: the INFN network for cultural heritage

The network is composed of nodes :

- ✓ INFN structures - level 1 nodes;
- ✓ Universities and Restoration Centers - level 2 nodes;
- ✓ Scientific Research Centers Abroad Outside Europe - Level 3 nodes

Multidisciplinary and international network





INFN
CHNet
Istituto Nazionale di Fisica Nucleare
Cultural Heritage Network

SESAME

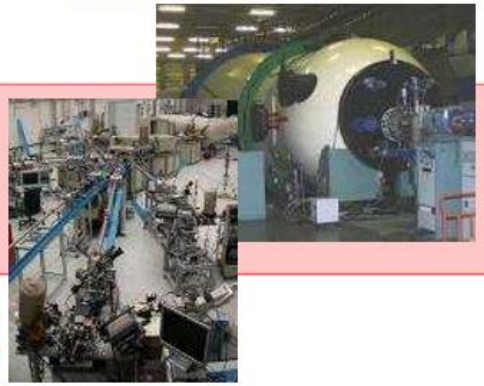
Call for proposals: January 27, 2020

https://www.sesame.org.jo/news/sesame-call-proposals-0

CHNet: Le piattaforme operative

INFN CHNet
Istituto Nazionale di Fisica Nucleare
Cultural Heritage Network

FIXLAB



TL dating

X-ray imaging

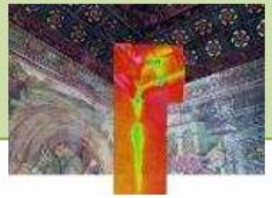
Mass Spectrometry

Medium-large scale facilities (IBA, ^{14}C, ...)

X-ray imaging

MOLAB

Thermography

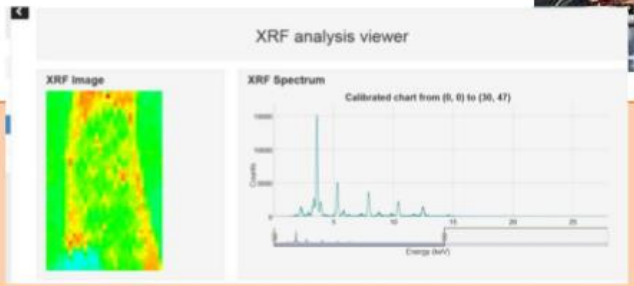


XRD

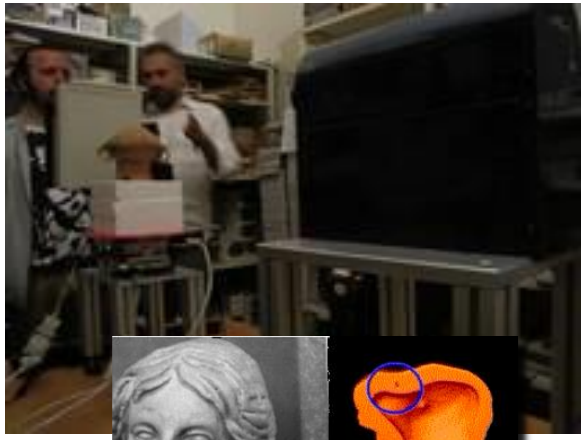
XRF

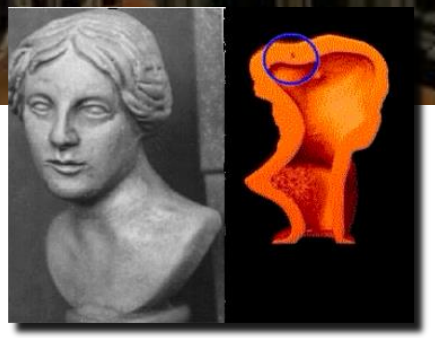
DIGILAB

Web tool for data fruition



Data Storage and fruition



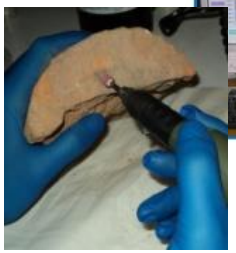


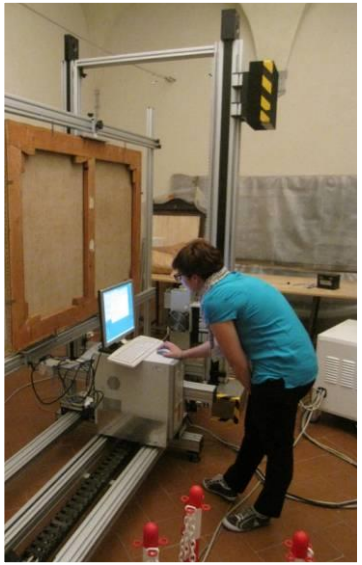
INFN

CHNet

Istituto Nazionale di Fisica Nucleare

Cultural Heritage Network





The scientific approach to conservation

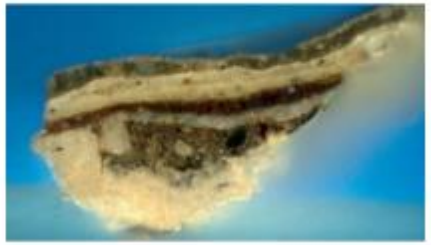
Material ageing, climate change, atmospheric pollution, anthropic pressure combined with inappropriate conservation and restoration procedures have also contributed to degradation of artworks.
The modern approach to conservation requires a deep scientific investigation before any treatment.

Sampling techniques

* Non destructive

- Multispectral Imaging (UV, VIS, NIR, SWIR)
- Micro-photography
- Raman Spectroscopy
- FT-IR Spectroscopy
- XRF

* Micro destructive



- Micro-FT-IR Spectroscopy with conventional and Syncrotron radiation Source
- SEM-EDS
- Micro-Raman Spectroscopy
- FT-IR Spectroscopy

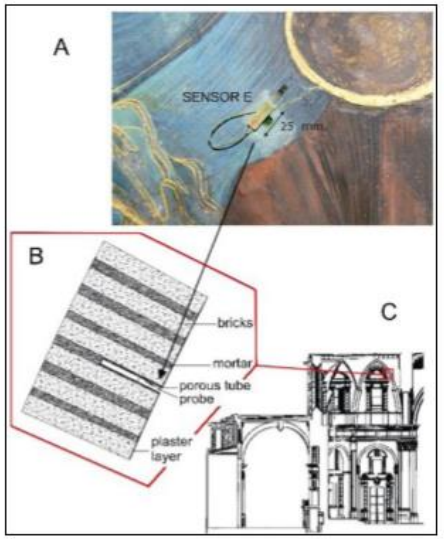
Metodi non distruttivi e micro-distruttivi

In situ diagnostic

Laboratory diagnostic

Conservation

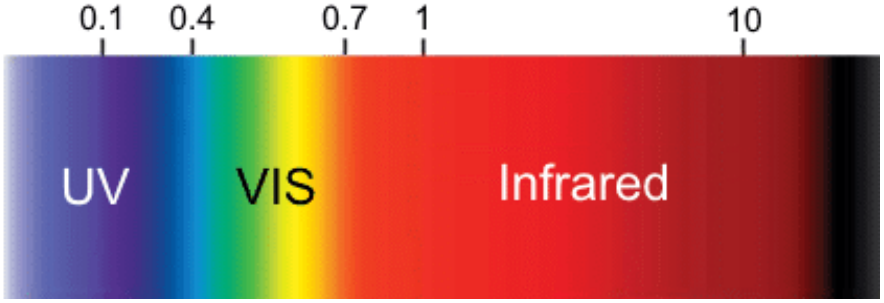
Monitoring

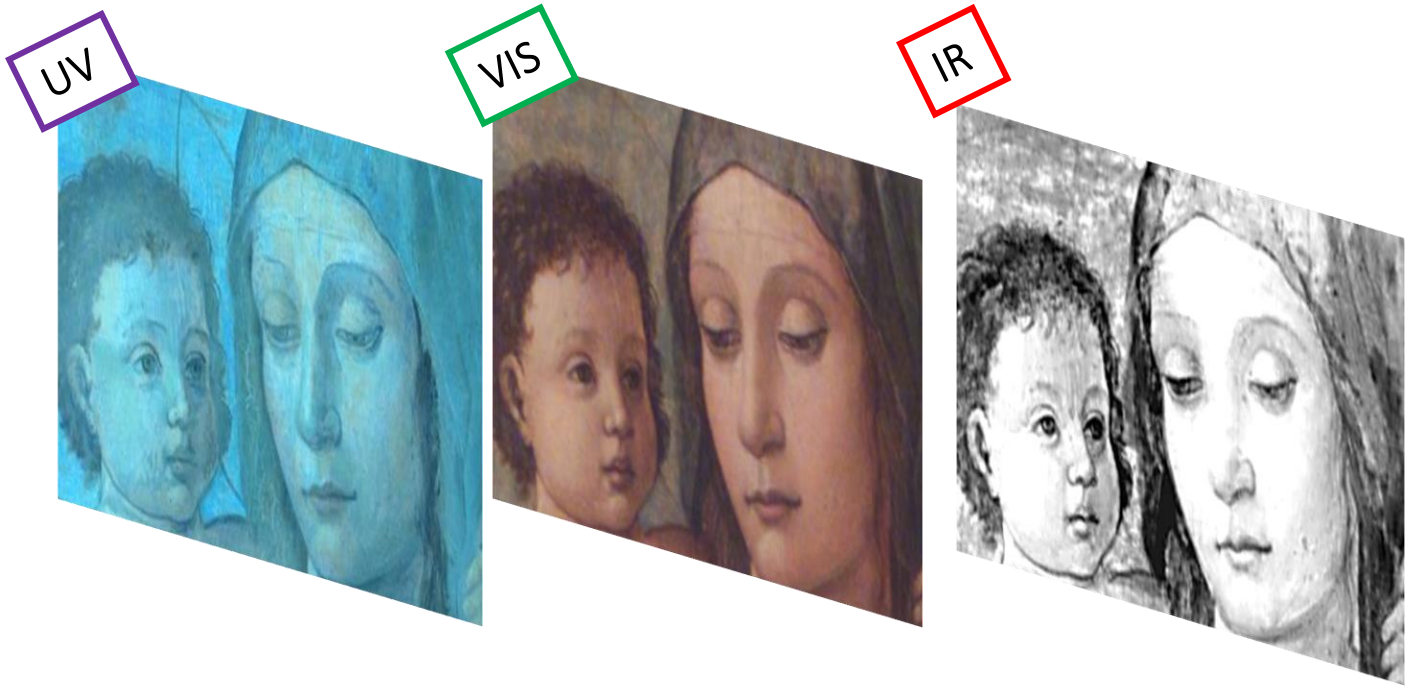


Imaging Techniques

Multispectral Imaging Techniques

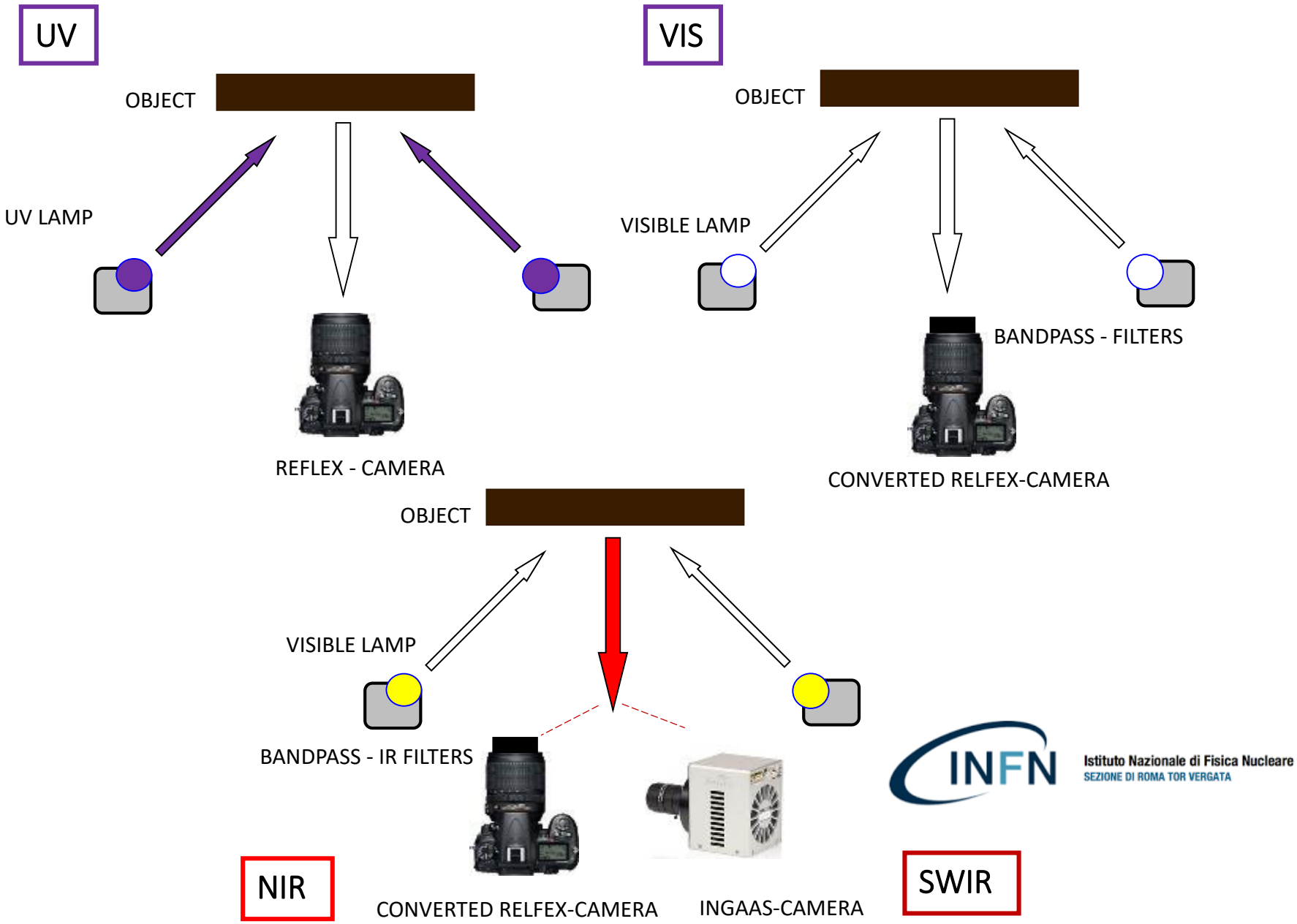
Imaging techniques: are the conversion into visible photographic images of surface interaction with electromagnetic radiation that cannot be detected by the human eye



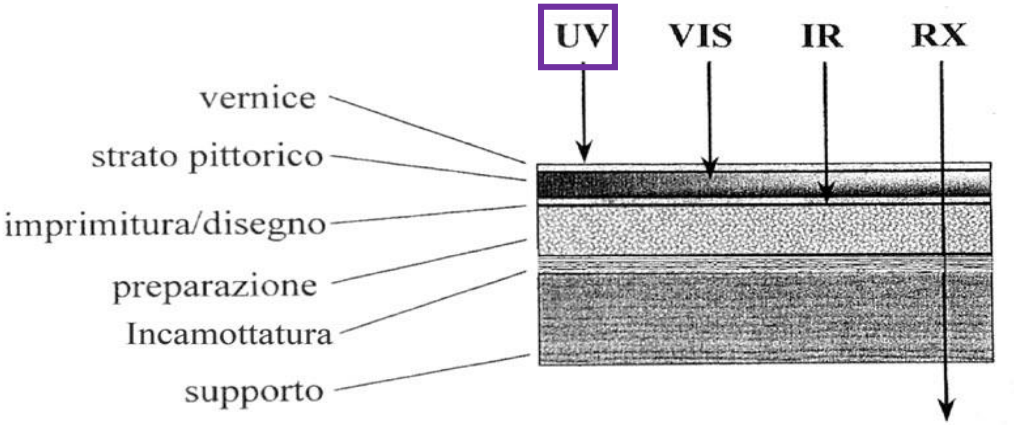


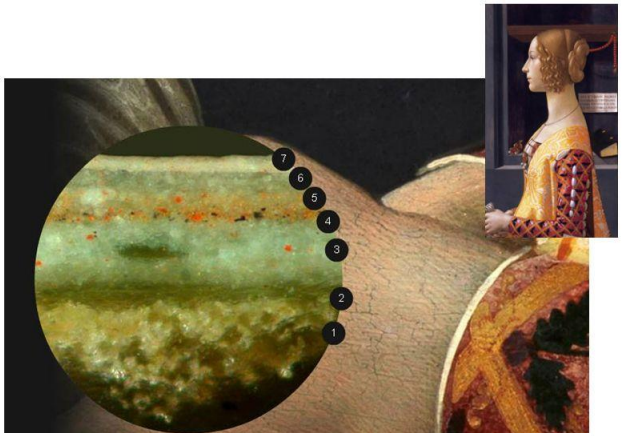
UV FLUORESCECE PHOTOGRAPHY IR REFLECTOGRAPHY

Non-invasive Analysis set up for in situ analyses (UV, VIS, NIR, SWIR)

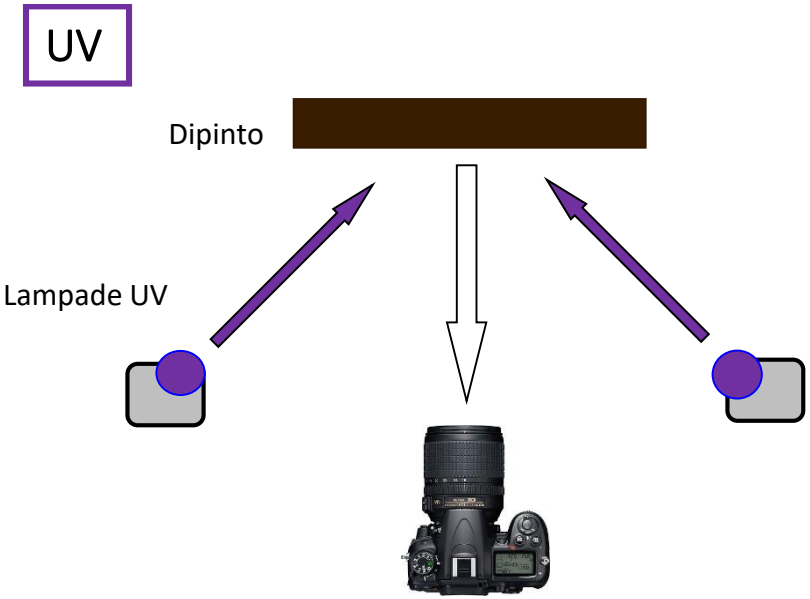


Multispectral imaging techniques

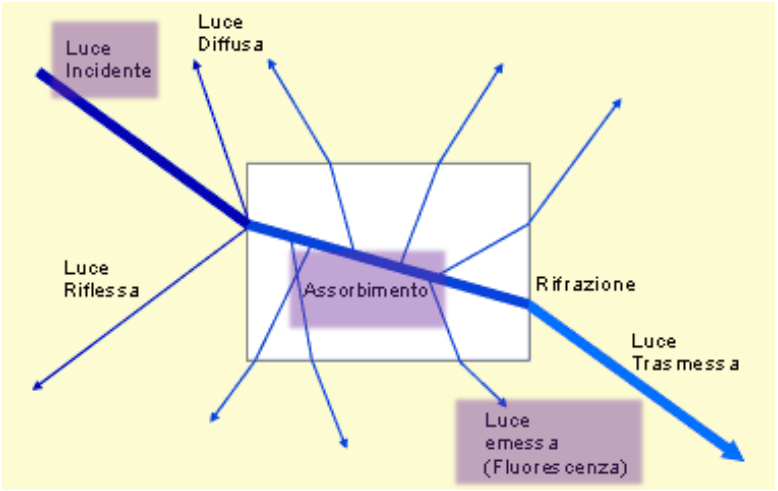




Stratificazione del dipinto «Ritratto di Giovanna Tornabuoni» di Domenico Ghirlandaio :
1 preparazione (gesso e colla)
2 disegno preparatorio
3 verde di Boemia che fa da base a tutte le parti di incarnato
4-7 diversi strati di colore (poi completati da una mano di vernice)



SISTEMA DI ACQUISIZIONE DI IMMAGINI



Multispectral imaging techniques

UV FLUORESCENCE IMAGING

QUALITATIVE ANALYSIS
(Camera acquisition system)

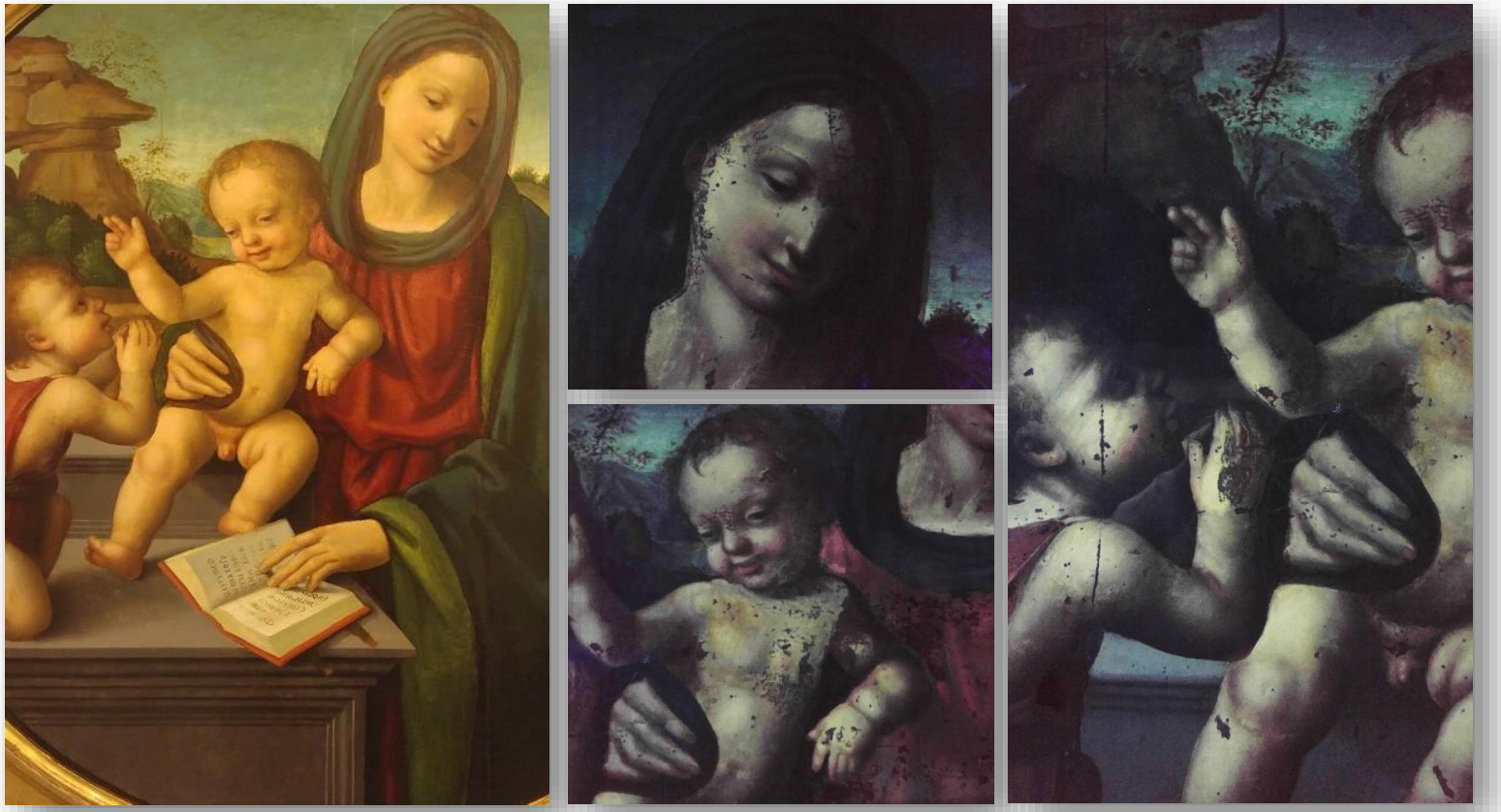
1) Modern restoration interventions (absence of uv fluorescence emission)

olio su tavola «Madonna con Bambino» di Francesco di Giorgio Martini (XV sec.) – Accademia di San Luca (Roma)

olio su tavola «Madonna con Bambino» di scuola veneta (XV sec.) – Accademia di San Luca (Roma)

Multispectral imaging techniques

UV FLUORESCENCE IMAGING

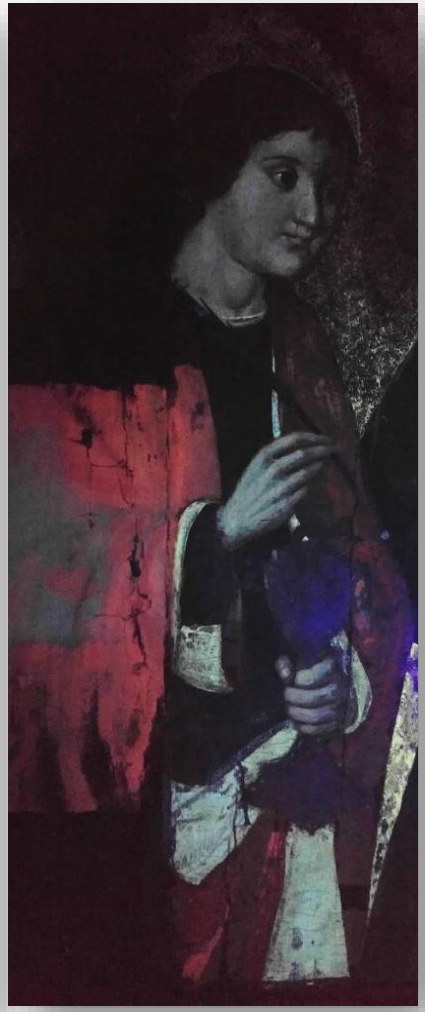


olio su tavola «Madonna con Bambino e San Giovannino» di pittore toscano (Tommaso di Credi?) (inizi secolo XVI) – Palazzo Rosso (Genova)

Multispectral imaging techniques

UV FLUORESCENCE IMAGING

2) Pictorial materials with UV fluorescence

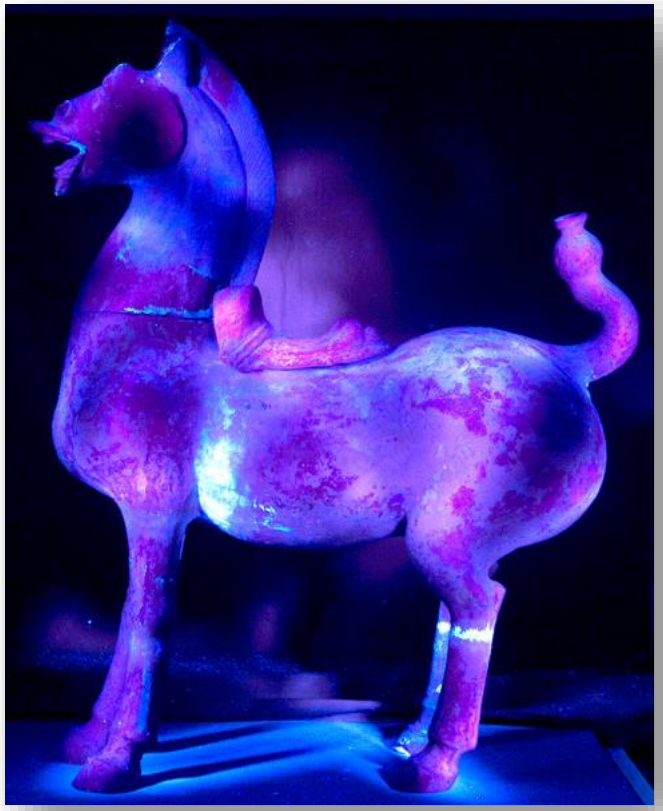


Olio su tavola «San Giovanni Evangelista, San Zaccaria e una Santa» di Francesco Brea (Nizza?, 1512 - 1555) – Palazzo Rosso (Genova)

Multispectral imaging techniques

Non solo dipinti….

UV FLUORESCENCE IMAGING



Cavallo di ceramica della dinastia Han, China.
National Gallery of Australia

Particolare dell'Afrodite detta "*del Fréjus*".
Museo del Louvre

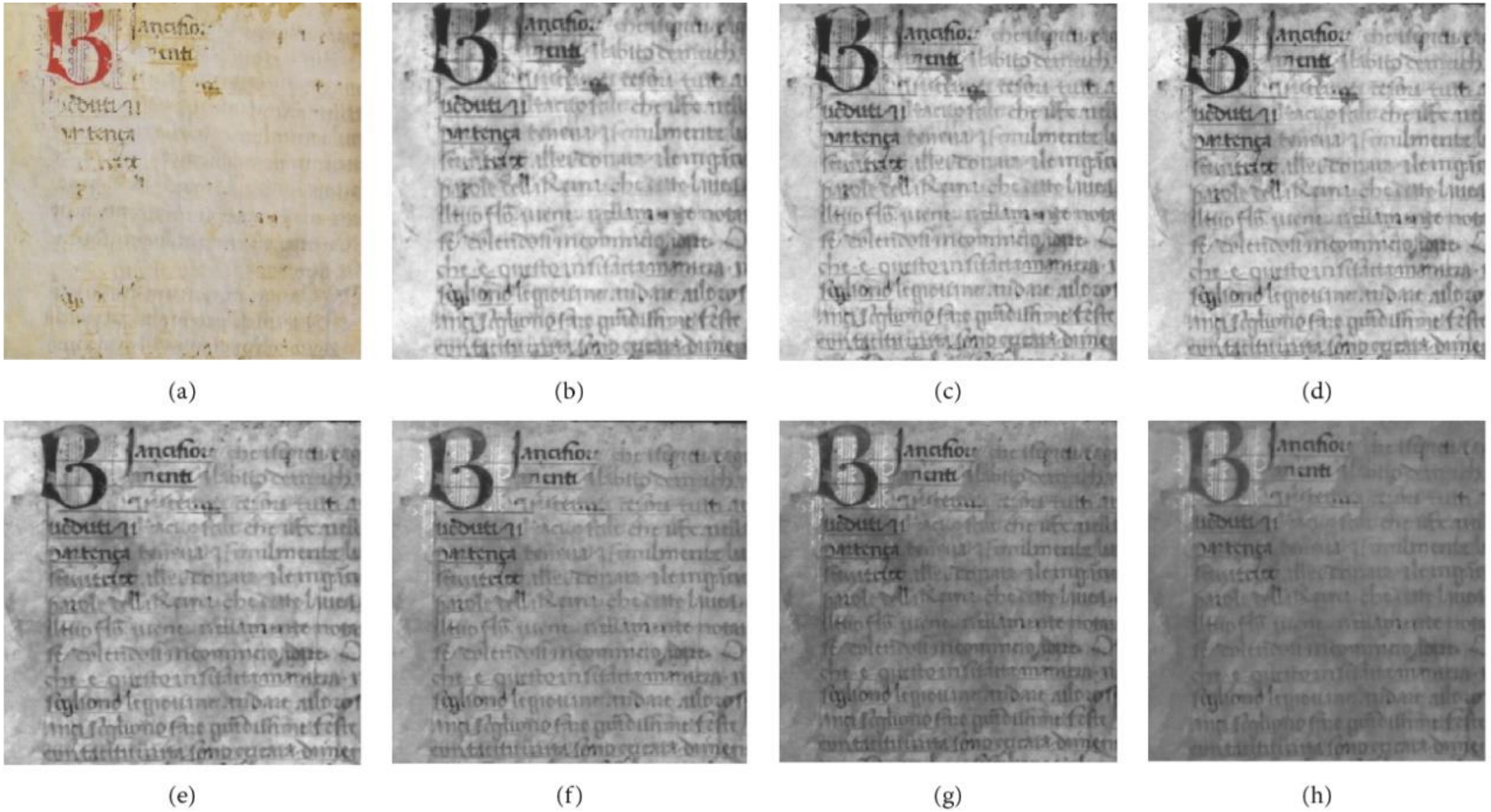
Multispectral imaging techniques

INFN CHNet
Istituto Nazionale di Fisica Nucleare
Cultural Heritage Network

UV FLUORESCENCE IMAGING

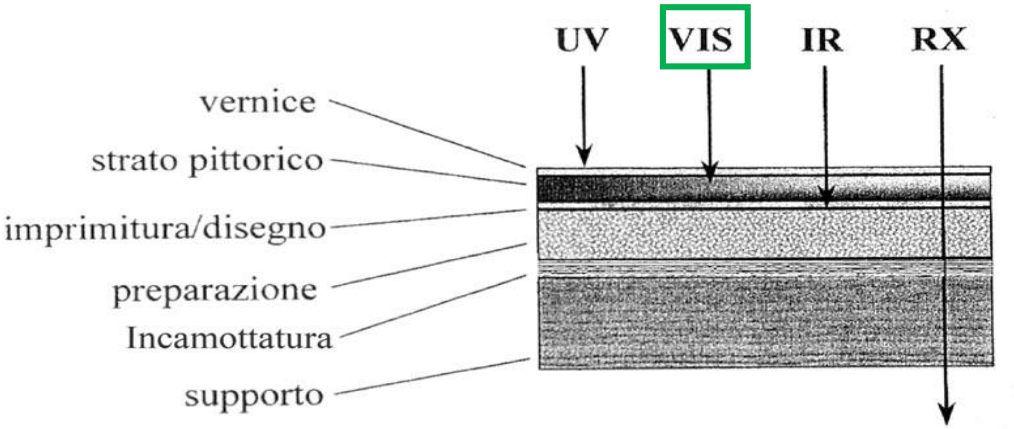
Not only paintings….

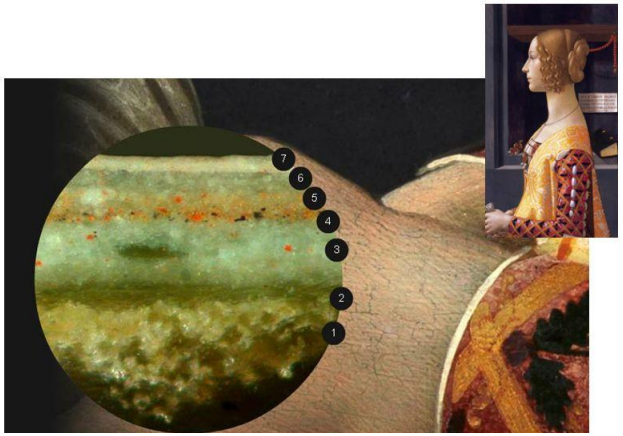
"Provvisorio 38" - foglio di pergamena del 15 secolo che contiene un frammento del "Filocolo" di Giovanni Boccaccio.



Immagini multispettrali prese a 470 nm (b), 500 nm (c), 532 nm (d), 600 nm (e), 680 nm (f), 700 nm (g), e 750 nm (h)

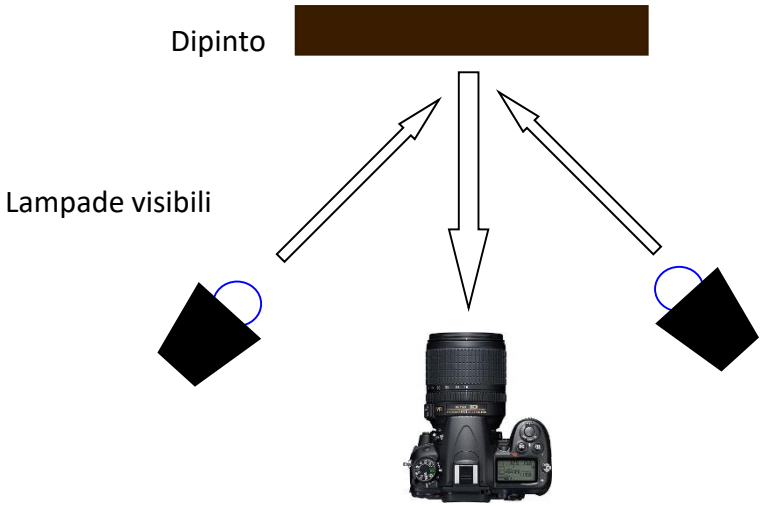
Multispectral imaging techniques



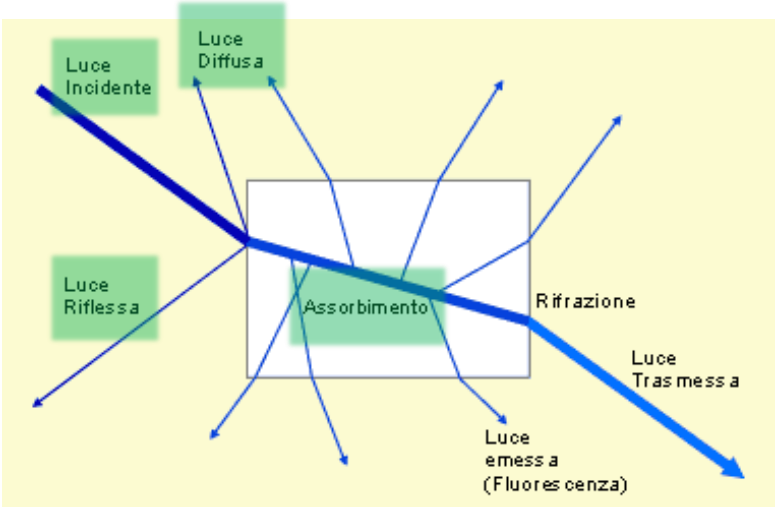


Stratificazione del dipinto «Ritratto di Giovanna Tornabuoni» di Domenico Ghirlandaio :
1 preparazione (gesso e colla)
2 disegno preparatorio
3 verde di Boemia che fa da base a tutte le parti di incarnato
4-7 diversi strati di colore (poi completati da una mano di vernice)

VIS



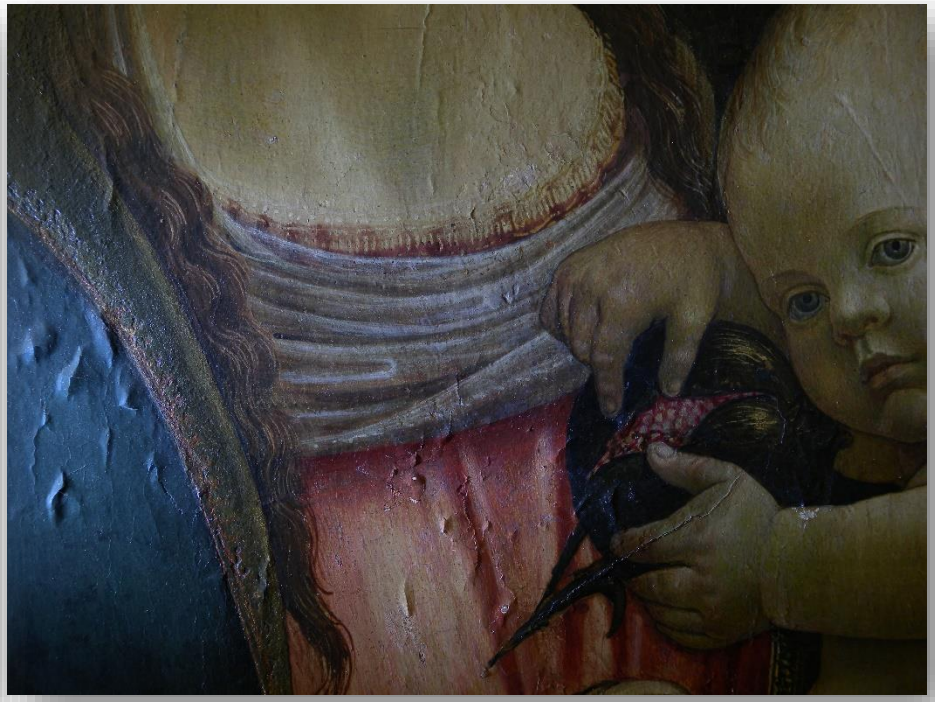
SISTEMA DI ACQUISIZIONE DI IMMAGINI



Tecniche di imaging multispettrale

FOTOGRAFIA IN LUCE RADENTE

- ✓ Deformazione del supporto in tela/tavola
- ✓ Rigonfiamenti, lacerazioni, strappi, cuciture o integrazioni
- ✓ La presenza di elementi per l'assemblaggio
- ✓ Lo spessore degli strati pittorici e loro sequenza di applicazione
- ✓ Sollevamenti, cadute e integrazioni del colore

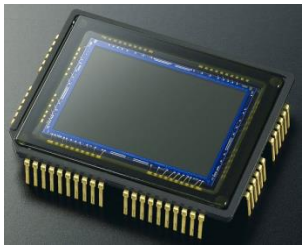


Olio su tavola «Madonna con Bambino e San Giovannino di scuola fiorentina (XV sec.) – Accademia di San Luca (Roma)

Multispectral imaging techniques

CAMERE CCD

FOTOGRAFIA

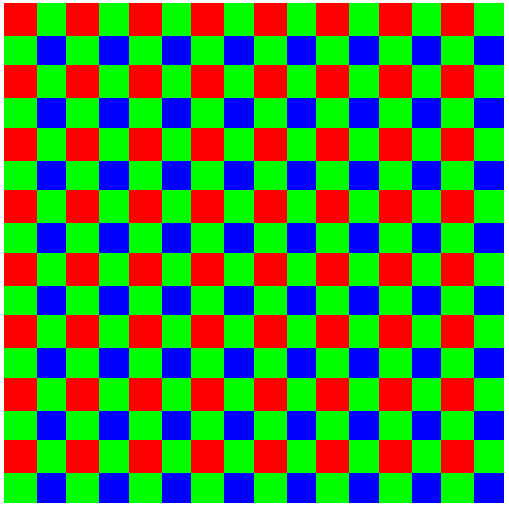


SENSORE CCD o CMOS

matrice di fotodiodi (al silicio) in grado di trasformare un segnale luminoso in un segnale elettrico (effetto fotoelettrico)

IMMAGINI A COLORI

filtra RGB o Matrice di Bayer o Color filter array (CFA) o Color filter mosaic (CFM)

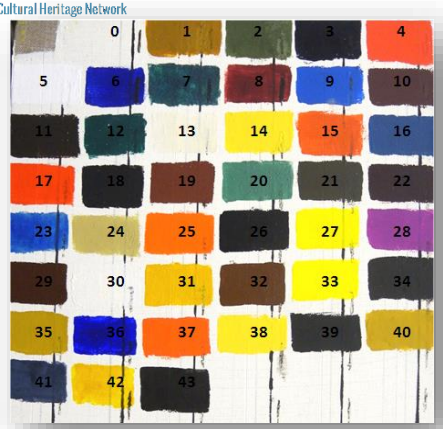


Matrice di Bayer

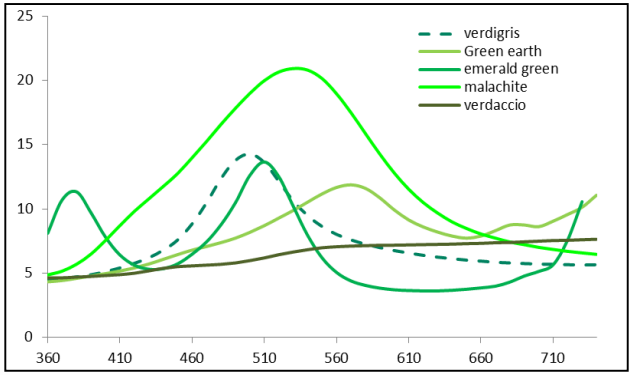
R = 700 nm
G = 546.1 nm
B = 435.8 nm

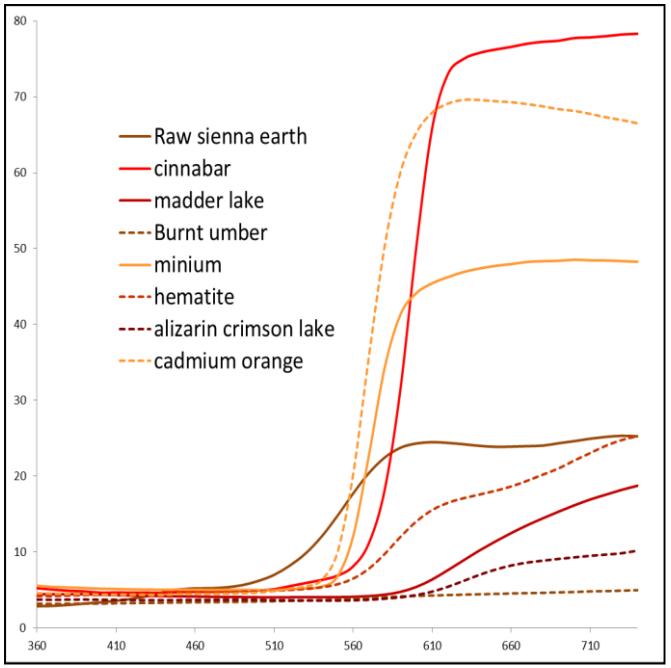
Combinazione RGB

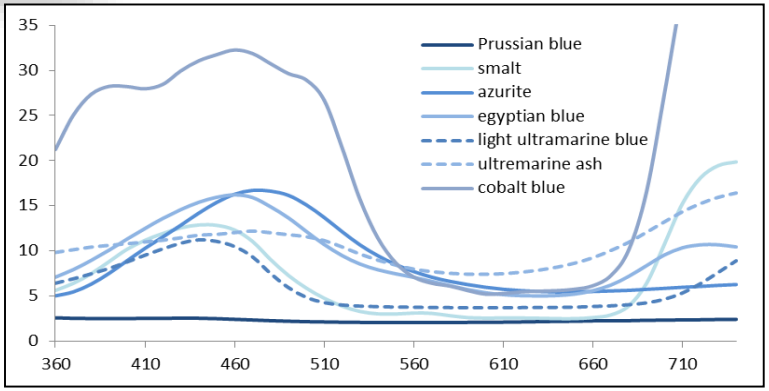
Multispectral imaging techniques



Pigmenti diversi stesi con il tuorlo



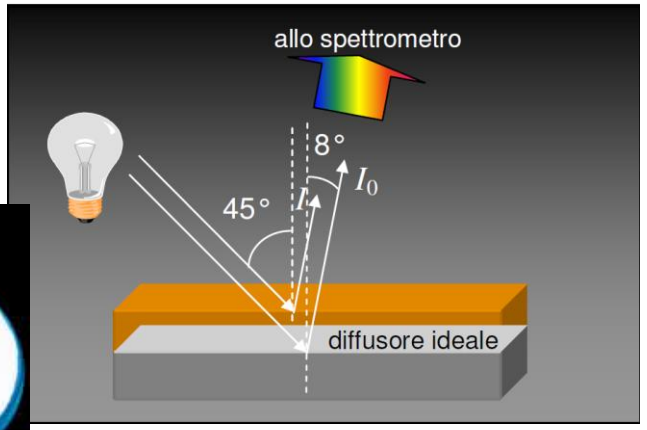




Spettroscopia di riflettanza

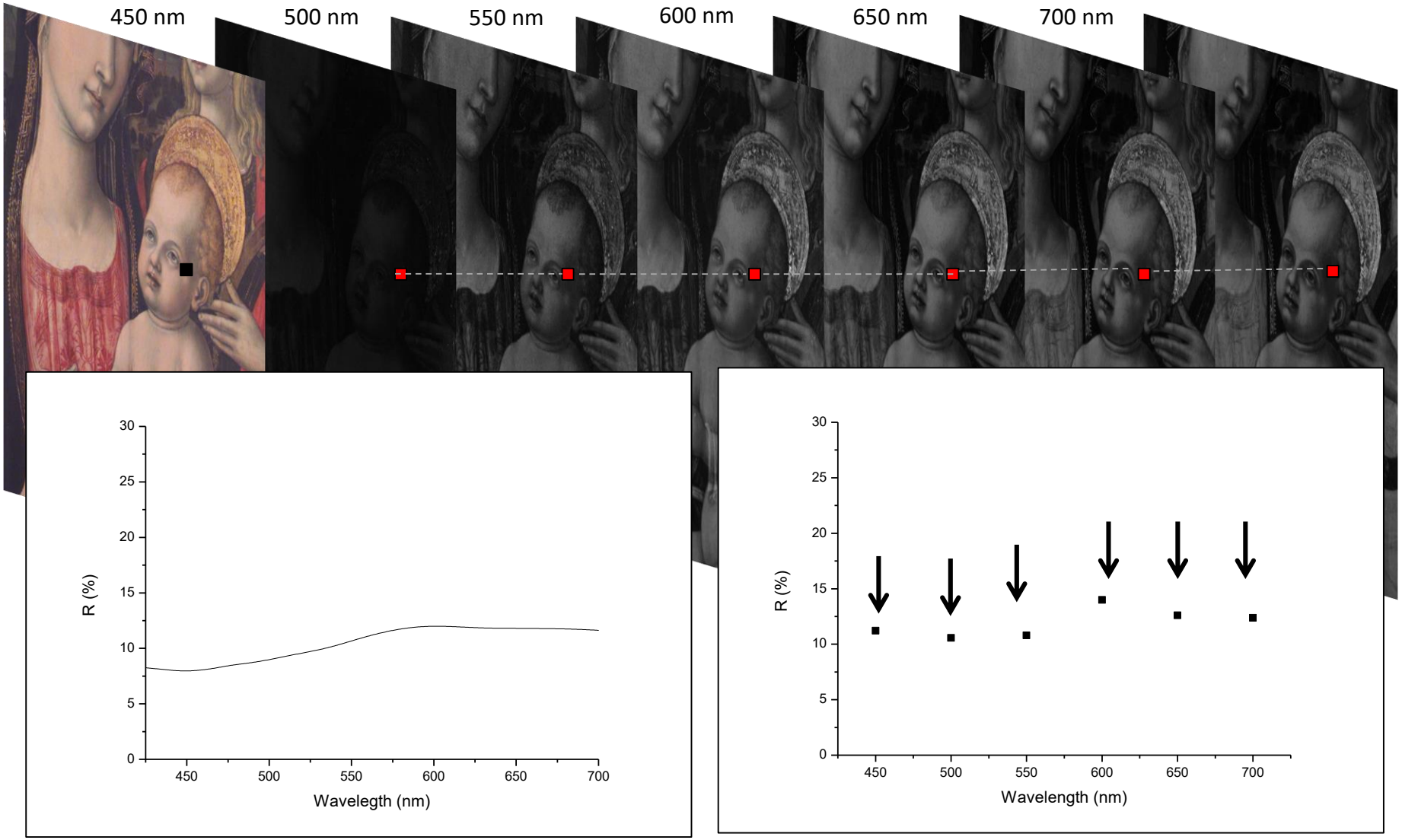
- Fattore di riflessione spettrale

$$R_{(\lambda)} = \frac{I_{(campione)}}{I_{(riferimento)}} \; x \; 100$$

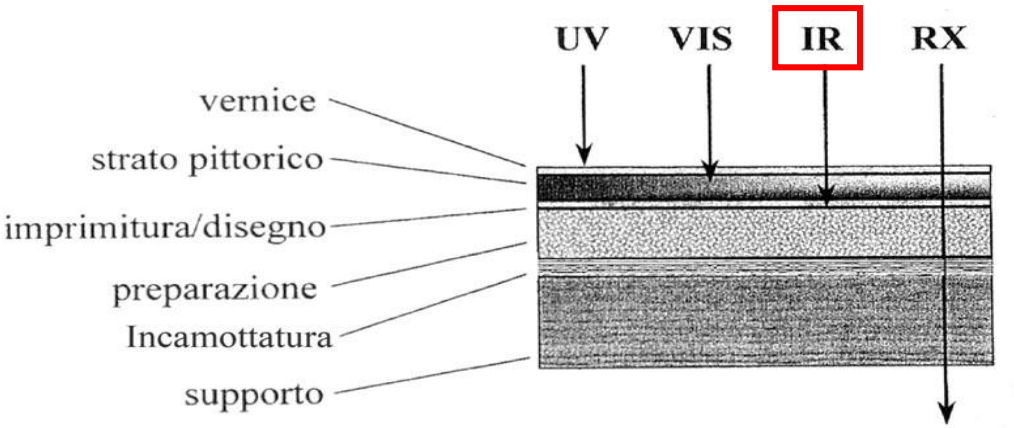


Multispectral imaging techniques

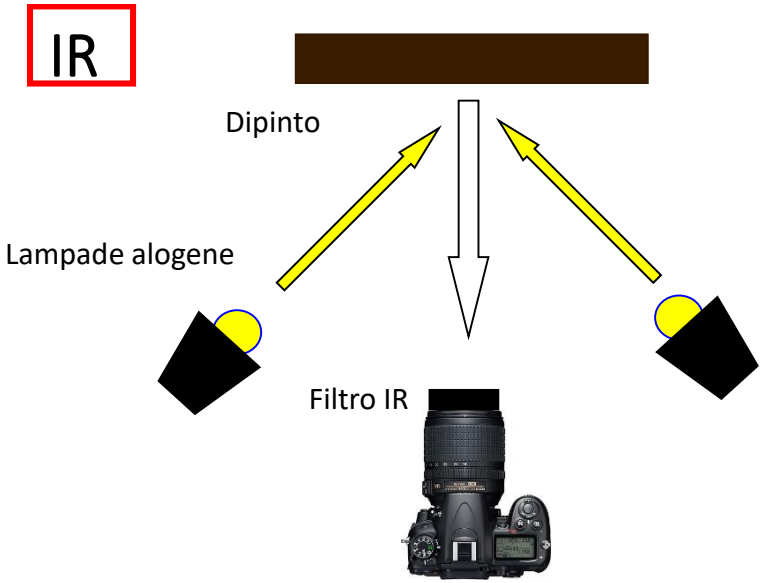
Multispectral Reflectance Imaing



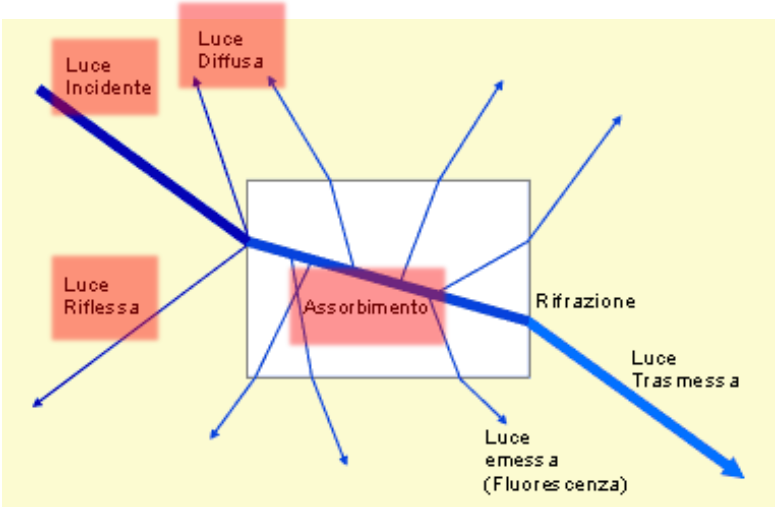
Multispectral imaging techniques



Stratificazione del dipinto «Ritratto di Giovanna Tornabuoni» di Domenico Ghirlandaio :
1 preparazione (gesso e colla)
2 disegno preparatorio
3 verde di Boemia che fa da base a tutte le parti di incarnato
4-7 diversi strati di colore (poi completati da una mano di vernice)



SISTEMA DI ACQUISIZIONE DI IMMAGINI
(macchina fotografica modificata)



Multispectral imaging techniques

IR REFLECTOGRAPHY

La riflettografia IR viene impiegata principalmente per:

- Preparatory drawings or hidden tracks
- "Pentimenti"
- Identification of some pigments or heterogeneity of the pictorial layout
- Characterization of mixed inks

VISIBILE (B/N)

RIFLETTOGRAFIA IR

Olio su tela «Annunciazione» Lorenzo di Credi – Accademia di San Luca (Roma)

Tecniche di imaging multispettrale

IR REFLECTOGRAPHY

La riflettografia IR viene impiegata principalmente per:

- Preparatory drawings or hidden tracks
- "Pentimenti"
- Identification of some pigments or heterogeneity of the pictorial layout
- Characterization of mixed inks

VISIBILE (B/N)

RIFLETTOGRAFIA IR

Olio su tela «Madonna con Bambino e San Giovannino» Lorenzo di Credi – Galleria Borghese (Roma)

Tecniche di imaging multispettrale

RIFLETTOGRAFIA IR

La riflettografia IR viene impiegata principalmente per:

- Preparatory drawings or hidden tracks
- "Pentimenti"
- Identification of some pigments or heterogeneity of the pictorial layout
- Characterization of mixed inks

VISIBILE

RIFLETTOGRAFIA IR

Affresco romano «Il Grifo» – Ostia Antica (Roma)

Tecniche di imaging multispettrale

RIFLETTOGRAFIA IR

La riflettografia IR viene impiegata principalmente per:

- Preparatory drawings or hidden tracks
- “Pentimenti”
- Identification of some pigments or heterogeneity of the pictorial layout
- Characterization of mixed inks

VISIBILE

RIFLETTOGRAFIA IR

Olio su tavola «Madonna col Bambino e i santi Giovanni Battista e Maria Maddalena » Palma il Vecchio – Palazzo Rosso (Genova)

Tecniche di imaging multispettrale

RIFLETTOGRAFIA IR

La riflettografia IR viene impiegata principalmente per:

- Preparatory drawings or hidden tracks
- “Pentimenti”
- Identification of some pigments or heterogeneity of the pictorial layout
- Characterization of mixed inks

VISIBILE

RIFLETTOGRAFIA IR

Olio su tavola «Ritratto femminile» Angiolo Allori (Bronzino) – Accademia di San Luca (Roma)

Tecniche di imaging multispettrale

RIFLETTOGRAFIA IR

La riflettografia IR viene impiegata principalmente per:

- Preparatory drawings or hidden tracks
- “Pentimenti”
- Identification of some pigments or heterogeneity of the pictorial layout
- Characterization of mixed inks

VISIBILE

RIFLETTOGRAFIA IR

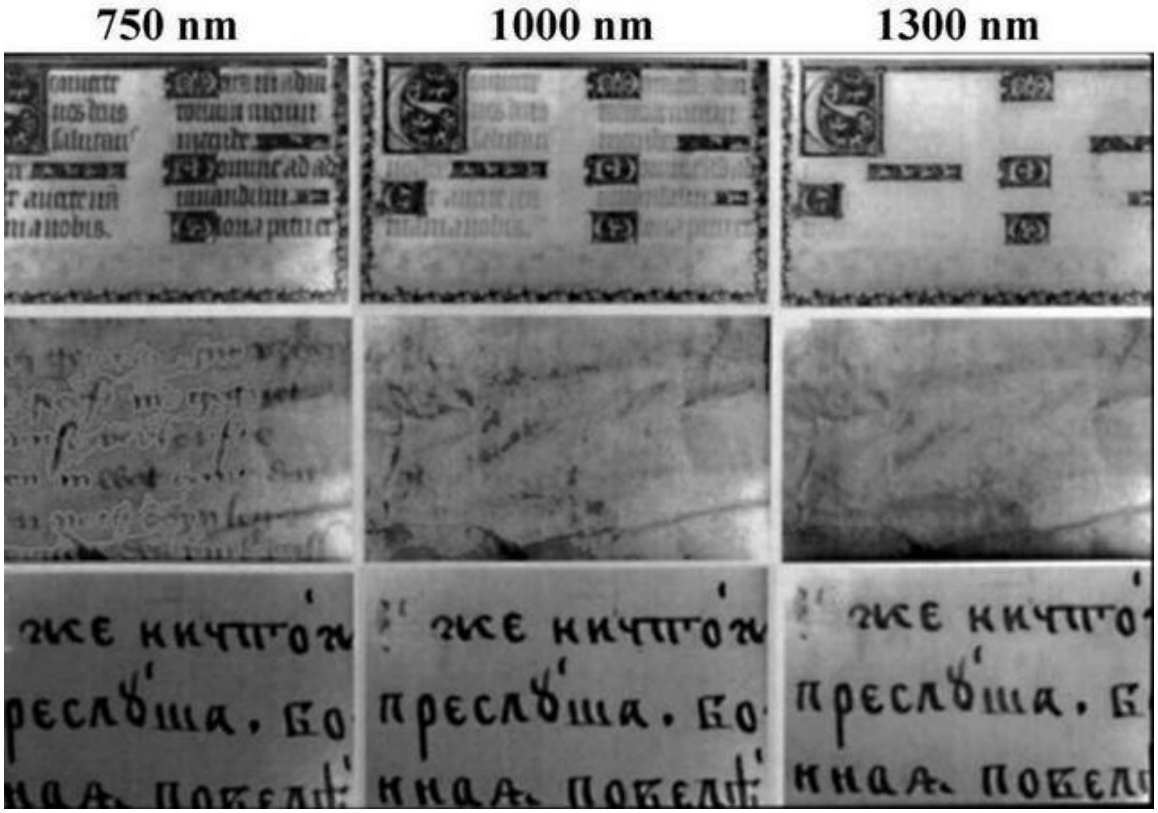
Affresco a Santa Luca delle Malve (Matera)

Tecniche di imaging multispettrale

RIFLETTOGRAFIA IR

La riflettografia IR viene impiegata principalmente per:

- Disegni preparatori o tracce nascoste
- Eventuali pentimenti
- Identificazione di alcuni pigmenti o eterogeneità della stesura pittorica
- Caratterizzazione degli inchiostri misti



Inchiostro ferrogallico

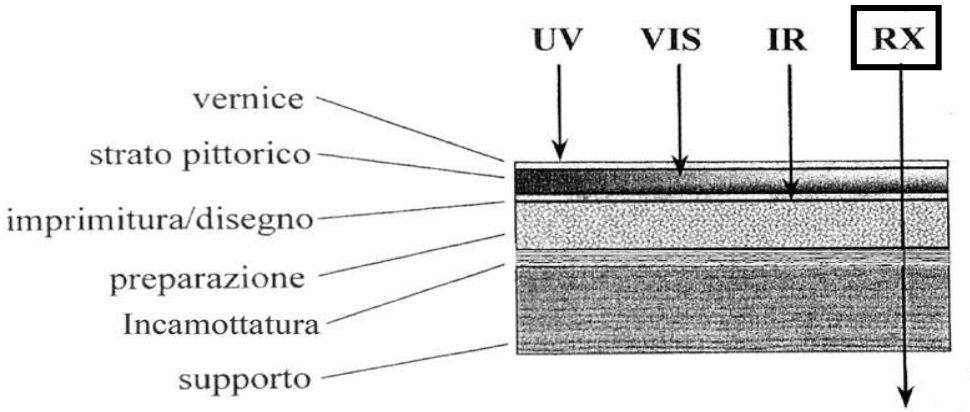
Inchiostro vegetale

Inchiostro a base di carbonio

RIFLETTOGRAFIA IR

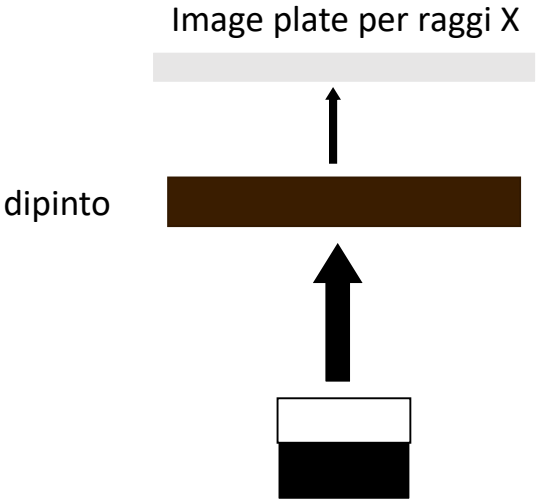
Tecniche di imaging multispettrale

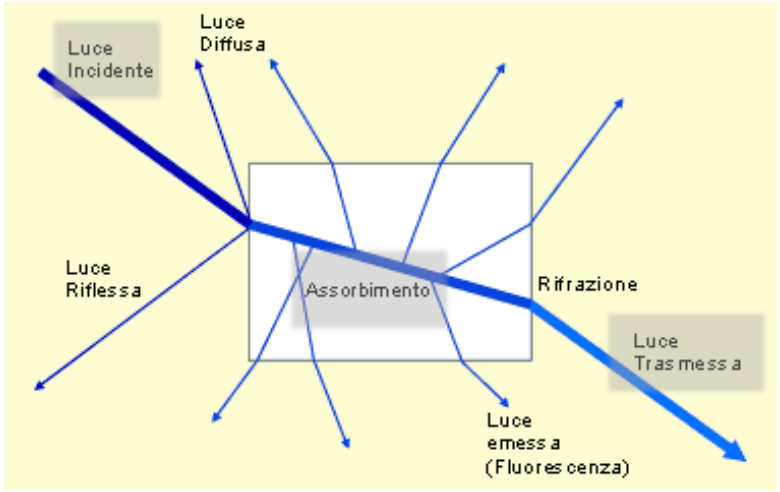
Tecniche di imaging multispettrale



Stratificazione del dipinto «Ritratto di Giovanna Tornabuoni» di Domenico Ghirlandaio :
1 preparazione (gesso e colla)
2 disegno preparatorio
3 verde di Boemia che fa da base a tutte le parti di incarnato
4-7 diversi strati di colore (poi completati da una mano di vernice)

Raggi X





Tecniche di imaging multispettrale

RADIOGRAFIA

La radiografia consente l'analisi della struttura del supporto sia per quanto riguarda la realizzazione che lo stato di conservazione e permette di trarre informazioni sulla tecnica esecutiva

VISIBILE

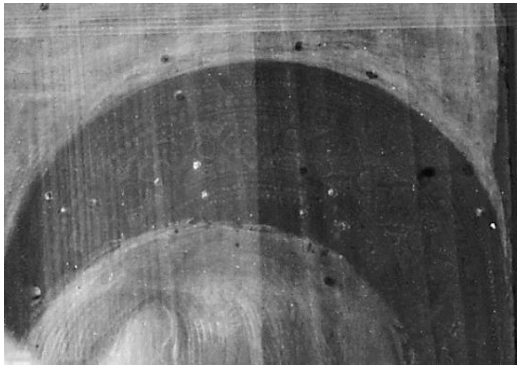
RADIOGRAFIA

Olio su tavola «Madonna con Bambino e San Giovannino» di scuola fiorentina – Accademia di San Luca (Roma)

Tecniche di imaging multispettrale

RADIOGRAFIA

VISIBILE



RADIOGRAFIA

Olio su tavola «Madonna con Bambino e Santa Caterina d'Alessandria» di Matteo di Giovanni – Accademia di San Luca (Roma)

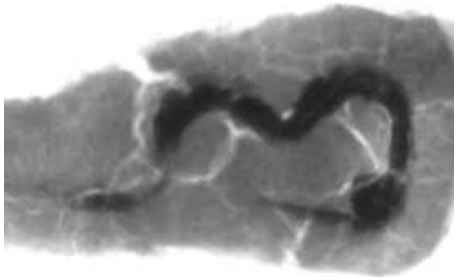
Tecniche di imaging multispettrale

INFN CHNet
Istituto Nazionale di Fisica Nucleare
Cultural Heritage Network

RADIOGRAFIA

Non solo dipinti….

Foto del pane di terra durante la radiografia



Radiografia frontale

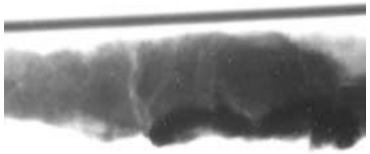


Immagine radiografica laterale

Immagine dell'oggetto dopo il restauro

Piccolo pane di terra provenienti da Crustumerium , che conteneva una fibuletta in ferro. Lo spillo della fibula ed il suo gancio sono quasi del tutto scomparsi ed anche il corpo della fibula risulta fortemente compromesso. Inoltre a causa della forte disidratazione della terra si erano formate delle fratture

Asse di Tiberio per il Divo Augusto (14-37 d.C.)

Quadrante di Claudio (41-54 d.C.)

Immagine visibile | Radiografia | Ipotesi di attribuzione

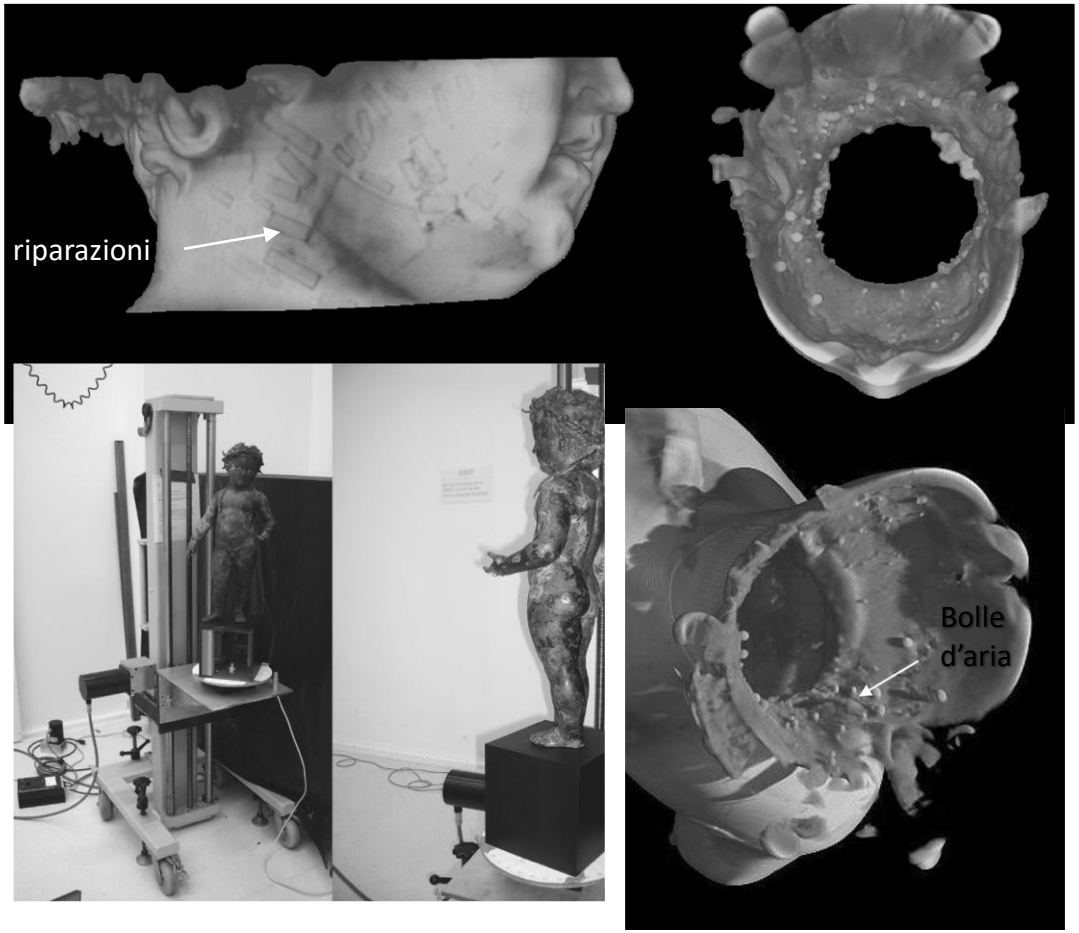
La radiografia consente il recupero dell'impronta del conio anche in situazioni di avanzato stato di corrosione della moneta.

Tecniche di imaging multispettrale

TOMOGRAFIE

Non solo dipinti….

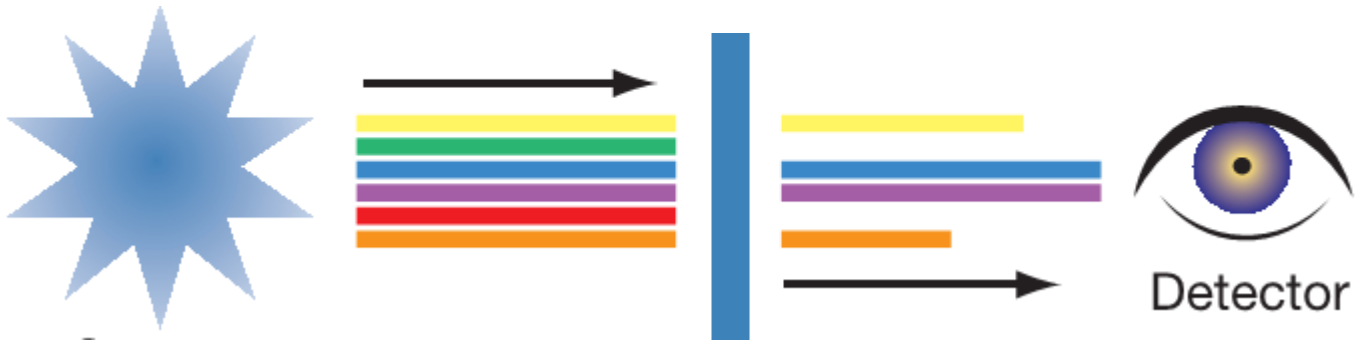
La tomografia consente lo studio dello spessore dello strato di metallo e l'identificazione di buchi, deformazioni e riparazioni.



Statua romana di bronzo Roman bronzo di Cupido (96.AB.53) - Getty Museum

SPECTROSCOPIC TECHNIQUES

Le tecniche spettroscopiche



Sorgente Campione Rivelatore

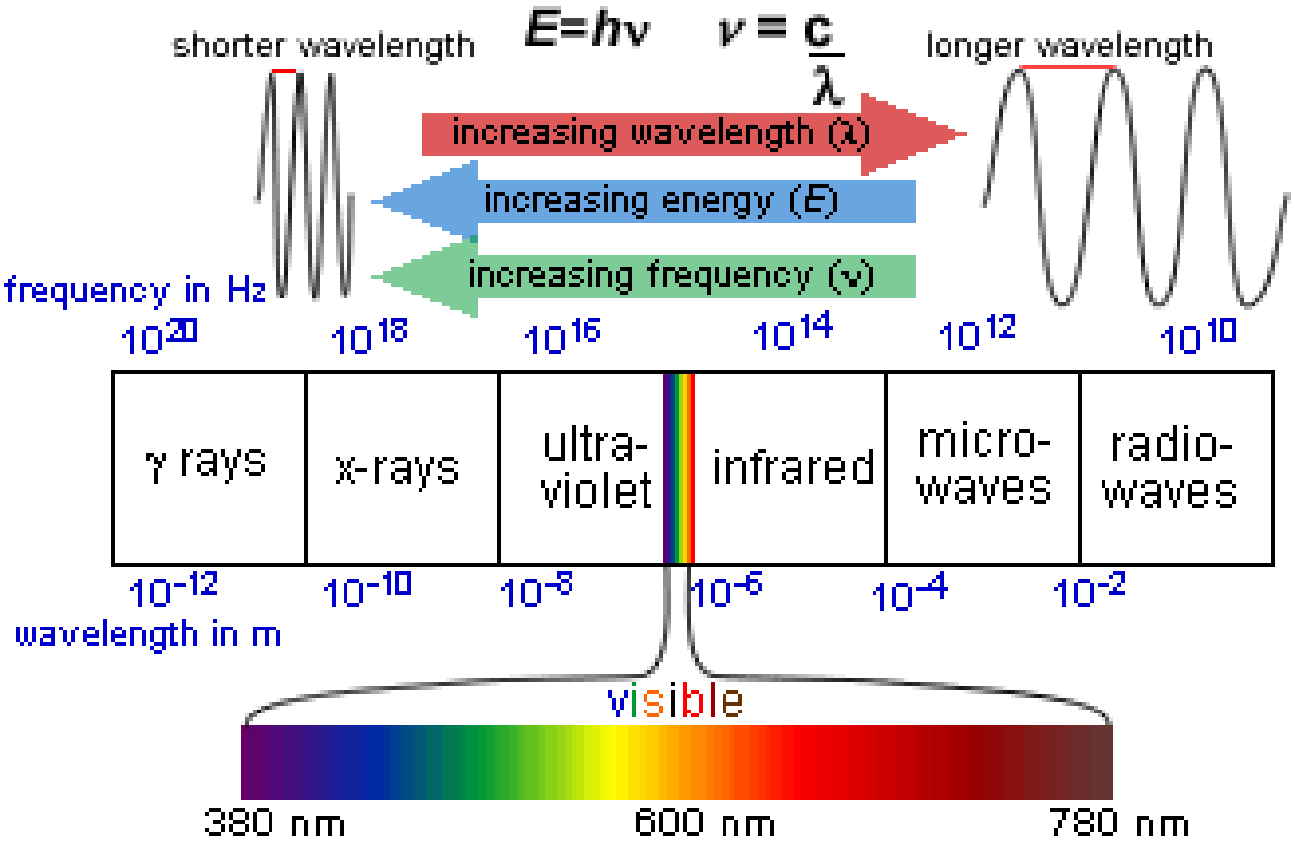
The sample absorbs some components of the incident radiation.
By analyzing the transmitted light we can obtain information on the chemical nature of the sample

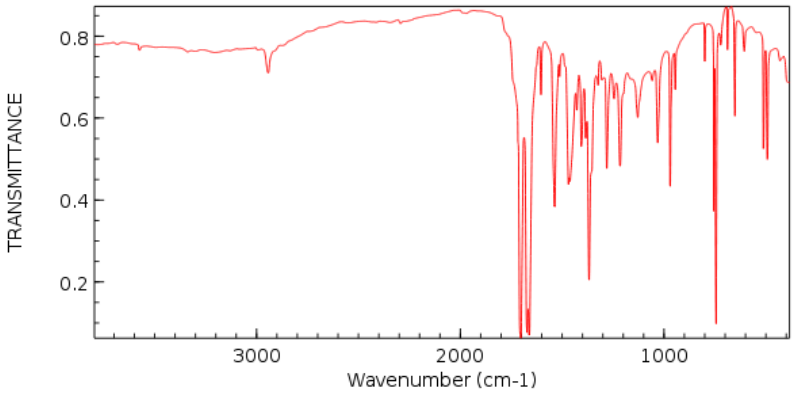
INFN CHNet
Istituto Nazionale di Fisica Nucleare
Cultural Heritage Network

FT-IR micro spectroscopy and imaging

INFN
Istituto Nazionale di Fisica Nucleare
LABORATORI NAZIONALI DI FRASCATI

LA SPETTROSCOPIA INFRAROSSA



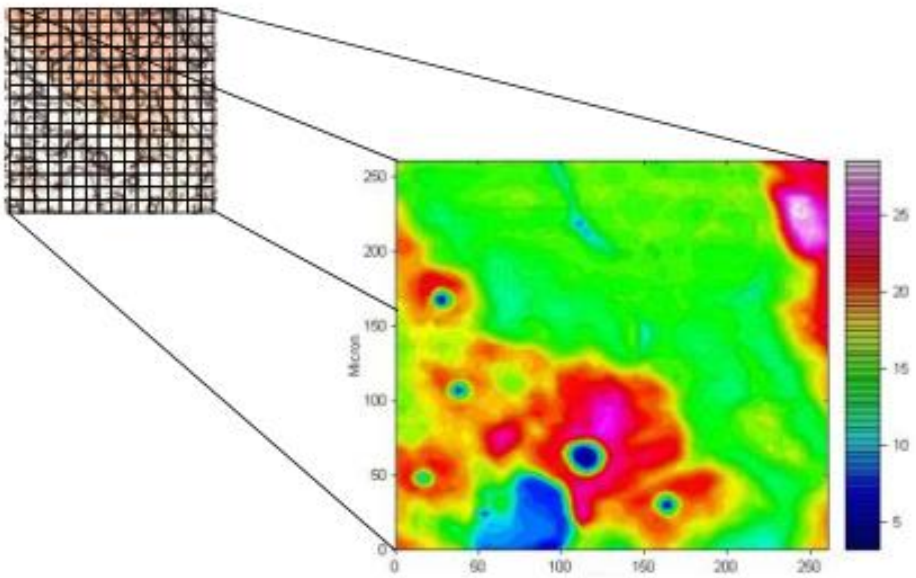

TRANSMITTANCE
0.8
0.6
0.4
0.2
3000
2000
1000
Wavenumber (cm-1)


Caffeine
Download from
Dreamstime.com

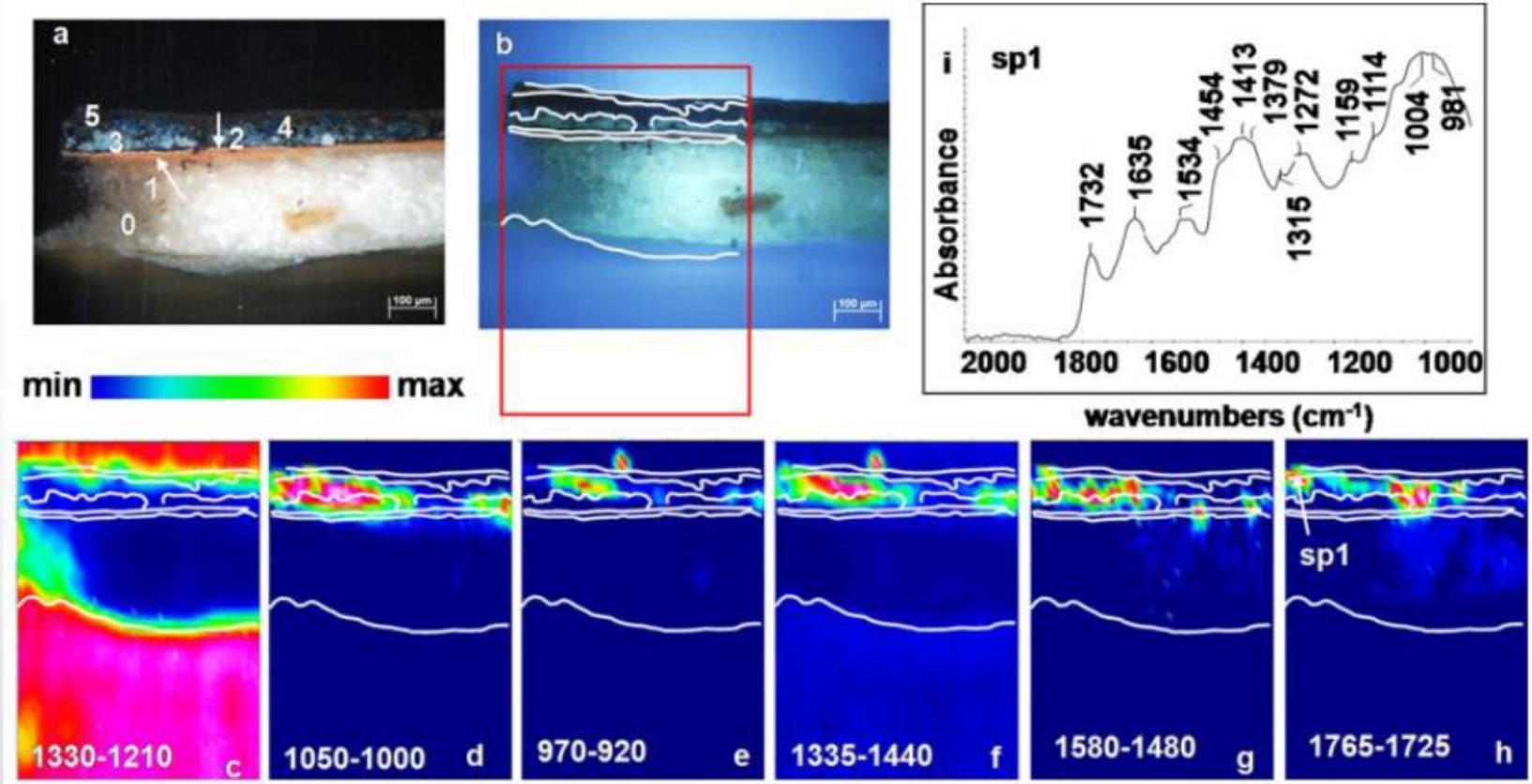
Microscopy and Imaging

The objective of mapping and imaging is to generate an image, called a chemical image, containing spectral information, which can be superimposed on the visible image.

Depending on the detector used, it is possible to obtain a chemical image:



- Point by point (raster scan, mapping): single point detector MCT (250 μm)
- In a single shot (using matrix detectors FPA: 64x64, 128x128, 256x256, pixel 40 μm size)



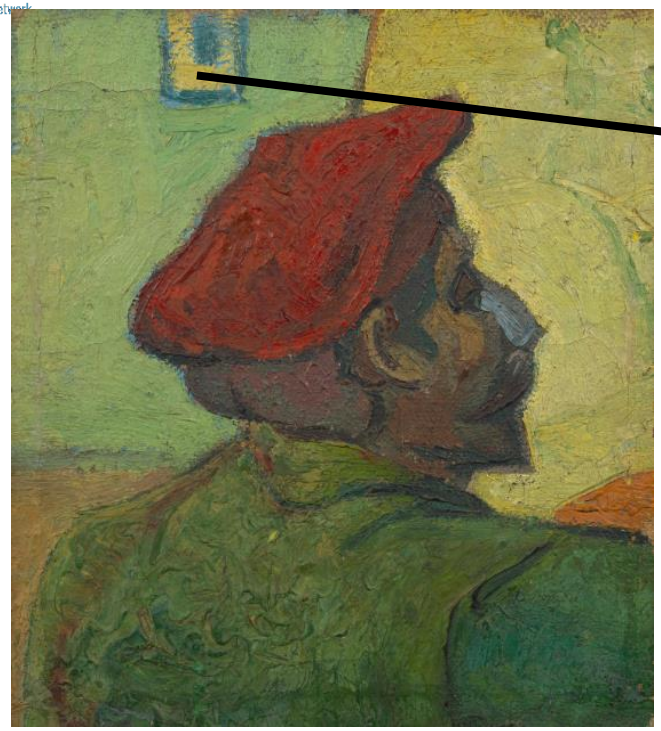
Resina | Silicati | Azzurrite | Carbonato | Ammide II | Trigliceridi

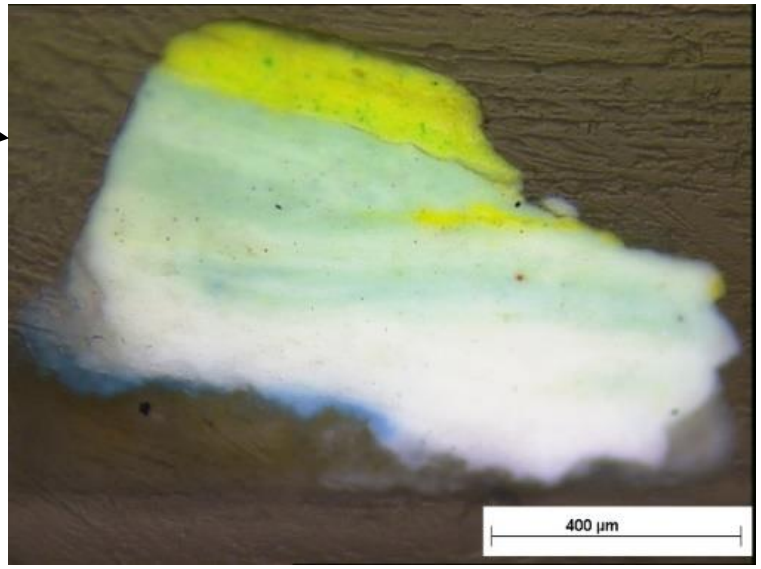
Analisi di sezioni stratigrafiche

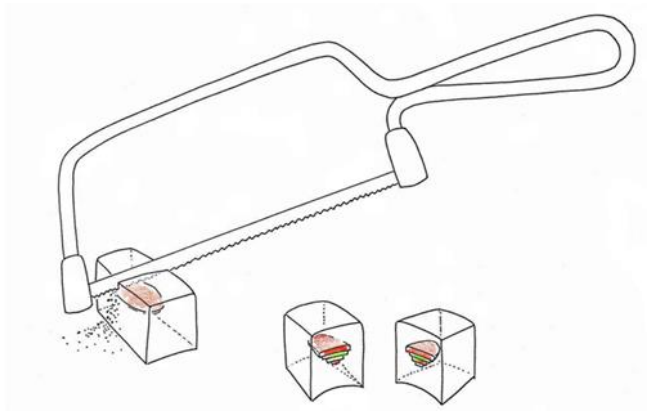
Studio dei processi di degradazione
dei pigmenti gialli di Van Gogh

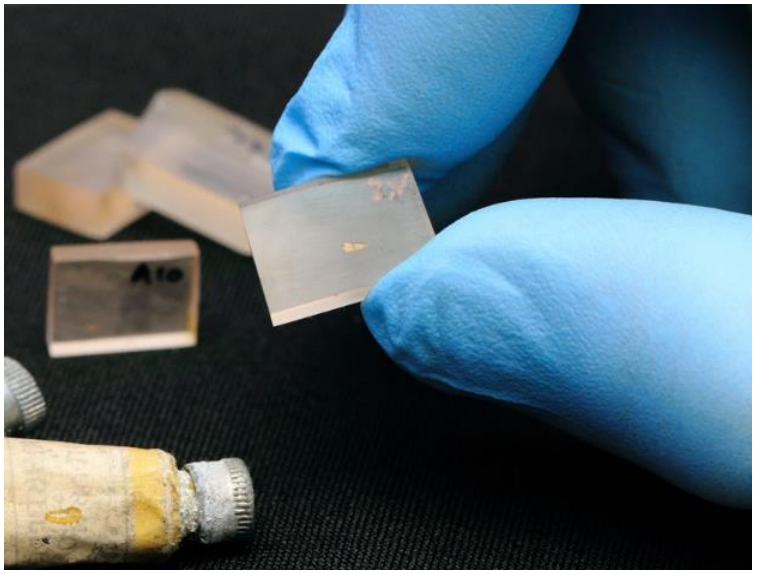
http://www.vangogh.ua.ac.be/

Sezioni stratigrafiche: micro-distruttivo



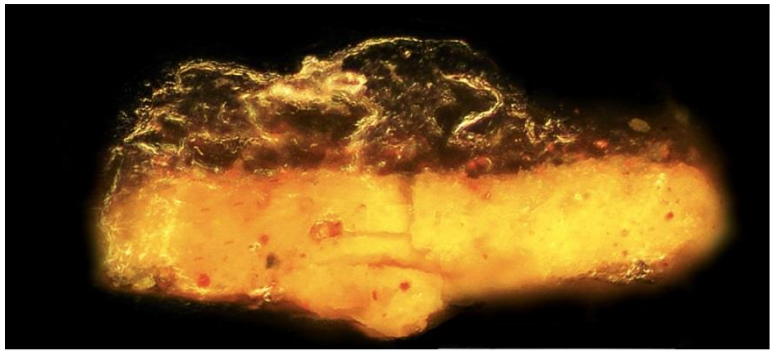






Studio del degrado dei pigmenti gialli di Van Gog

Il "Girasoli " di Vincent Van Gogh

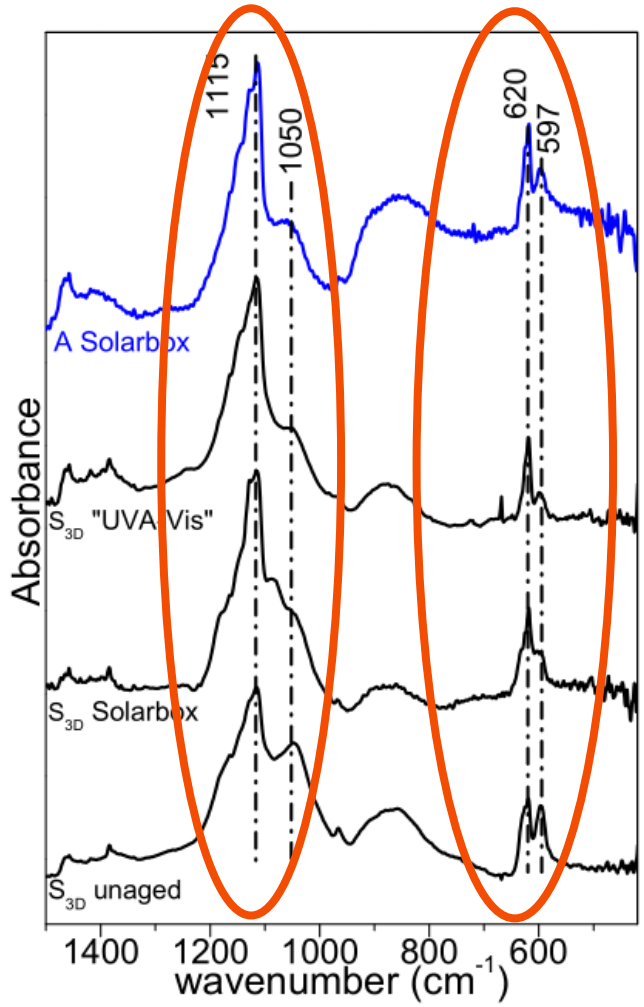


Pigmenti gialli a base di cromo
($PbCrO_4$, $PbCrO_4 \cdot xPbSO_4$, o $PbCrO_4 \cdot xPbO$)

Non invecchiato Invecchiato

Studio del degrado dei pigmenti gialli di Van Gog

Il motivo dell'alterazione risiede nel cambiamento del numero di ossidazione del cromo (da Cr(VI) a Cr(III)) che avvene soprattutto in presenza di solfati e solfuri

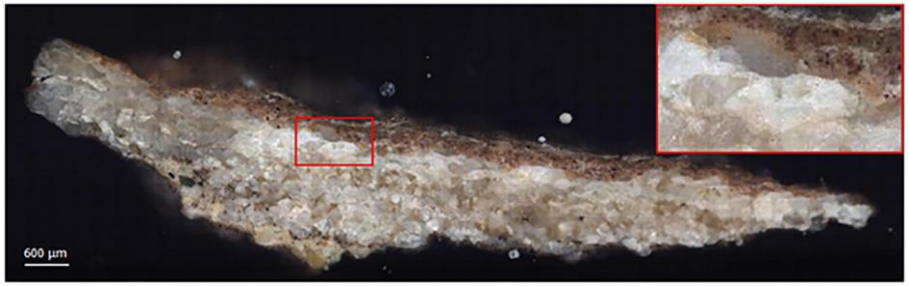


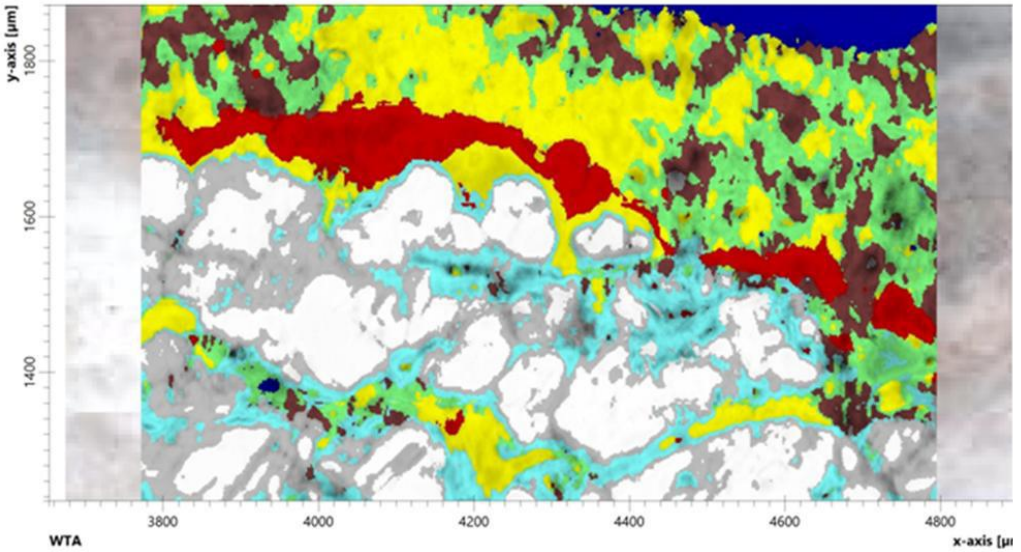
Diminuzione della banda a 1050 cm^{-1} [$\nu_1(SO_4^{2-})$] e una modifica dell'intensità relativa delle bande a 620 e 597 cm^{-1} [$\nu_4(SO_4^{2-}$]

Modifica della struttura dei solfati indica che il processo di degrado è in atto

Analisi dei prodotti di degrado

L' Arco di Settimio Severo





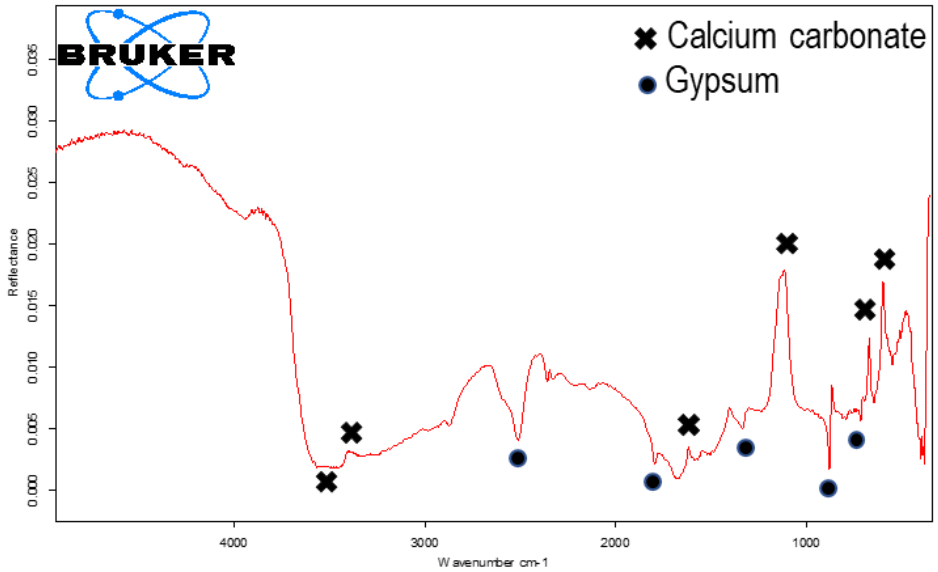
- Resin (Cluster 1)
- Silicates + Gypsum (Cluster 3-4-5 average)
- Gypsum (Cluster 9)
- Gypsum+Silicates (Cluster 8)
- Oxalate+Silicates (Cluster 10)
- Gypsum+Calcite+Silicates (Cluster 7)
- Calcite+Gypsum (Cluster 6)
- Calcite (Cluster 2)

In-situ analysis

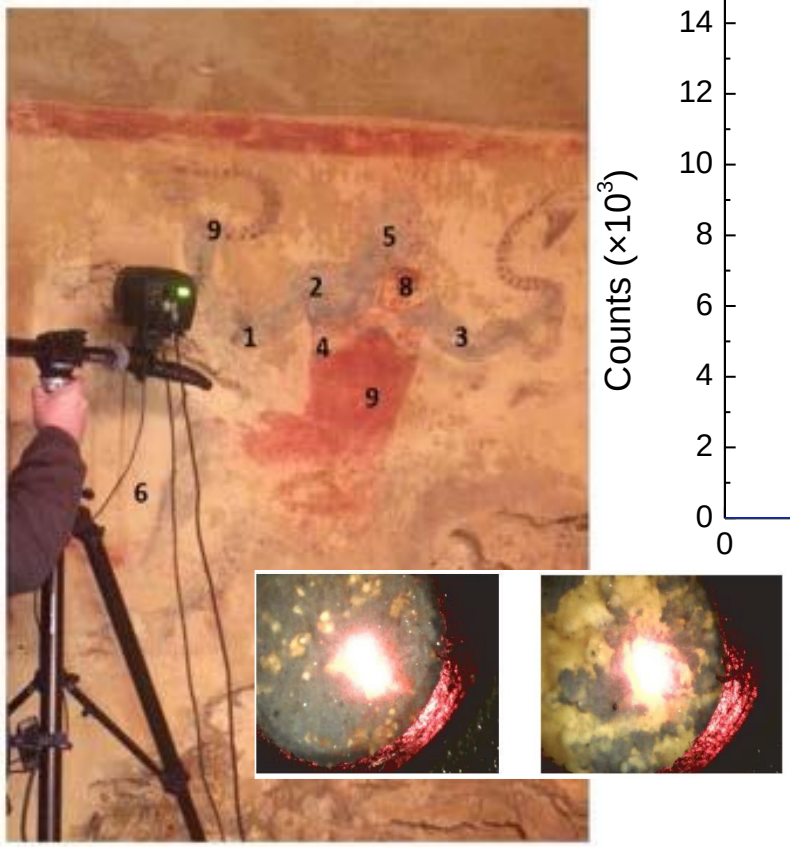
"PALAZZO CHIGI" (Ariccia, Rome)

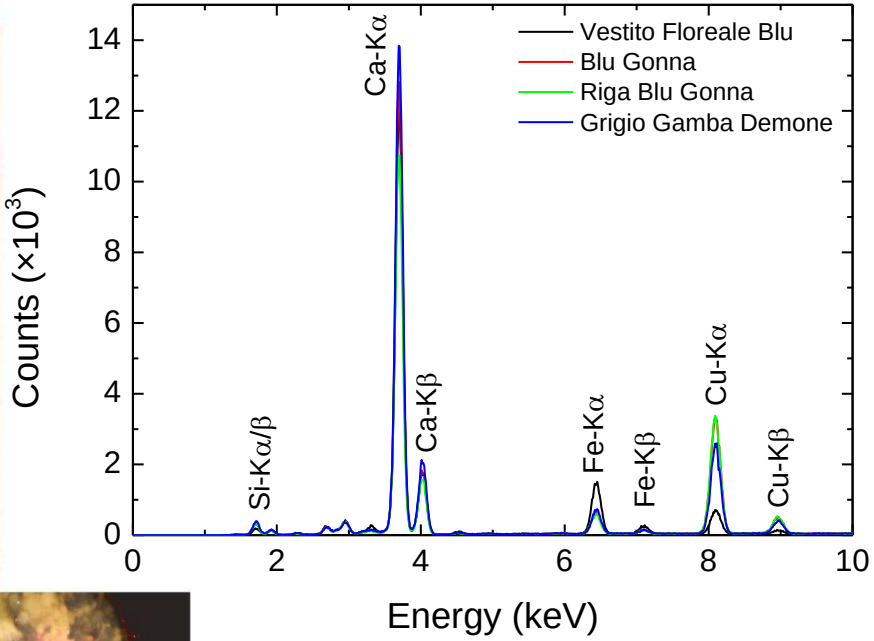
Portable Spectrometer ALPHA (Bruker)

Sanguigna (o Sinopia) di Gian Lorenzo Bernini



XRF analyses at Tarquinia (Tomba dei Demoni Azzurri)



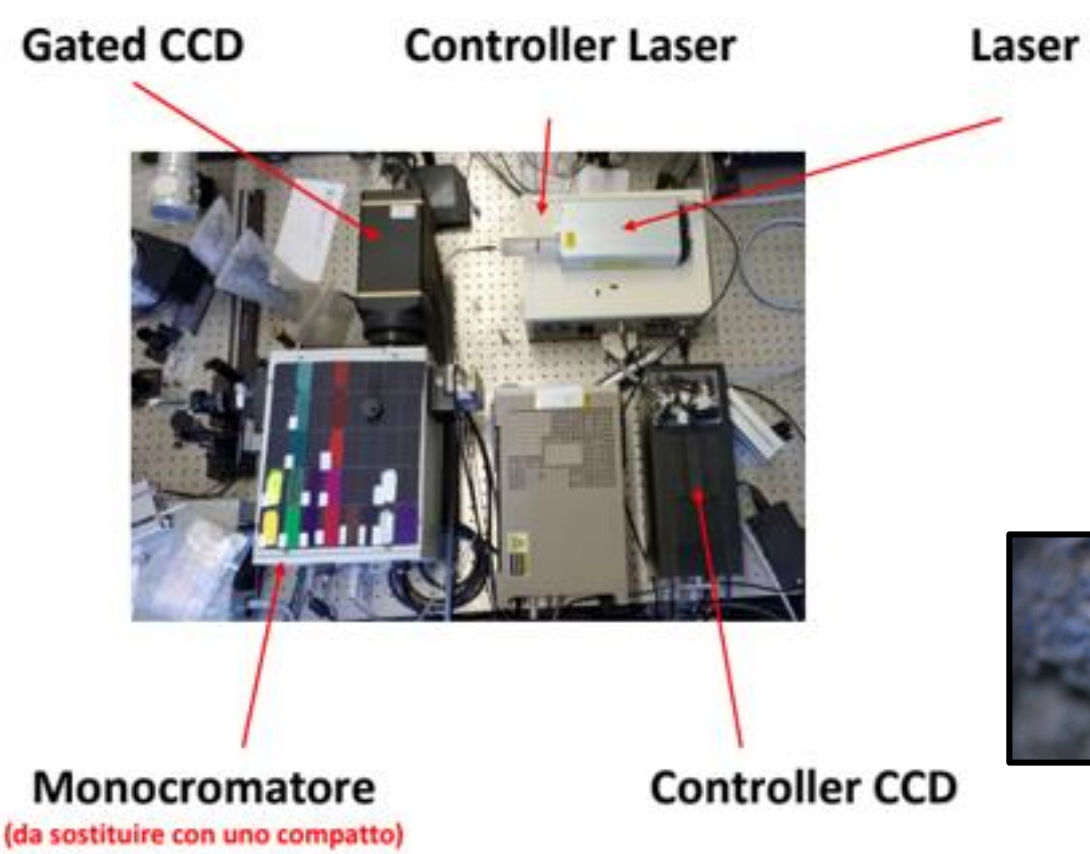


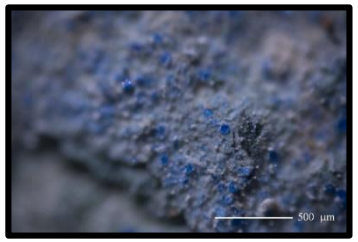
Pigmento	Identificazione
Neri	Pigmenti Organici
Blu	Cuprorivaite o Blu Egizio: (CaCuSi4O10 or CaO·CuO·4SiO2)
Rossi/Marroni	Ocre ed Ossidi di Ferro: (Rossi: ematite-Gialli: goetite)

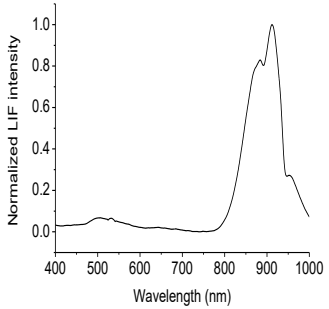
INFN Istituto Nazionale di Fisica Nucleare
SEZIONE DI ROMA TOR VERGATA

Romani, M., et.al., NON-DESTRUCTIVE CHARACTERIZATION OF FRESCOS IN THE ETRUSCAN TOMB OF BLUE DEMONS (ITALY) BY SPECTROSCOPY TECHNIQUES, Presented at Art'17, 22th-24th November 2017, Torino

Time Gated (TG) Laser Induced Fluorescence (LIF)

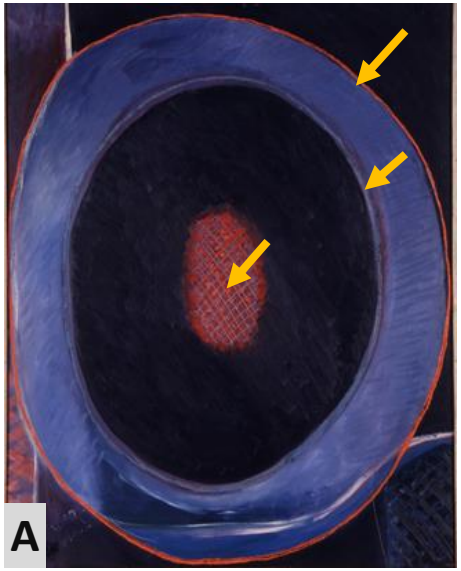




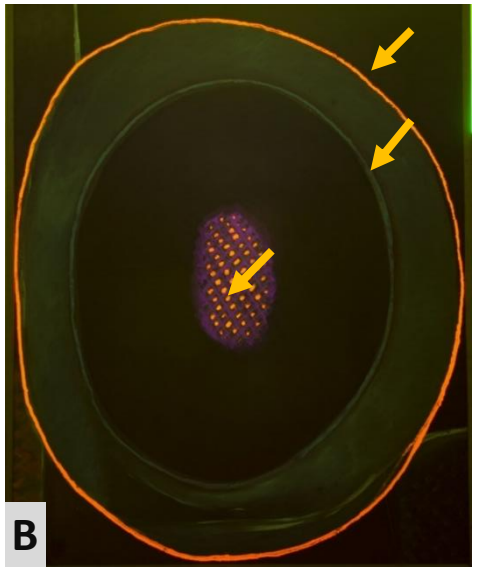


Caratterizzazione di Opere d'Arte Contemporanea

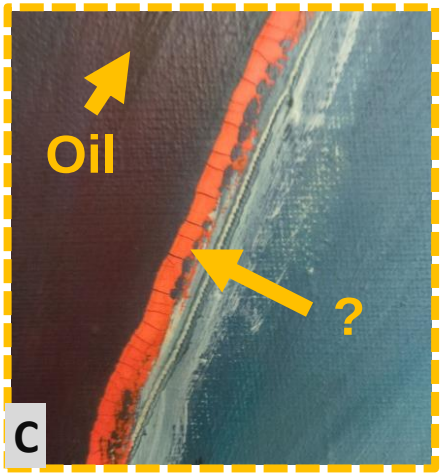
Nato Frascà, Nascita della forma, 1962, Museo MACRO (Roma)



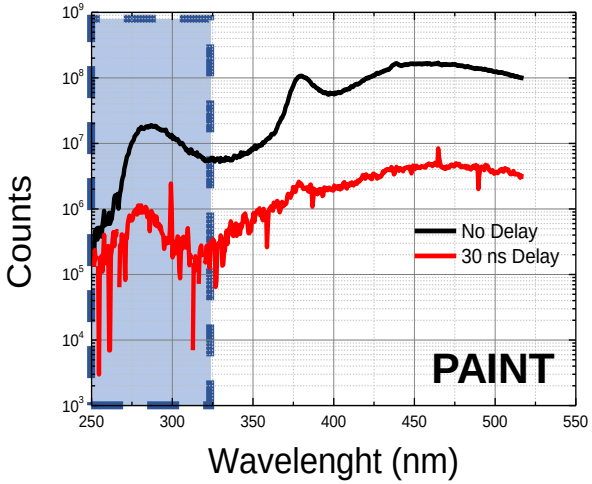
A. Foto

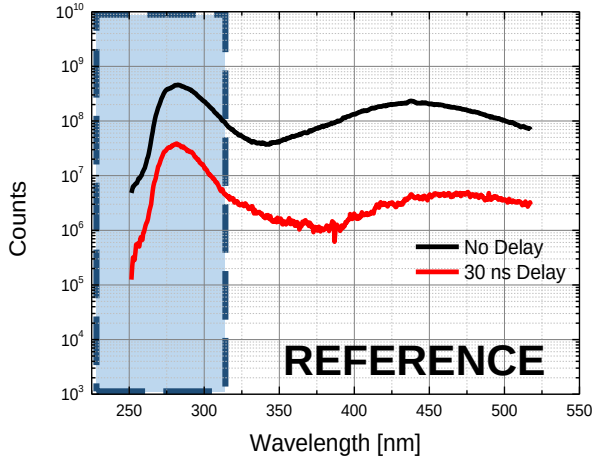


B. Fluorescenza



C. Dettaglio





Opera catalogata Olio su tela

Pigmenti blu e arancio appaiono maggiormente degradati

Identificazione di legante acrilico nelle zone più degradate

Romani, M., et al., A preliminary study of contemporary binders by TR-LIF spectroscopy for the study of the painting "Nascita della Forma" by Nato Frascà, Proceedings of LACONA XI

Importanza di avere un laboratorio di diagnostica nei Musei

THE MET Visit Exhibitions Events Art Learn Join and Give Shop Search

About The Met / Conservation and Scientific Research

Conservation and Scientific Research

Scientists and conservators collaborate with curators to study, preserve, and conserve the works in The Met collection.

Objects Conservation

Objects conservators provide for the conservation of three-dimensional works of art in The Met collection. Staff members also provide conservation support on a number of archaeological excavations, including those

Paintings Conservation

Paintings conservators support many different facets of the institution's activities, checking hundreds of paintings for loan and taking responsibility for many hundreds more that arrive at the Museum as honored guests

Paper Conservation

The Paper Conservation Department is dedicated to the preservation, technical analysis, and research of works of art on paper, parchment, and related materials from all periods and cultures held in the Museum's

Sviluppo di tecnologie avanzate: l'acceleratore portatile «MACHINA»

Corriere della Sera, 25-08-2019

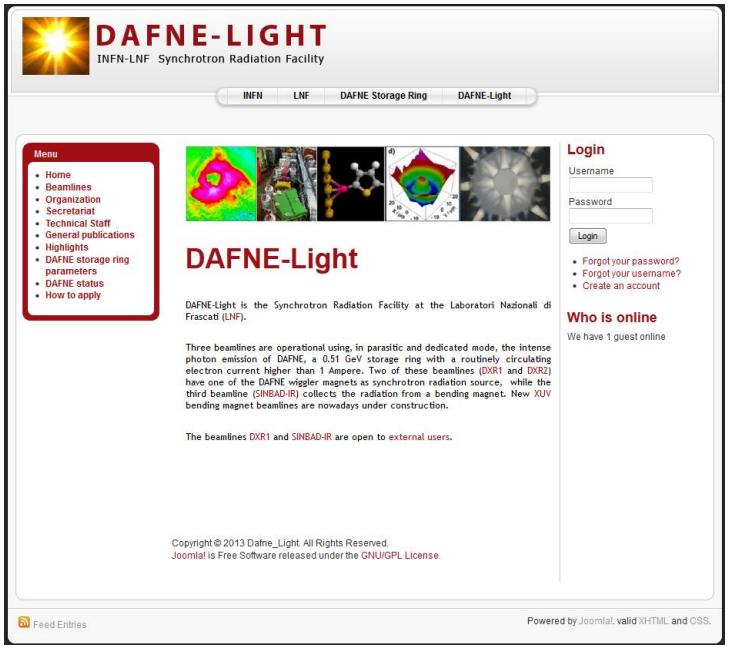
- **INFN-LNF:**
- M.Cestelli-Guidi, A. Grilli, A. Raco (FTIR and Raman analysis set-up)

- **INFN-RM2:**
- M. Marinelli, G. Verona Rinati (XRF, Multispectral Imaging, TG-LIF portable system analysis),

- **CHNet:** F. Taccetti (National Coordinator), V. Virgili (Latium Spokesperson),
- M. Cestelli-Guidi (INFN-LNF Spokesperson)

Follow us :)

http://w3.lnf.infn.it/



https://web2.infn.it/Dafne_Light/

cestelli@lnf.infn.it

Instagram

http://chnet.infn.it/it/home-2/