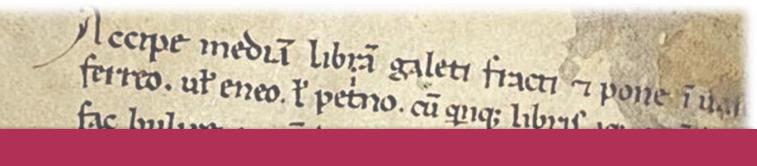
PhD in Physics, End-of-Year Seminars, 17th and 18th September 2025



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Discriminating superimposed historical inks exploiting a non-invasive and multi-analytical strategy

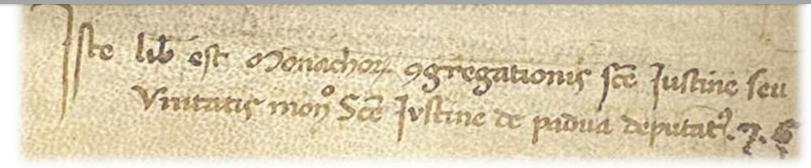
Dr. Chiara Delledonne (chiara.delledonne@unipv.it)

Department of Physics, University of Pavia

Arvedi Laboratory of Non-Invasive Diagnostics, Department of Musicology and Cultural Heritage, University of Pavia

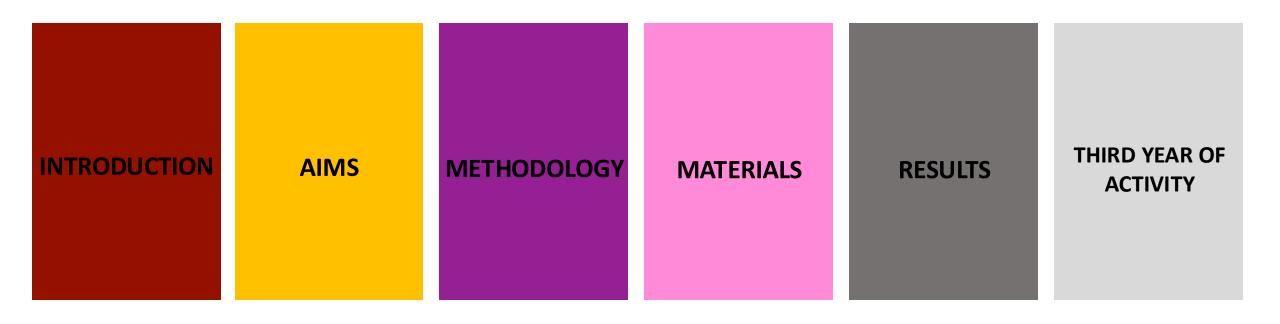
















Manuscripts: Complex Heritage Artefacts

Supports:

- Papyrus
- □ Parchment
- □ Paper

Writing materials:

- **⇒** Inks
- ⇒ Pigments
- ⇒ Dyes





Ms.Ald. 211, 14th century, Biblioteca Universitaria di Pavia



Mss-Turri-D-73, 16th century, Biblioteca digitale, Reggio Emilia





Manuscripts: Complex Heritage Artefacts

Supports:

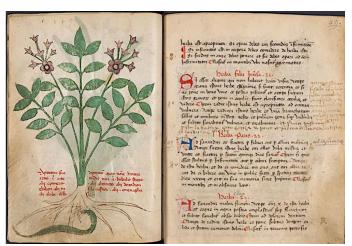
- □ Papyrus
- □ Parchment
- □ Paper



Writing materials:

- (⇔ Inks
- ⇒ Pigments
- ⇒ Dyes





Ms.Ald. 211, 14th century, Biblioteca Universitaria di Pavia



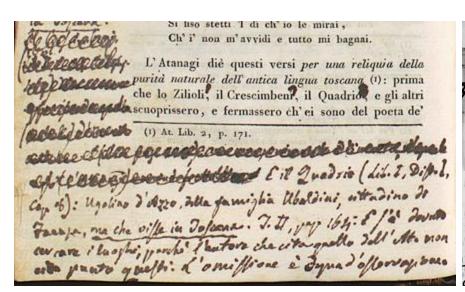
Mss-Turri-D-73, 16th century, Biblioteca digitale, Reggio Emilia



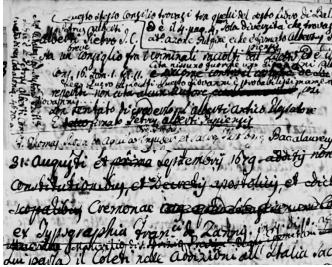


Manipulations of original writings:

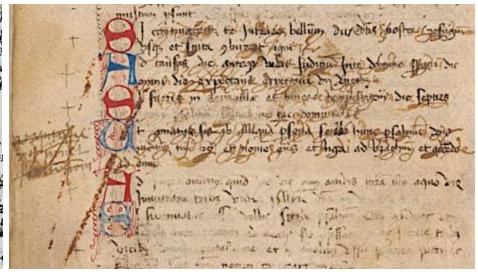
issues arise related to reading and interpreting texts



MANZ. 15. 0037-43, 19th century, Biblioteca Nazionale Braidense, Milano



Ms.Tic. 38, 18th-19th century, Biblioteca Universitaria di Pavia



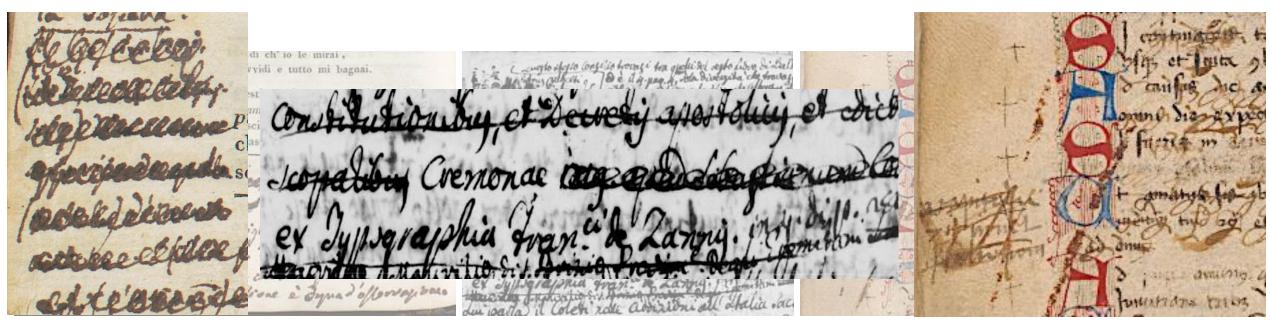
Ms.Ald. 211, 14th century, Biblioteca Universitaria di Pavia





Manipulations of original writings:

issues arise related to reading and interpreting texts



MANZ. 15. 0037-43, 19th century, Biblioteca Nazionale Braidense, Milano

Ms.Tic. 38, 18th-19th century, Biblioteca Universitaria di Pavia

Ms.Ald. 211, 14th century, Biblioteca Universitaria di Pavia





Characterisation and discrimination between inks of different and similar composition and appearance



Improve legibility when the original writing is compromised by overwriting or cross-outs marks

Validation of a non-invasive and multi-analytical methodological approach





METHODOLOGY

Non-invasive and accessible

X-ray Fluorescence Spectroscopy (XRF)

ELIO - Bruker XGLab s.r.l.

- Single point
- Mapping



Micro-Raman Spectroscopy

XploRA PLUS confocal microRaman System Instrument – HORIBA Scientific and Analytical Instruments

Portable Raman spectrometer i-Raman Plus 785S – Metrohm

- Single point
- Mapping





Elemental chemical composition

Structural composition





METHODOLOGY

Non-invasive and accessible

Hypercolorimetric Multispectral Imaging (HMI)

Profilocolore s.r.l.

- High-resolution image acquisition and calibration system in 34 equispaced bands from 300-1000 nm with 20 nm steps
- Software tools with image-processing functions



Spectral reflectance and colourimetric properties

X-ray Fluorescence Spectroscopy (XRF)

ELIO - Bruker XGLab s.r.l.

- Single point
- Mapping



Micro-Raman Spectroscopy

XploRA PLUS confocal microRaman System Instrument – HORIBA Scientific and Analytical Instruments

Portable Raman spectrometer i-Raman Plus 785S

– Metrohm

- Single point
- Mapping





Structural composition







Carbon ink

 C_{l}

Giovanni Alcherio, 1411 (Tasseva, J., Analyst, 2017)

- Carbon black
- Gum Arabic
- Water









Carbon ink

C

Giovanni Alcherio, 1411 (Tasseva, J., Analyst, 2017)

- Carbon black
- Gum Arabic
- Water



Iron-gall ink

IGI1 - IGI2 - IGI3 - IGI4

Giovanni Battista Palatino, 1545

- Gall-nuts
- Iron(II) Sulphate
- (Copper(II) Sulphate)
- Gum Arabic
- Water









Carbon ink

C

Giovanni Alcherio, 1411 (Tasseva, J., Analyst, 2017)

- Carbon black
- Gum Arabic
- Water



Iron-gall ink

IGI1 - IGI2 - IGI3 - IGI4

Giovanni Battista Palatino, 1545

- Gall-nuts
- Iron(II) Sulphate
- (· Copper(II) Sulphate)
- Gum Arabic
- Water



Logwood ink

LI1 - LI2 - LI3- LI4

Pierre de Ribeaucourt, 1792

- Gall-nuts
- Logwood
- Iron(II) Sulphate
- Copper(II) Sulphate
- Gum Arabic
- Sugar
- Water







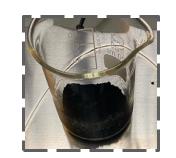


Carbon ink

 C_{l}

Giovanni Alcherio, 1411 (Tasseva, J., Analyst, 2017)

- Carbon black
- Gum Arabic
- Water









Iron-gall ink

IGI1 - IGI2 - IGI3 - IGI4

Giovanni Battista Palatino, 1545



- Iron(II) Sulphate
- (· Copper(II) Sulphate)
- Gum Arabic
- Water







Logwood ink

LI1 - LI2 - LI3- LI4

Pierre de Ribeaucourt, 1792



- Logwood
- Iron(II) Sulphate
- Copper(II) Sulphate
- Gum Arabic
- Sugar
- Water











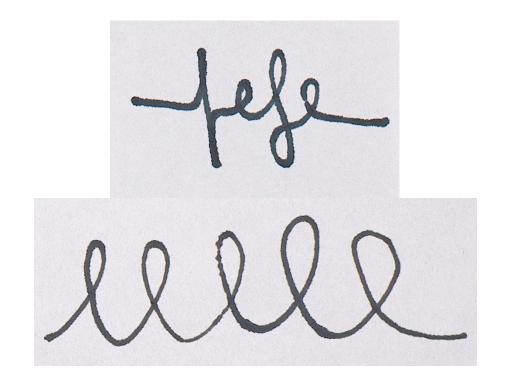


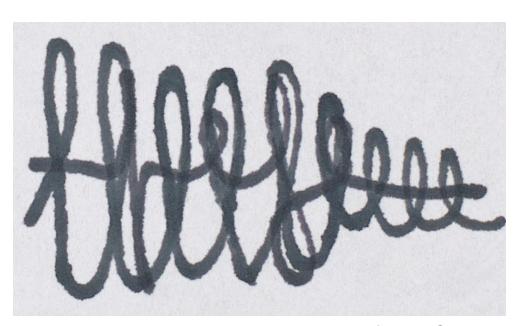
- ► Inks with distinct chemical composition (i.e., carbon ink and iron-gall ink)
- ► Inks with similar chemical composition (i.e., logwood ink and iron-gall ink)
- ► Inks with the same raw materials but in different amounts (i.e., iron-gall ink(1) and iron-gall ink(2))





- ► Inks with distinct chemical composition (i.e., carbon ink and iron-gall ink)
- ► Inks with similar chemical composition (i.e., logwood ink and iron-gall ink)
- ightharpoonup Inks with the same raw materials but in different amounts (i.e., iron-gall ink₍₁₎ and iron-gall ink₍₂₎)





Whatman® paper







Manuscripts

Original manuscripts preserved at the Biblioteca Universitaria di Pavia

Ms.Ald.52, 11th century

Collection: Manoscritti Aldini



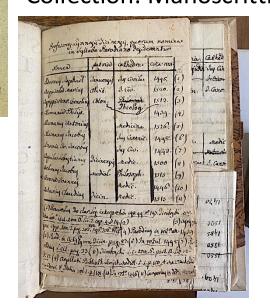
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Ms.Tic.67, 18th–19th century Collection: Manoscritti Ticinesi



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Mapping analysis - Mock-ups

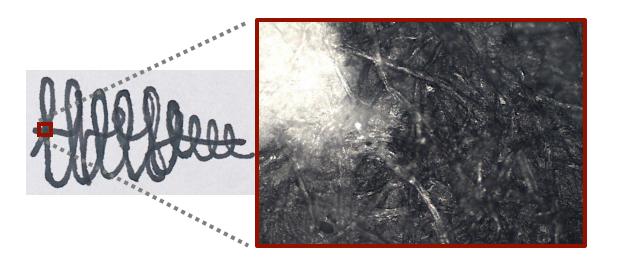
Iron-gall ink₍₃₎ on Logwood ink₍₄₎

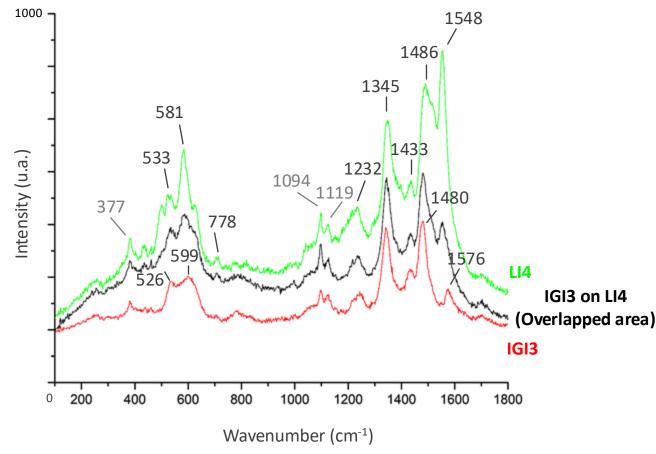
Bench-top set-up

Laser excitation line: 638 nm line - Objective lens: 10X - Laser power: 1.32×10⁴ W/cm²

Integration time: 15 s - Accumulation: 30

Map size: 214 μm x 203 μm - Spectra acquired: 120











Mapping analysis - Mock-ups

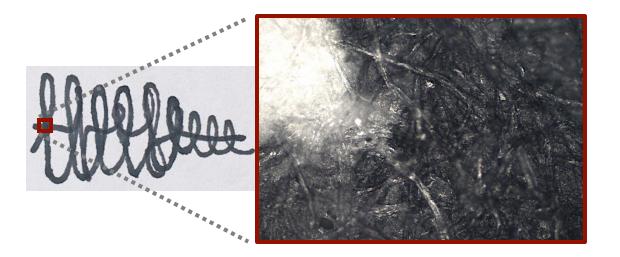
Iron-gall ink₍₃₎ on Logwood ink₍₄₎

Bench-top set-up

Laser excitation line: 638 nm line - Objective lens: 10X - Laser power: 1.32×10⁴ W/cm²

Integration time: 15 s - Accumulation: 30

Map size: 214 μm x 203 μm - Spectra acquired: 120



Metal polyphenol complex 1000 Intensity (u.a.) IGI3 on LI4 (Overlapped area) IGI3 200 400 600 800 1000 1200 1400 1600 1800 Wavenumber (cm⁻¹)







Mapping analysis - Mock-ups

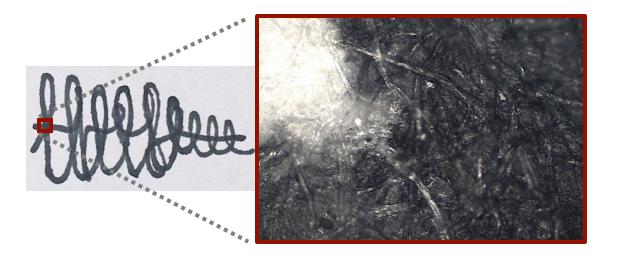
Iron-gall ink₍₃₎ on Logwood ink₍₄₎

Bench-top set-up

Laser excitation line: 638 nm line - Objective lens: 10X - Laser power: 1.32×10⁴ W/cm²

Integration time: 15 s - Accumulation: 30

Map size: 214 μm x 203 μm - Spectra acquired: 120



Metal polyphenol complex 1000 Intensity (u.a.) IGI3 on LI4 (Overlapped area) IGI3 200 400 600 800 1000 1200 1400 1600 1800 Wavenumber (cm⁻¹)





Principal Component Analysis

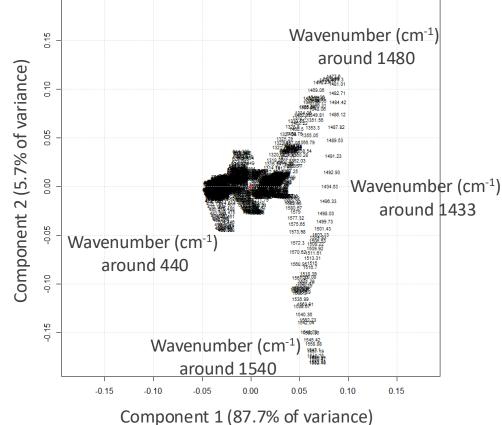
Mock-ups

Iron-gall ink₍₃₎ on Logwood ink₍₄₎

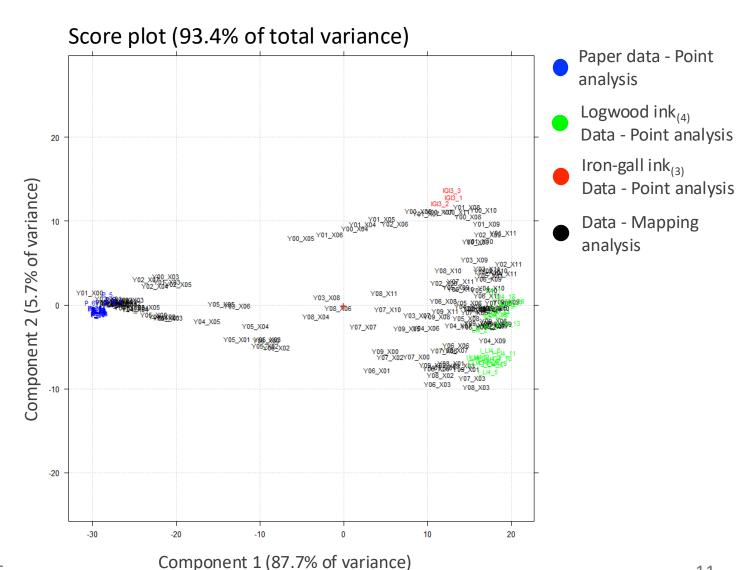
Row pre-processing: Standard Normal Variate (SNV)

Column pre-processing: Centering

Loading plot (93.4% of total variance)











Principal Component Analysis

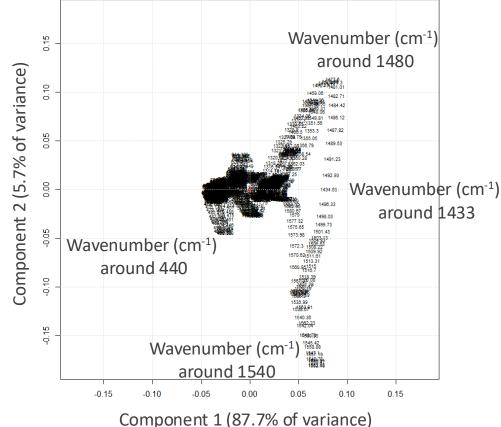
Mock-ups

Iron-gall ink₍₃₎ on Logwood ink₍₄₎

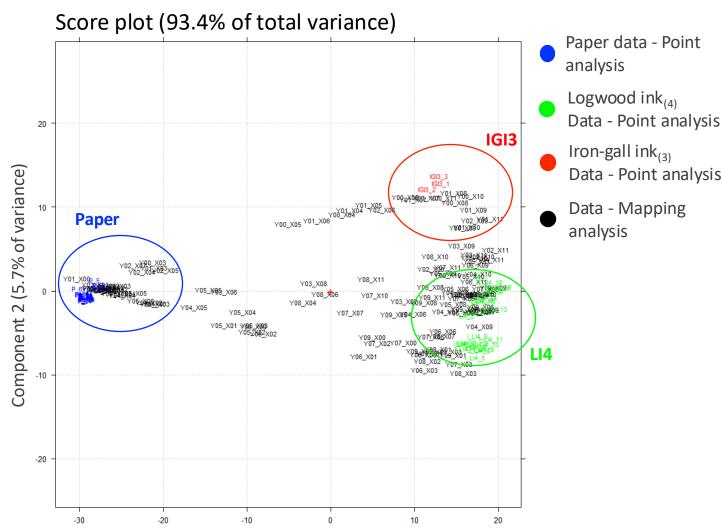
Row pre-processing: Standard Normal Variate (SNV)

Column pre-processing: Centering

Loading plot (93.4% of total variance)





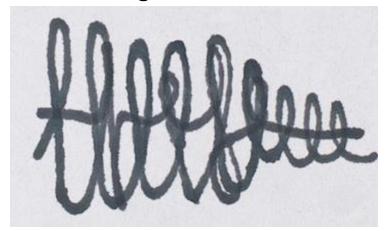






Iron-gall ink₍₃₎ on Logwood ink₍₄₎

Visible image:

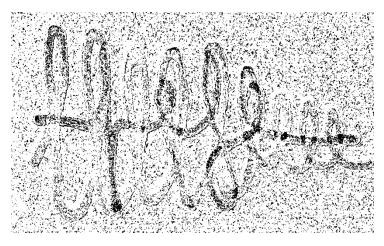


Colorimetry:

RGB="78,84,91" Lab="34.95,-2.16,-6.01"

RGB="87,92,100" Lab="38.68,-1.12,-6.11"

Image of normalised difference indexes:



Hypercolorimetric Multispectral Imaging Mock-ups

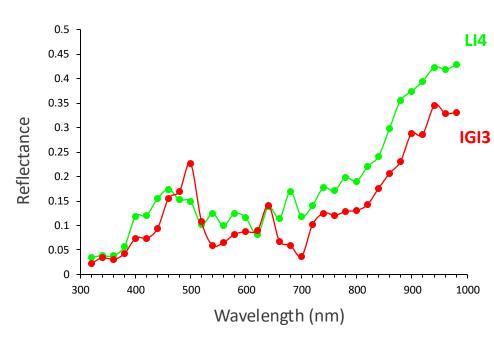
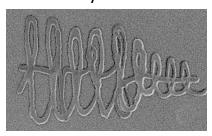


Image of Principal Component Analysis – PCA2:



Image of Principal Component Analysis – PCA3:









X-ray Fluorescence Spectroscopy

Mock-ups

Logwood ink₍₁₎ on Logwood ink₍₄₎

80% FeSO₄*7H₂O - 20% CuSO₄*5H₂O_70% FeSO4*7H₂O - 30% CuSO₄*5H₂O

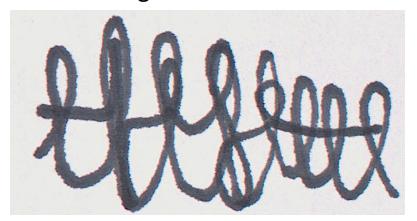
Single point analysis

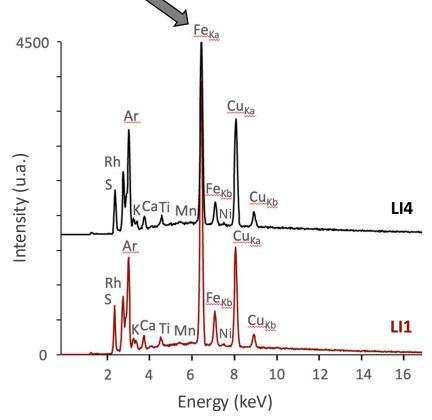
Measurement time: 90 s - Tube voltage: 40 kV - Tube current: 100 μ

Mapping analysis

Tube voltage: 40 kV - Tube current: 100 μA - Map size: 3 cm x 3 cm

Visible image:











X-ray Fluorescence Spectroscopy

Mock-ups

Logwood ink₍₁₎ **on Logwood ink**₍₄₎ 80% FeSO₄*7H₂O - 20% CuSO₄*5H₂O_70% FeSO4*7H₂O - 30% CuSO₄*5H₂O

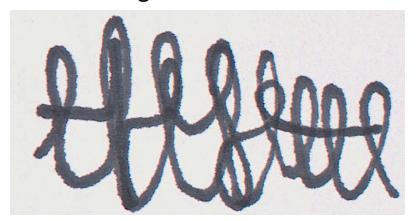
Single point analysis

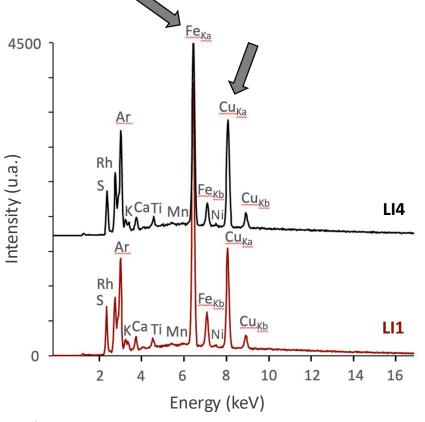
Measurement time: 90 s - Tube voltage: 40 kV - Tube current: 100 μ

Mapping analysis

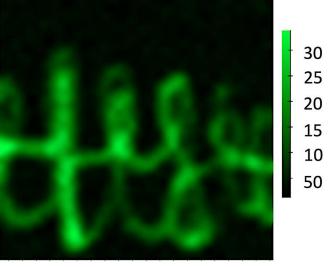
Tube voltage: 40 kV - Tube current: 100 μA - Map size: 3 cm x 3 cm

Visible image:





Elemental map Cu_{Ka}:





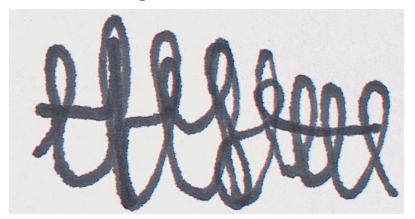




Logwood ink₍₁₎ on Logwood ink₍₄₎

80% FeSO₄*7H₂O - 20% CuSO₄*5H₂O _70% FeSO4*7H₂O - 30% CuSO₄*5H₂O

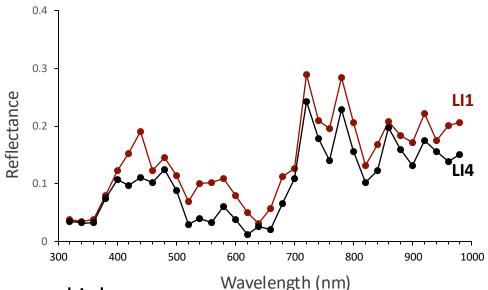
Visible image:



Colorimetry:

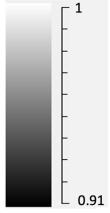
RGB="90,92,103" Lab="39.05,1.04,-7.29"

RGB="88,89,99" Lab="38.14,1.06,-6.50"



Map of multispectral similarity - Logwood ink $_{(4)}$:











Point analysis - Manuscripts

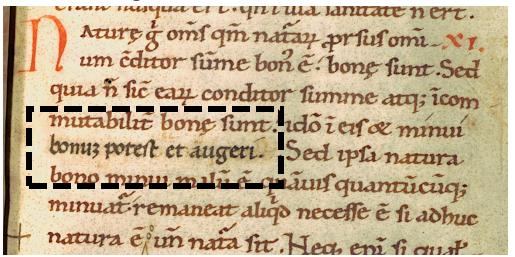
Ms.Ald.52, 11th century

Collection: Manoscritti Aldini – Biblioteca Universitaria di Pavia

Portable set-up

Laser excitation line: 785 nm line - Laser power: 1.01×10⁵ W/cm² - Integration time: 5 s - Accumulation: 5 Laser excitation line: 785 nm line - Laser power: 3.03×10⁵ W/cm² - Integration time: 10 s - Accumulation: 1 Laser excitation line: 785 nm line - Laser power: 2.02×10⁵ W/cm² - Integration time: 5 s - Accumulation: 3

Visible image



Parchment manuscript







Point analysis - Manuscripts

Ms.Ald.52, 11th century

Collection: Manoscritti Aldini – Biblioteca Universitaria di Pavia

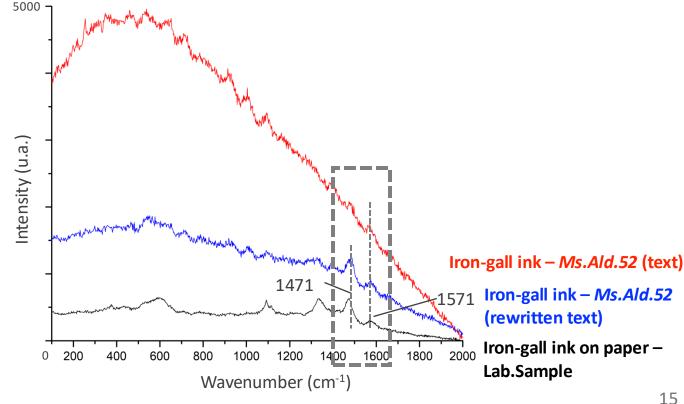
Portable set-up

Laser excitation line: 785 nm line - Laser power: 1.01×10⁵ W/cm² - Integration time: 5 s - Accumulation: 5 Laser excitation line: 785 nm line - Laser power: 3.03×10⁵ W/cm² - Integration time: 10 s - Accumulation: 1 Laser excitation line: 785 nm line - Laser power: 2.02×10⁵ W/cm² - Integration time: 5 s - Accumulation: 3

Visible image

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Parchment manuscript









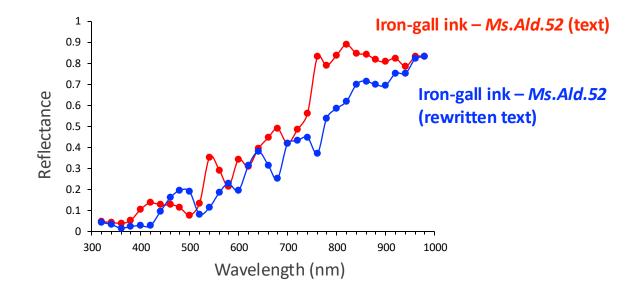
Manuscripts

Ms.Ald.52, 11th century

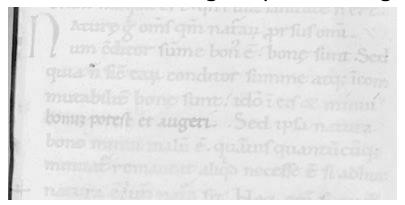
Collection: Manoscritti Aldini – Biblioteca Universitaria di Pavia

Visible image - spectral range 380-780 nm:

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Near-infrared image - spectral range 780-1000 nm:









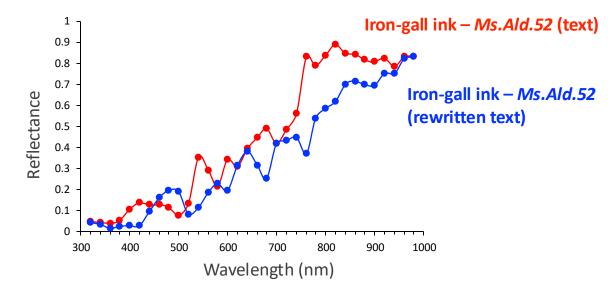
Manuscripts

Ms.Ald.52, 11th century

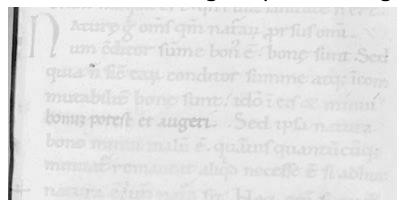
Collection: Manoscritti Aldini – Biblioteca Universitaria di Pavia

Visible image - spectral range 380-780 nm:

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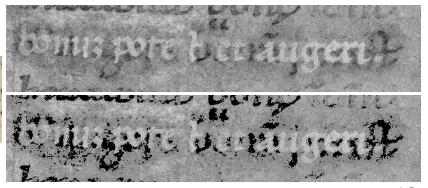
Near-infrared image - spectral range 780-1000 nm:



Visible image:

bonus potest et augeri.

Image of Principal Component Analysis - PCA2:







Manuscripts

Ms.Tic.67, 18th-19th century, Autograph section by Siro Comi

Collection: Manoscritti Ticinesi – Biblioteca Universitaria di Pavia

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Paper manuscript





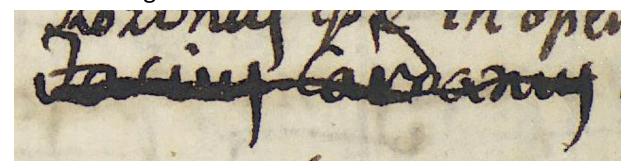


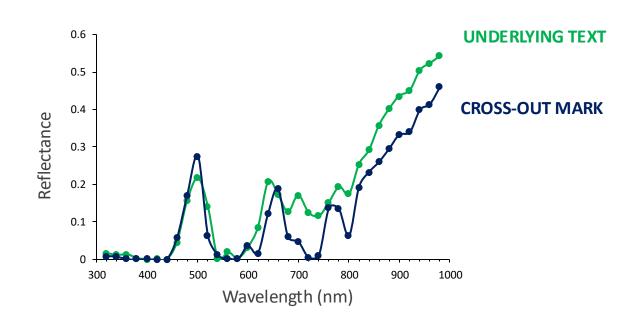
Manuscripts

Ms.Tic.67, 18th-19th century, Autograph section by Siro Comi

Collection: Manoscritti Ticinesi – Biblioteca Universitaria di Pavia

Visible image:





Manuscripts





Hypercolorimetric Multispectral Imaging

Ms.Tic.67, 18th-19th century, Autograph section by Siro Comi

Collection: Manoscritti Ticinesi – Biblioteca Universitaria di Pavia

Visible image:

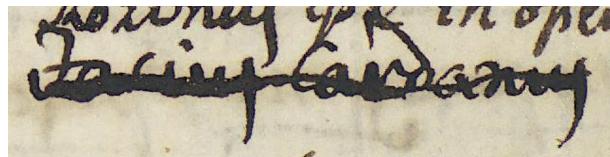
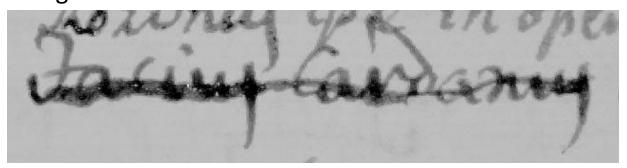
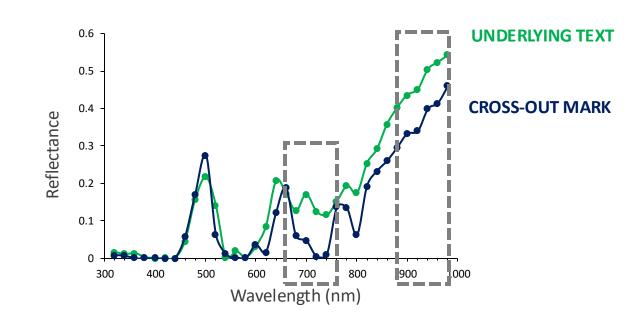


Image of normalised difference indexes:









Manuscripts

Ms.Tic.67, 18th-19th century, Autograph section by Siro Comi

Collection: Manoscritti Ticinesi – Biblioteca Universitaria di Pavia

Visible image:

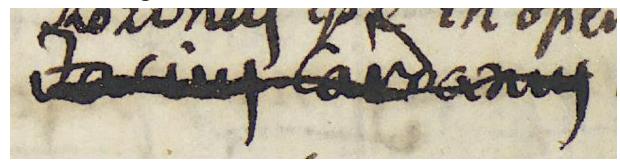
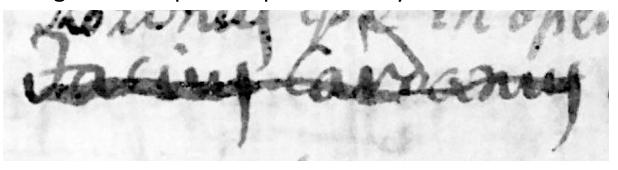
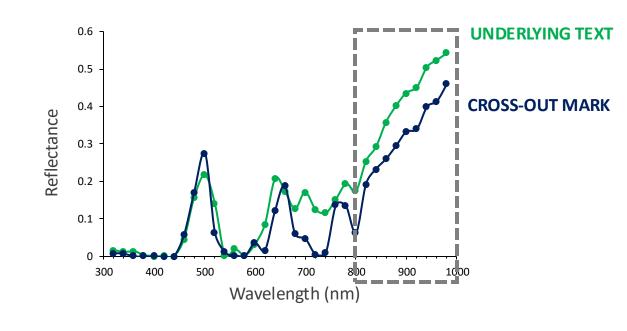


Image of Principal Component Analysis – PCA1:







Mock-ups – Manuscripts

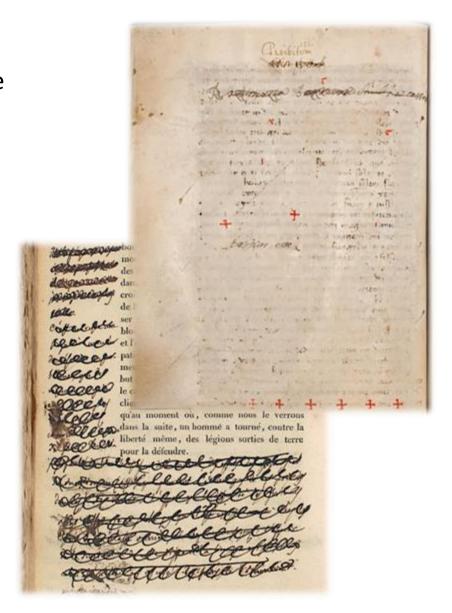
The non-invasive and multi-analytical methodology:

- ✓ characterisation and discrimination of inks with similar chemical compositions and those used for writing, with the inks superimposed by erasure
- √ enhancing legibility of text overwritten by cross-outs
- √ potential and optimal combined use of different techniques





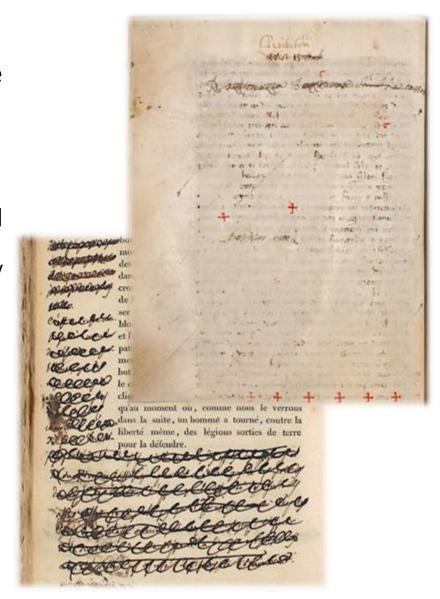
Ongoing collaboration with the *Biblioteca Universitaria di Pavia* on case studies of original manuscripts (e.g., Ms.Ald.211, 14th century)







- Ongoing collaboration with the *Biblioteca Universitaria di Pavia* on case studies of original manuscripts (e.g., Ms.Ald.211, 14th century)
- Ongoing processing of data from diagnostic campaigns on original manuscripts (e.g., manuscripts by Alessandro Manzoni, 19th century; 13th century reused polyphonic parchments)





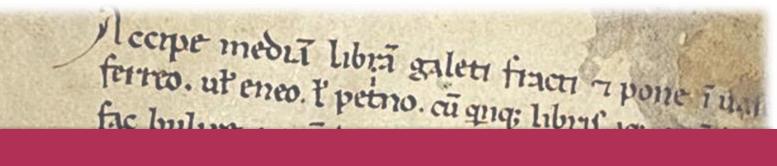


Ongoing collaboration with the *Biblioteca Universitaria di Pavia* on case studies of original manuscripts (e.g., Ms.Ald.211, 14th century)

- Ongoing processing of data from diagnostic campaigns on original manuscripts (e.g., manuscripts by Alessandro Manzoni, 19th century; 13th century reused polyphonic parchments)
- Implementation of other analytical techniques in collaboration with Optics Department of the Institute of Physics of the Czech Academy of Sciences in Prague (e.g., Micro X-Ray Fluorescence spectrometry; Terahertz Imaging; Surface-Enhanced Raman Scattering; Spatially Offset Raman Spectroscopy)



PhD in Physics, End-of-Year Seminars, 17th and 18th September 2025



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Thank you for your attention!

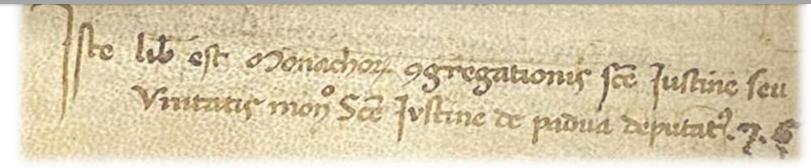
Dr. Chiara Delledonne (chiara.delledonne@unipv.it)

Department of Physics, University of Pavia

Arvedi Laboratory of Non-Invasive Diagnostics, Department of Musicology and Cultural Heritage, University of Pavia

















(Tasseva, J., Analyst, 2017)

Carbon ink Iron-gall ink

Giovanni Alcherio, 1411 Giovanni Battista Palatino, 1545

Carbon black - 0,6 g Gum Arabic - 0,7 g Water - 9 ml Gall-nuts - 15,4 g Iron (II) Sulphate - 10,2 g

Gum Arabic - 5,1 g

Water - 150 ml

Production of inks and mock-ups

Logwood ink

Ribeaucourt, 1792

Gall-nuts - 12,2 g

Logwood - 6,1 g

Iron (II) Sulphate - 6,1 g

Copper(II) Sulphate - 1,5 g

Gum Arabic - 4,6 g

Sugar - 1,5 g

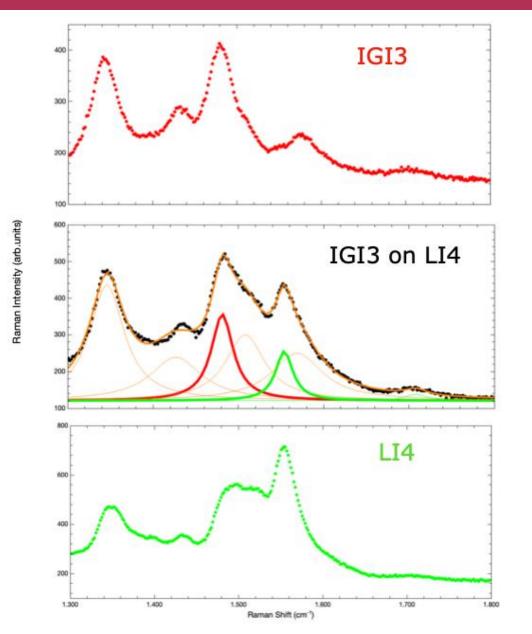
Water - 293,7 ml







Iron-gall $ink_{(3)}$ on Logwood $ink_{(4)}$



*Micro-Raman Spectroscopy*Mock-ups

Bench-top set-up Mapping analysis

Laser excitation line: 638 nm line

Objective lens: 10X

Laser power: 1.32×10⁴ W/cm²

Integration time: 15 s

Accumulation: 30

Map size: 214 μ m x 203 μ m,

Step = 23,8 μ m Y e 22,7 μ m X

Spectra acquired: 120

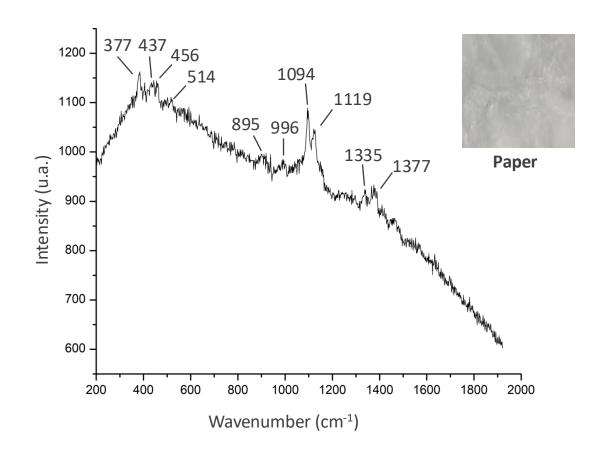




*Micro-Raman Spectroscopy*Mock-ups

Bench-top set-up - Point analysis

Laser excitation line: 638 nm line - Objective lens: 50X long working distance - Laser power: 5.23×10⁴ W/cm² - Integration time: 10 s - Accumulation: 10









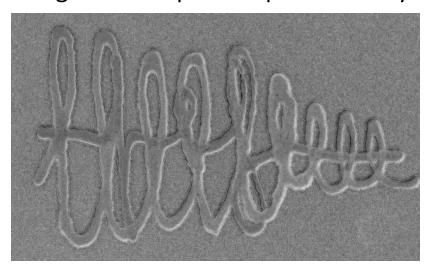
*Hypercolorimetric Multispectral Imaging*Mock-ups

Iron-gall ink₍₃₎ on Logwood ink₍₄₎

Image of Principal Component Analysis – PCA2:



Image of Principal Component Analysis – PCA3:



Canali in Ingresso 300-320-340, 320-340-360, 340-360-380, 360-380-400, 380-400-420, 400-420-440, 420-440-460, 440-460-480, 460-480-500, 480-500-520, 500-520-540, 520-540-560, 540-560-580, 560-580-600, 680-600-620, 600-620-640, 620-640-660, 640-660-680, 660-680-700, 680-700-720, 700-720-740, 720-740-760, 740-760-780, 760-780-800, 820-840-860, 840-860-880, 860-880-900, 880-900-920, 900-920-940, 920-940-960, 940-960-980, 960-980-1000

Coefficient PCA 1.9746, 0.0113, 0.0055, 0.0021, 0.0017, 0.0015, 0.0010, 0.0008, 0.0006, 0.0004, 0.0003, 0.0002, 0.0002, 0.0001, 0.0001, 0.0001, 0.0001, 0.0001, 0.0001, 0.0001, 0.0000, 0.00

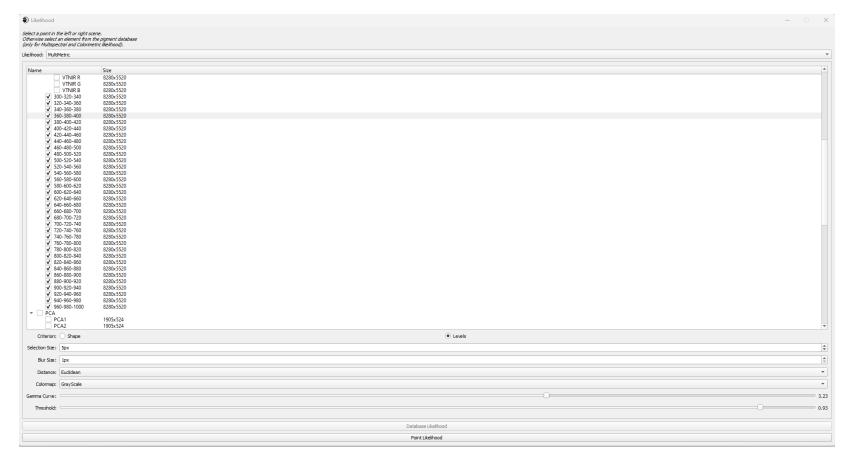




Logwood ink₍₁₎ on Logwood ink₍₄₎

*Hypercolorimetric Multispectral Imaging*Mock-ups

Map of multispectral similarity - Logwood ink (4):









Hypercolorimetries Medition espections

Point analysi Merkusuring

Ms.Ald.52, 11th century

Collection: Manoscritti Aldini – University Library of Pavia

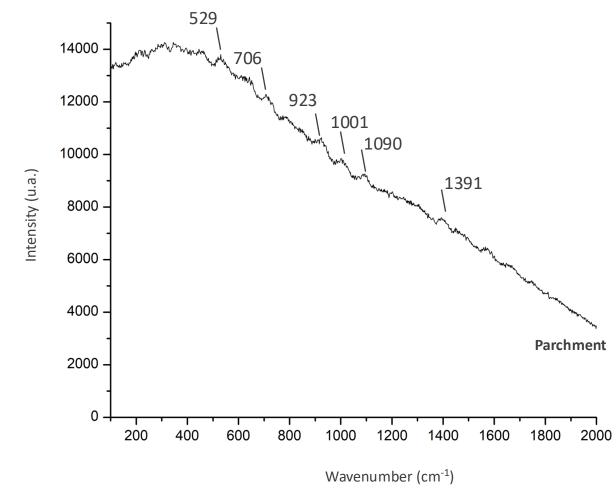
Portable set-up:

Laser excitation line: 785 nm line -

Laser power: 4.04×10⁵ W/cm² -

Integration time: 10 s -

Accumulation: 1









Hypercolorimetric Multispectral Imaging

Mock-ups

Ms.Ald.52, 11th century Collection: Manoscritti Aldini – University Library of Pavia

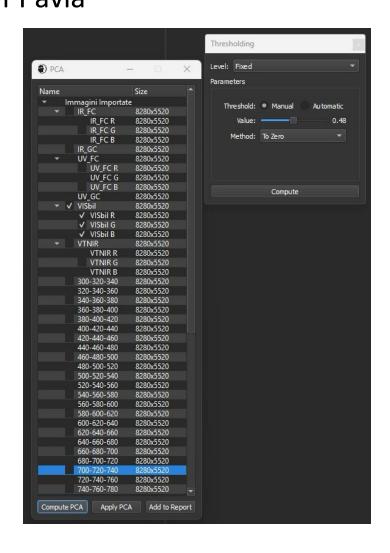
Image of Principal Component Analysis – PCA2:

Canali in Ingresso VISbil R, VISbil G, VISbil B
Coefficienti PCA 0.0797, 0.0012, 0.0004

Colorimetry:

RGB="96,84,68" Lab="36.99,5.19,13.22"

RGB="137,96,74" Lab="46.70,20.76,23.87"







Hypercolorimetric Multispectral Imaging

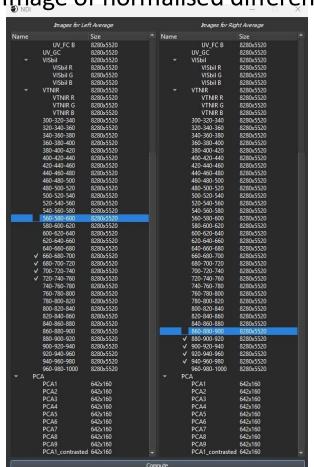
Manuscript

Ms.Tic.67, 18th-19th century, Autograph section by Siro Comi

Collection: Manoscritti Ticinesi – Biblioteca Universitaria di Pavia

Image of normalised difference indexes:

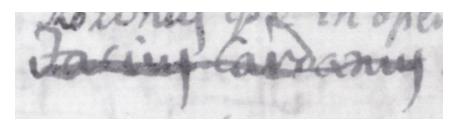




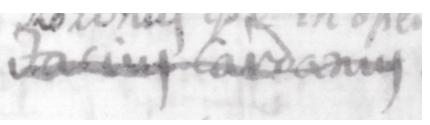
Canali in Ingresso Coefficienti PCA

PFCL IR1 R, PFCL IR1 G, PFCL IR1 B, PFCL IR2 R, PFCL IR2 G, PFCL IR2 B, PFCL IR3 R, PFCL IR3 G, PFCL IR3 B 0.1026, 0.0005, 0.0001, 0.0000, 0.0000, 0.0000, 0.0000, 0.0000, 0.0000

IR1-760-1000 nm



IR2-850-1000 nm



Colorimetry:

RGB="64,62,62" Lab="25.76,1.29,0.66"

IR3-930-1000 nm

Taking Cardaning

RGB="69,65,62" Lab="27.44,1.59,3.26"







XploRA PLUS – HORIBA Scientific and Analytical Instruments Software: LabSpec6 - HORIBA Scientific and Analytical Instruments

i-Raman Plus 785S – Metrohm Software: BWSpec® - B&W Tek, Metrohm







Bench-top instrumentation: XploRA PLUS confocal microRaman System Instrument -

Olympus Microscope BX41 and Raman module

Laser excitation lines – Power:

- 532 nm 100 mW
- 638 nm 100 mW
- 785 nm 300 mW

Portable instrumentation: Portable Raman spectrometer i-Raman Plus - BAC151C compact Raman microscope compatible with B&W Tek portable Raman system

Laser excitation lines – Power:

Objective lens:

• 785 nm - 300 mW

- 5X
- 10X
- 50X





Software:

- CapturePick® for the image acquisition
- SpectraPick ®for the image calibration processing
- PickViewer® for the image post-processing, provides image processing tools

Several kinds of analyses are possible with PickViewer, such as:

add and integrate any other imaging data (fluorescence, X-ray, thermal etc.); multichannel images viewer; any pixel colorimetry and spectral reflectance read-out; mapping by colour, spectra, arbitrary channels; principal components analysis; contrast enhancement through digital imaging processing algorithms; neural network based clustering; colour and spectral signature database; two ways mapping by database entry; any channel to RGB false colours visualization; channels math, indexes and normalised





The calibration procedure follows three steps:

- 1) white patches analysis to achieve correct white balance and even exposure across all the subject;
- 2) running an Artificial Intelligence based optimizer that finds the mathematical function to translate camera digital values of the colour-checker into radiometric and colorimetric measurements;
- 3) applying the calibration to the acquired images and producing 34 monochromatic images, containing the spectral reflectance at 320, 340, 360, 380, 400, 420, 440, 460, 480, 500, 520, 540, 560, 580, 600, 620, 640, 660, 680, 700, 720, 740, 760, 780, 800, 820, 840, 860, 880, 900, 920, 940, 960, 980 nm.
 - The achieved precision across the whole 36 megapixel image is better than 95% on the spectral reflectance images and colour error less than CIE2000 $\Delta E = 2$ for the colour image.



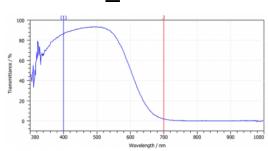


The radiometric references consist in a number of white patches (to sample any uneven lighting) surrounding the subject and of a 36 patches colour-checker.

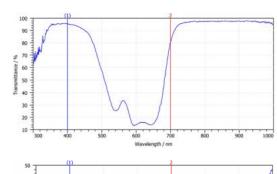
These references are built using colour's samples out of the NCS – Natural Colour Systemic® C catalog and their spectral reflectances are accurately measured in Profilocolore lab in the range of 220 to 1050 nm at 0.7 nm accuracy (Instrument System Spectroradiometer CAS 140 CT and dark room).

Optical filters:

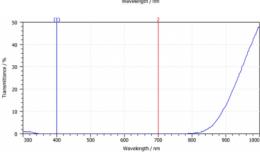
PFCL-A 77x2



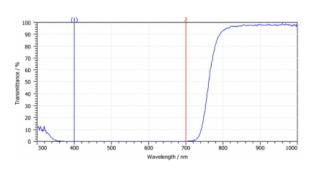
PFCL-B_77x2



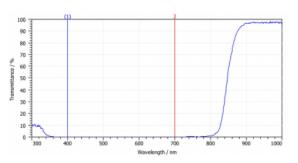
PFCL-IR3-930_77x2



PFCL-IR1-760_77x2



PFCL-IR2-850 77x2







Hypercolorimetric Multispectral Imaging (HMI), Profilocolore srl (Roma, Italia):

the system consists of a modified camera, a set of optical filters with different spectral transmittances, a checkerboard target for colour calibration and white balance of the images, white markers for balancing the exposure, and sophisticated software for image acquisition, calibration and processing.

Nikon Z8 mirrorless 45.7 megapixel digital camera (Minato, Tokyo, Japan), modified under a Nikon-Profilocolore project, to reach the full spectral range of sensitivity of silicon sensors from about 300 nm to 1000 nm.

AF-S 50mm 1:1.4 G Nikkor lens (Minato, Tokyo, Japan) mounted with FTZ adapter.

Lighting was obtained by Two Godoz TT600 xenon flashes (T = 5600 K) (Shenzhen, Guangdong, China) controlled by the Godox X2T-N transmitter and used after removing their front plastic lenses, thus allowing also the UV wavelength to be emitted.

Philips infrared incandescent lamps (PAR38 IR 175W E27 240V Red 1CT/12).

Visible images of fluorescence induced by ultraviolet light are acquired using Madatec CR230B-HP UV LED lamps (365 nm UV source with a power of about 3 W) (Pessano con Bornago, Italy).





Portable XRF spectrometer ELIO by Bruker XGLab s.r.l. (Milan, Italy) Low-power X-ray tube with Rh anode and 1.2 mm of analytical spot.

Working conditions

- Single point method, 90 s, 40 kV, 100 μ A 2048 acquisition channels Net area counts of the peak (K α) normalized to net area counts of the peak of Rh-L α .
- Mapping method 40 kV, 100 μ A 2048 acquisition channels Movement setup: Rows = 40, Columns = 40, Spectrum time = 1 s, Rows distance = 750 μ m, Columns distance = 750 μ m, Area = 3 cm x 3 cm

Software ELIO 1.60.57 by Bruker XGLab s.r.l. (Milan, Italy)