



Non destructive methods to identify the components and the techniques of works of art

Mady ELIAS

Institut des NanoSciences de Paris (INSP)

Université Pierre et Marie Curie (UPMC)

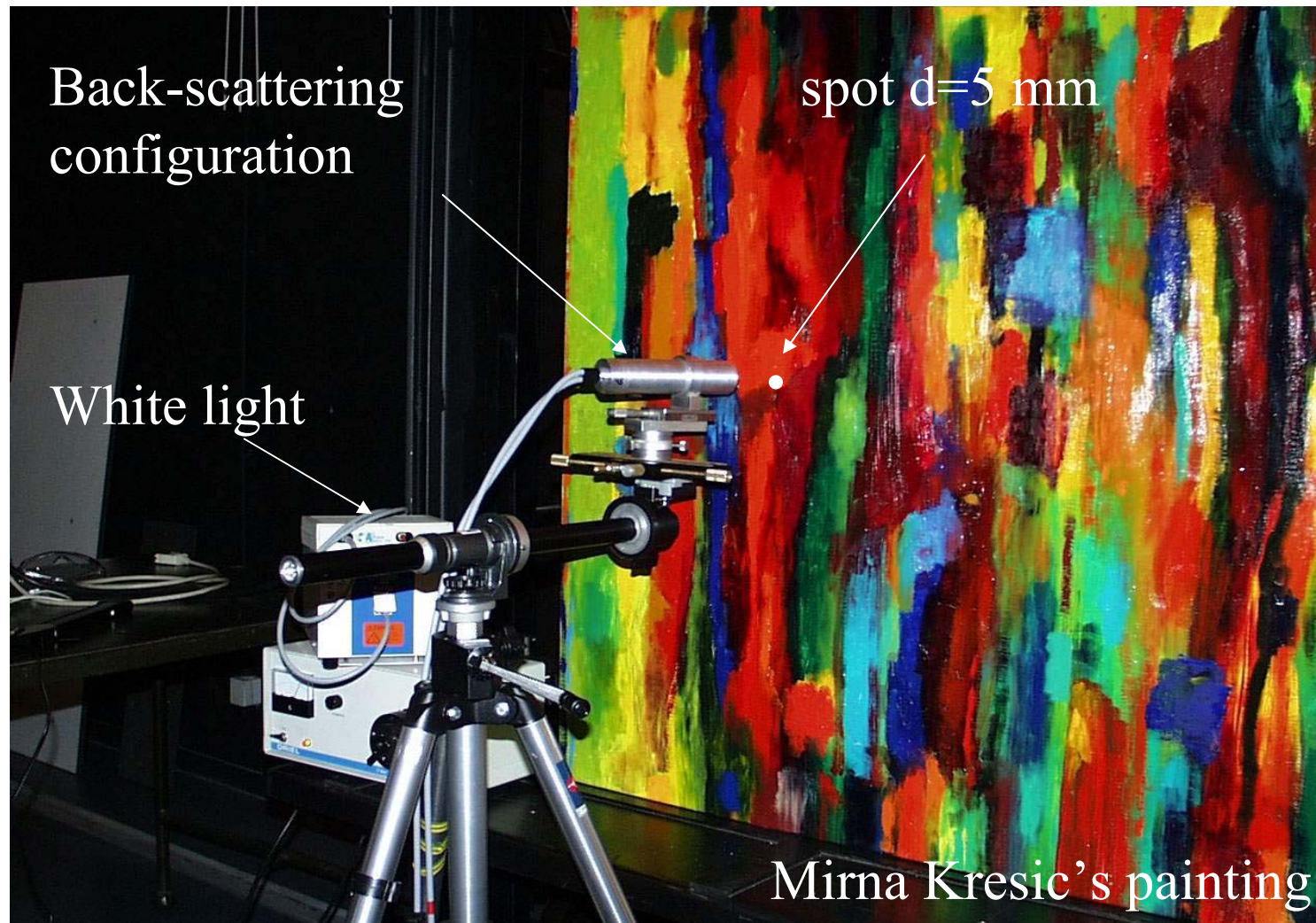
UMR 7488 CNRS

mady.elias@insp.jussieu.fr

Overview

- **Pigments and dyes identification**
 - Upper layer: reflectance spectra and databases
 - Under layer: OCT, RTE ?
- **Varnishes**
 - Topography: confocal microscopy, OCT
 - Identification: UV fluorescence
 - Virtual removing
- **Artistic techniques**
 - Gold techniques (goniophotometry)
 - Glazes (colorimetry, RTE)

Pigments and dyes identifications



Gonio-spectro-photo-colorimeter in back-scattering configuration

Pigments and dyes identifications



Carolingien manuscript of St Amand
les Eaux' scriptorium, IXth c.

Gonio-spectro-photo-colorimeter in back-scattering configuration

Pigments and dyes identifications

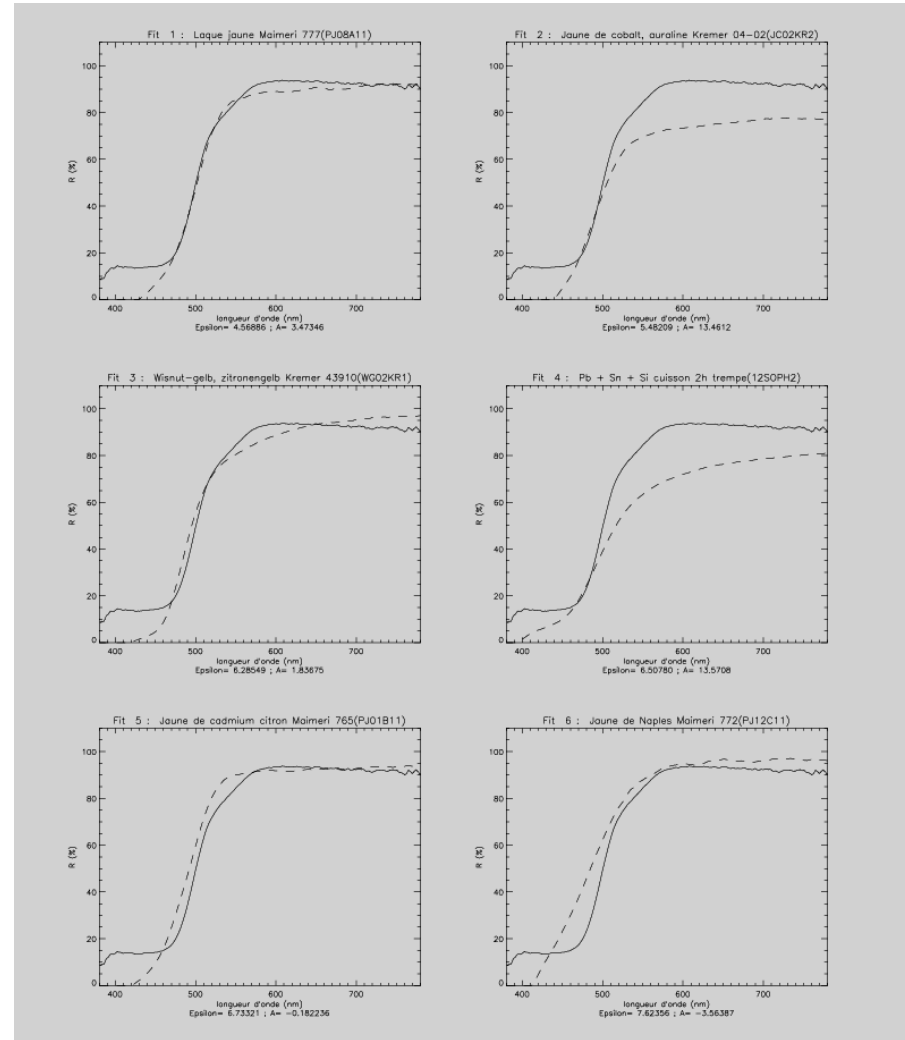


Olivier Mosset, Gone West, 1987

FRAC Dijon

Yellow laq Maimeri

G.Dupuis, M.Elias, L.Simonot, Pigment identification by fiber-optics diffuse reflectance spectroscopy”, Appl. Spectrosc. 56 n°10 (2002)1329-1336



Pigments and dyes identifications

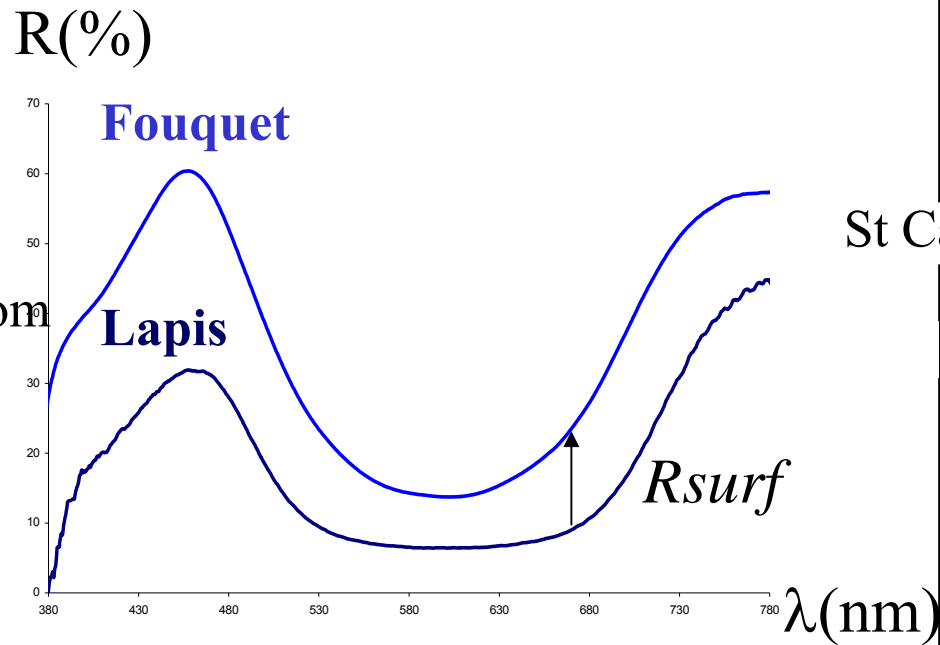


St Apolline's martyrdom



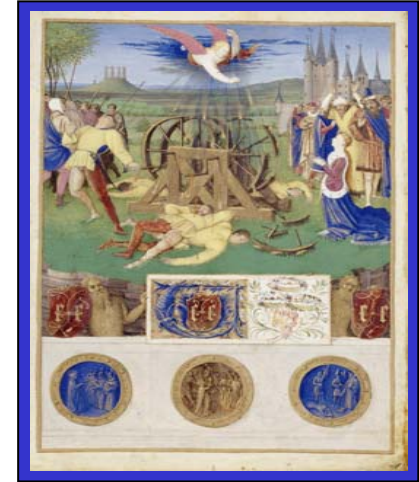
St Nicolas' consecration

Etienne Chevalier's « livre d'heures » Jean Fouquet ≈ 1450
Chantilly Museum



Blue areas : **lapis-lazuli**

Surface state \Rightarrow translation R_{surf}



St Catherine's martyrdom



St Hilaire's consecration

Pigments and dyes identifications

Numerous spectra

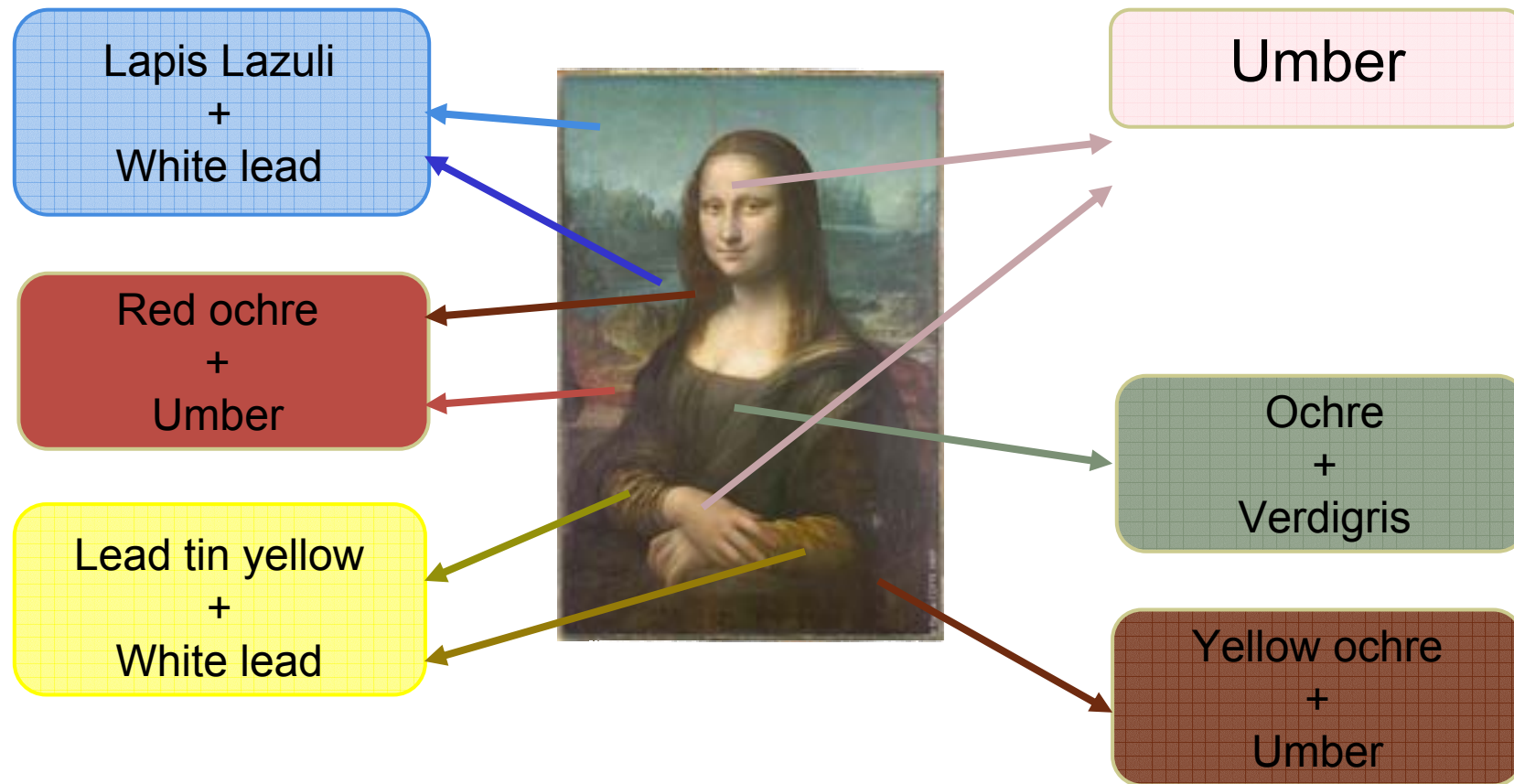


Multi spectral camera (Lumiere et Technology SAS)

⇒ 100,000,000 reflectance spectra

Pigments and dyes identifications

formulation software Colibri (Ciba, Minolta) + colour chart
pigment mixture recognition

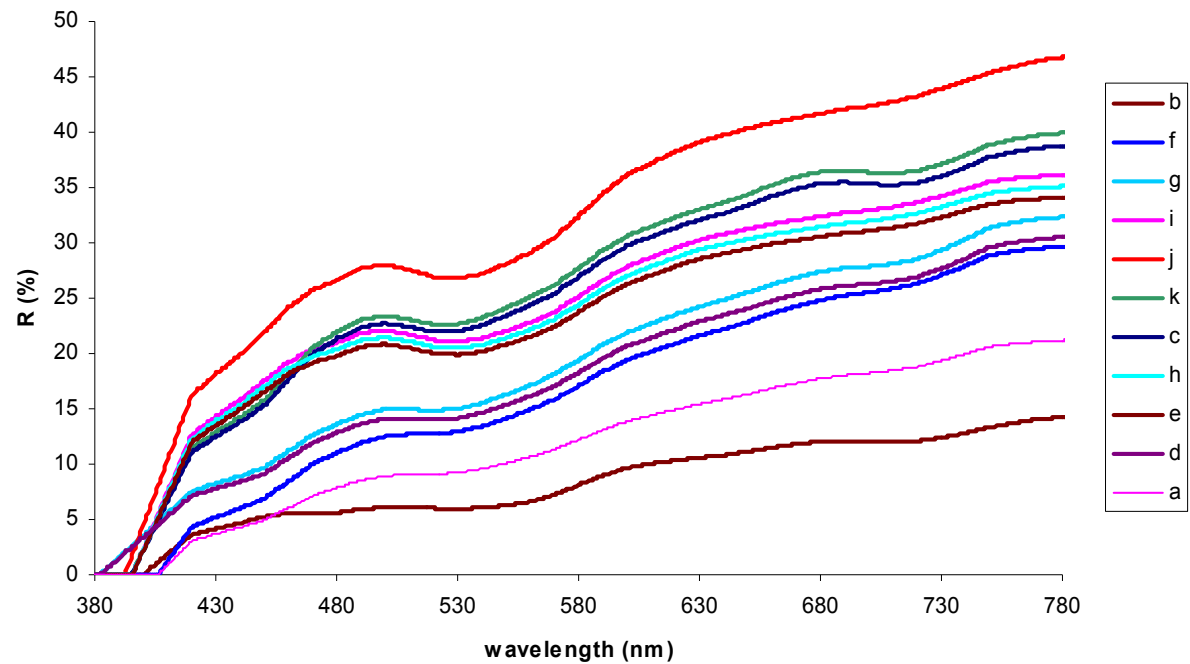
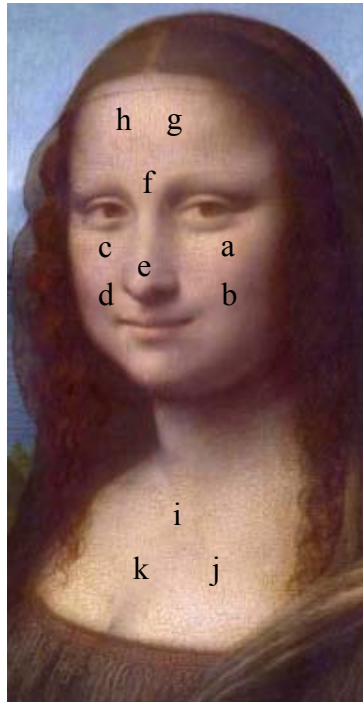


Multispectral camera (Lumiere et Technology SAS)

Pigments and dyes identifications

Composition of Mona Lisa's sfumato

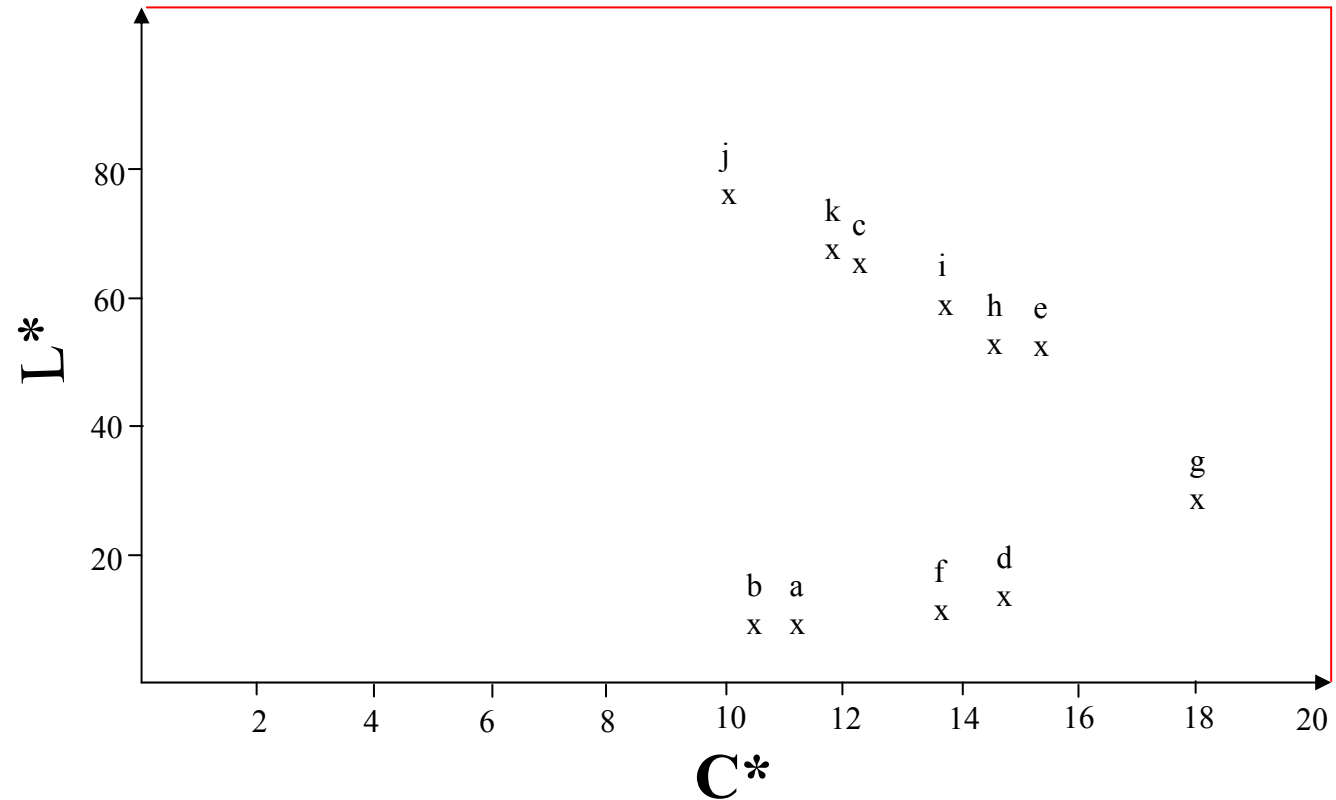
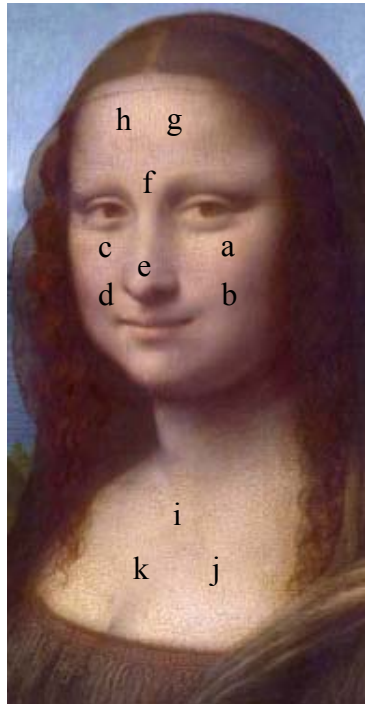
Unvarnished spectra



Pigments and dyes identifications

Composition of Mona Lisa's sfumato

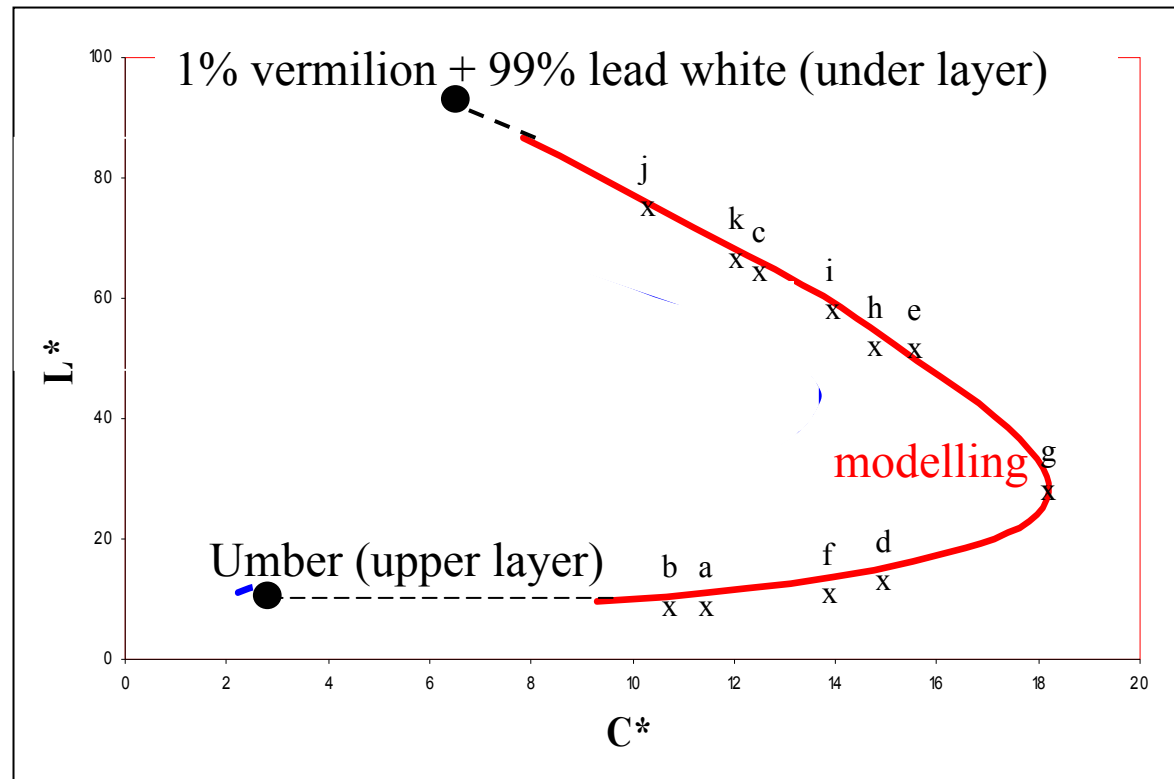
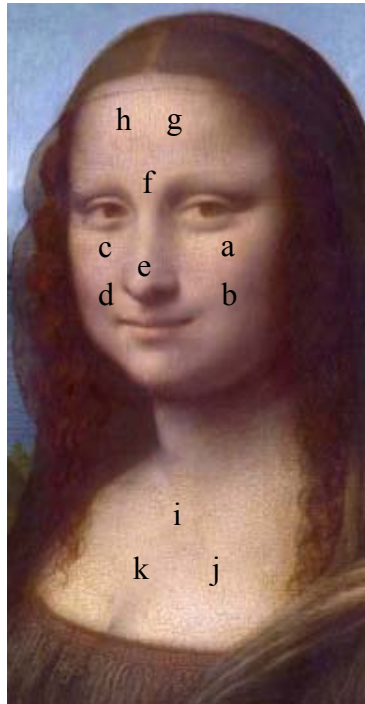
Spectra → colour L*a*b* space



Pigments and dyes identifications

Composition of Mona Lisa's sfumato

Modelling using RTE solved by AFM



an Umber in the under layer

a mixture of 1% vermilion and 99% lead white in the under layer

M. Elias, P. Cotte "Multispectral camera and radiative transfer equation used to depict Leonardo's sfumato in Mona Lisa" Applied Optics, Vol. 47, n°12, pp. 2146-2154

Pigments and dyes identifications

Identification in the upper layer

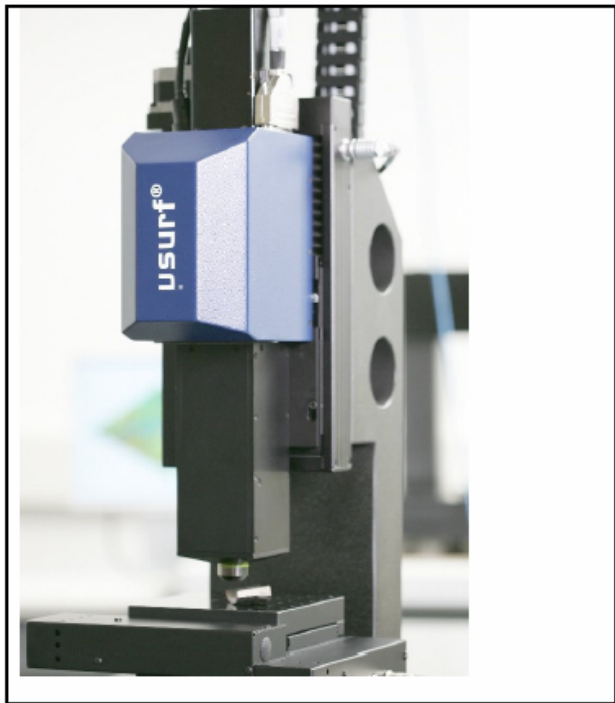
- Goniospectrophotometer (1 spectrum)
- Multispectral camera (100,000,000 spectra)

Identification in the under layer

- **Modelling using the radiative transfer equation (systemization in progress)**
- **OCT in the visible range (in progress)**

Varnishes

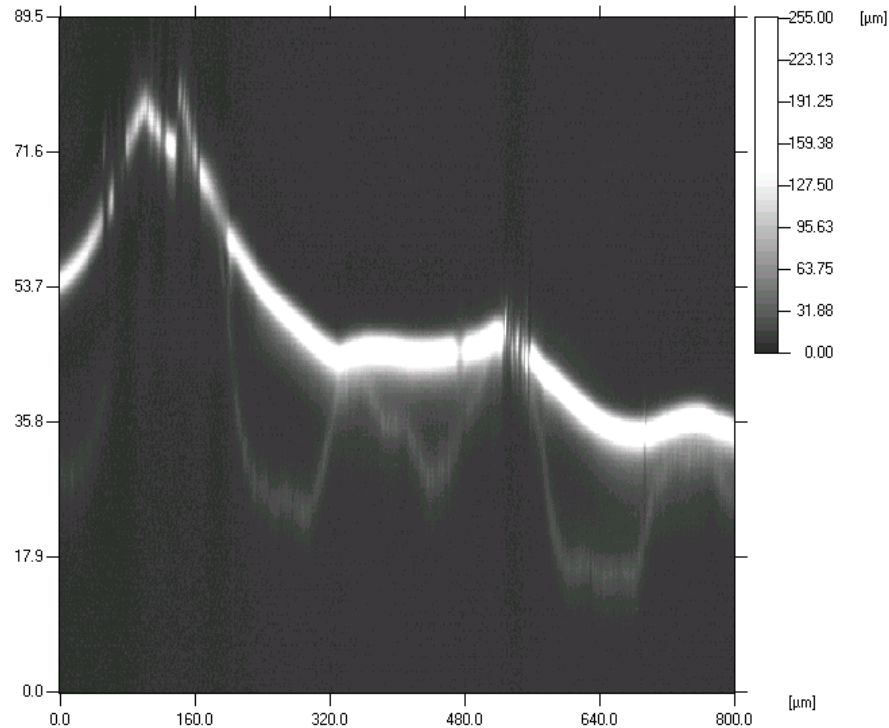
Topography : confocal microscopy



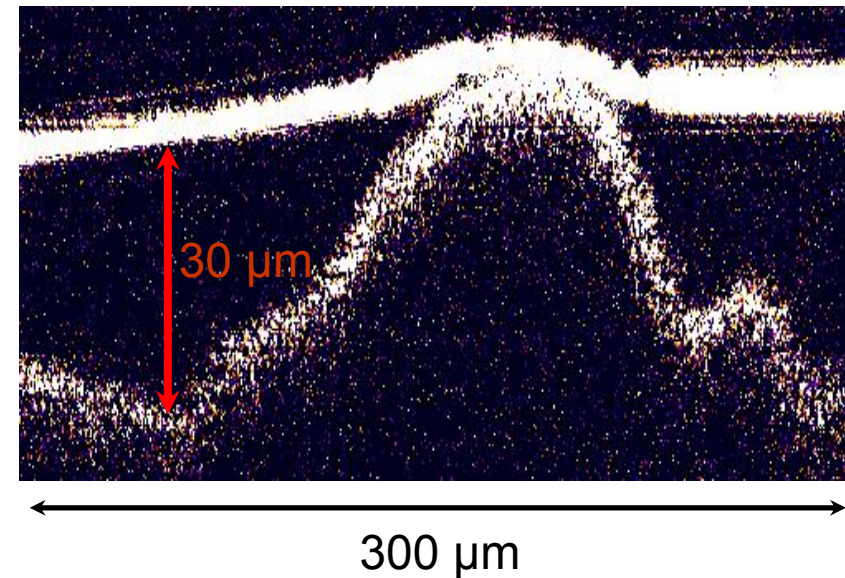
μ surf microscope – Nanofocus
European project FingArtPrint

Varnishes

Topography : cross section



Paint + mastic in turpentine
confocal microscopy

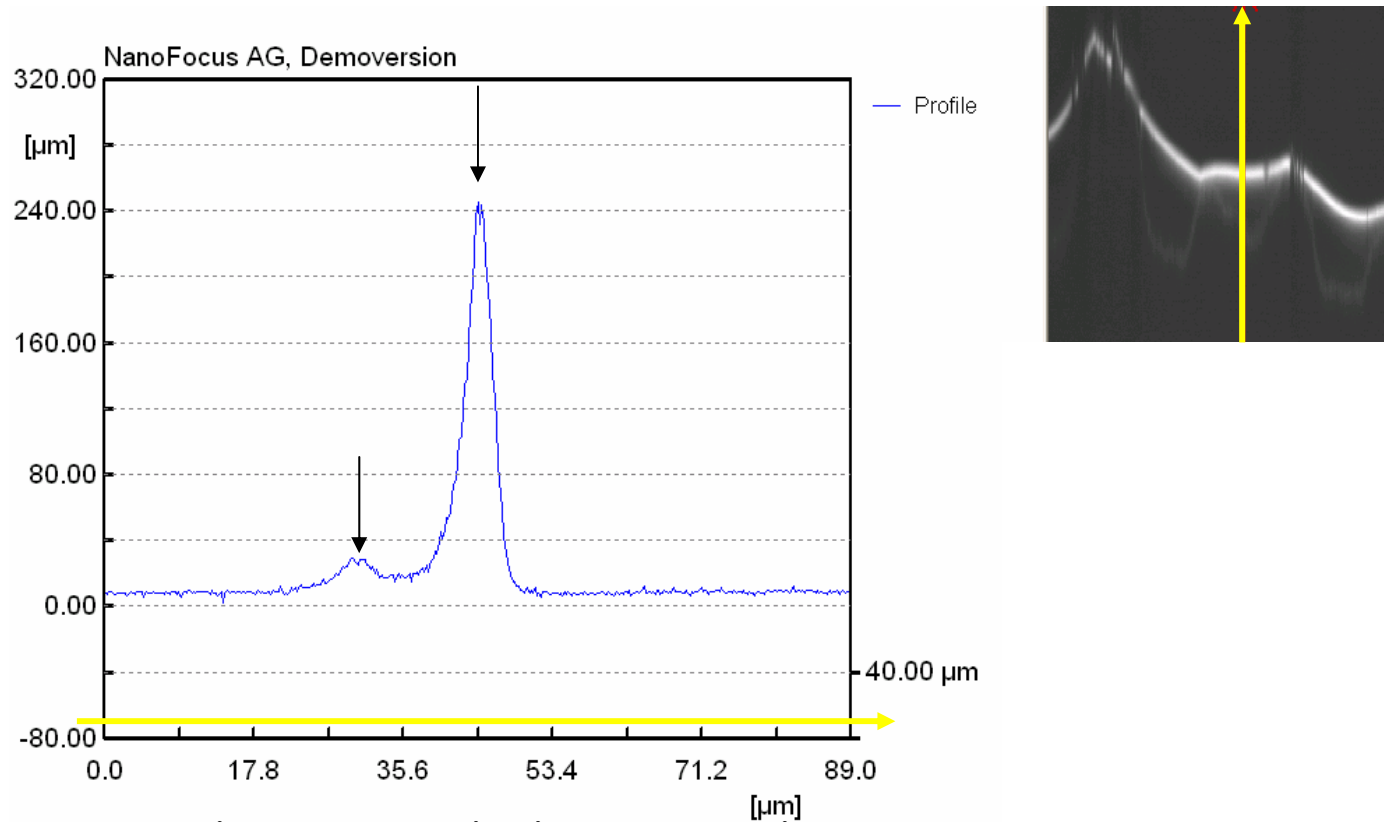


Paint + mastic in turpentine
OCT

Same accuracy $\approx 1.5 \mu\text{m}$

Varnishes

Topography : cross section profile

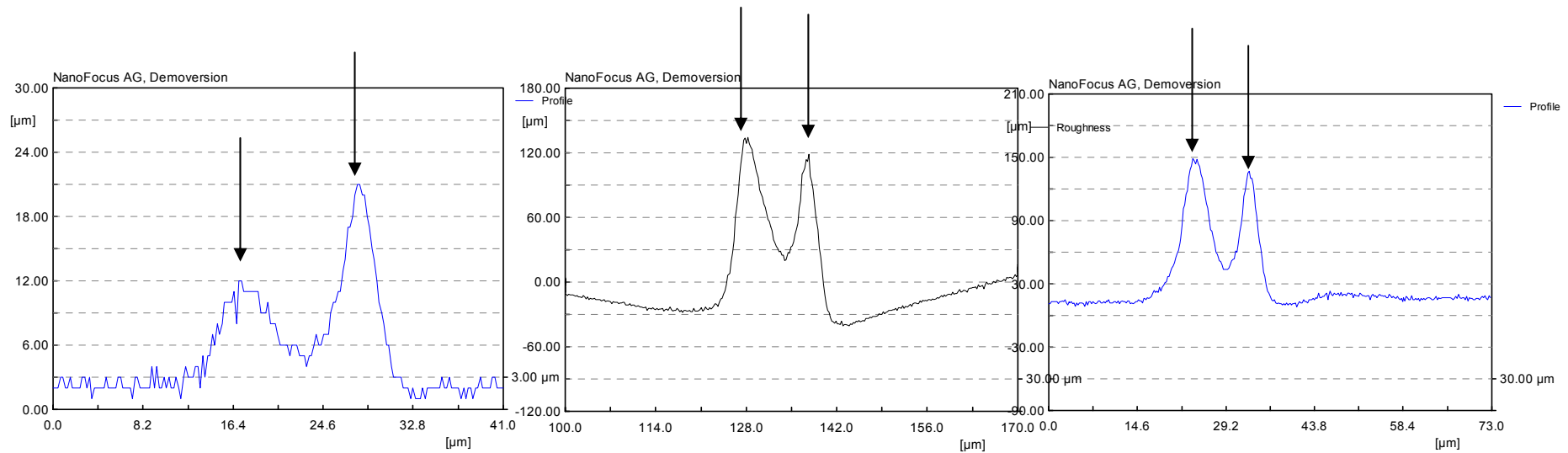


Paint + mastic in turpentine

$$\Rightarrow \text{Thickness varnish} = 16 \times 1.5 = 24 \mu\text{m}$$

Varnishes

Topography : cross section profiles



Metal +aged mastic
in linseed oil

Metal +aged mastic
in turpentine

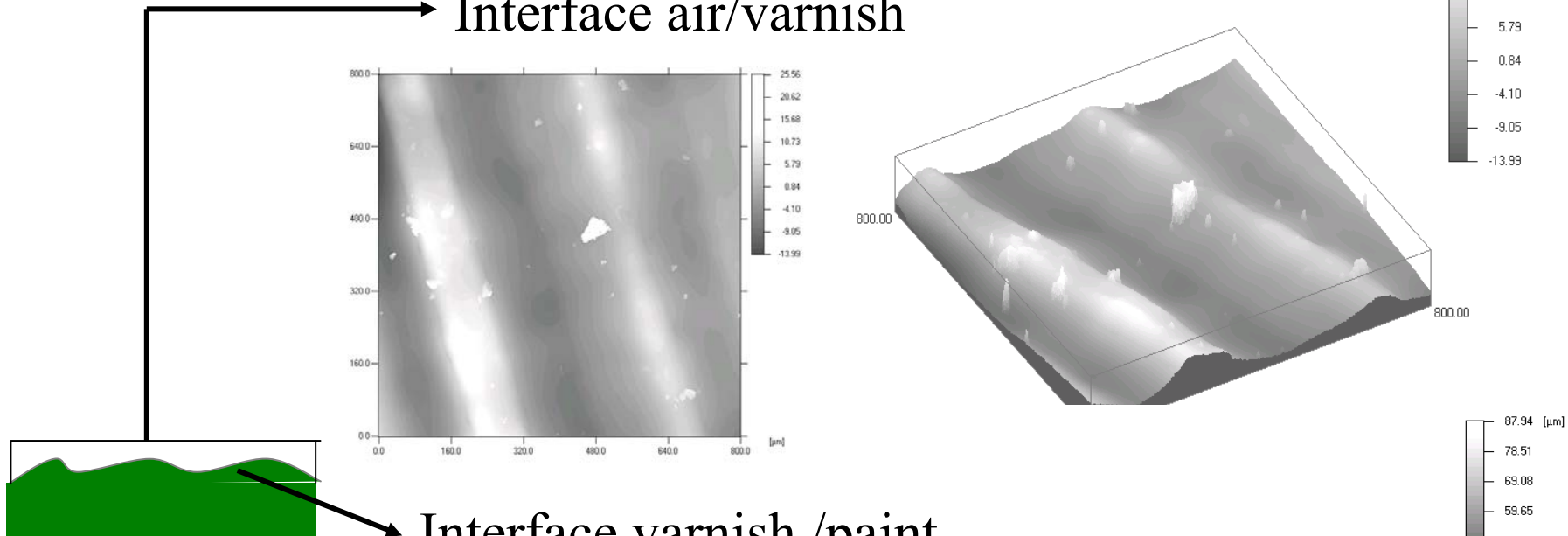
Metal + fresh mastic
in turpentine

\Rightarrow Thickness of the varnish measurable ∇ binder ∇ ageing

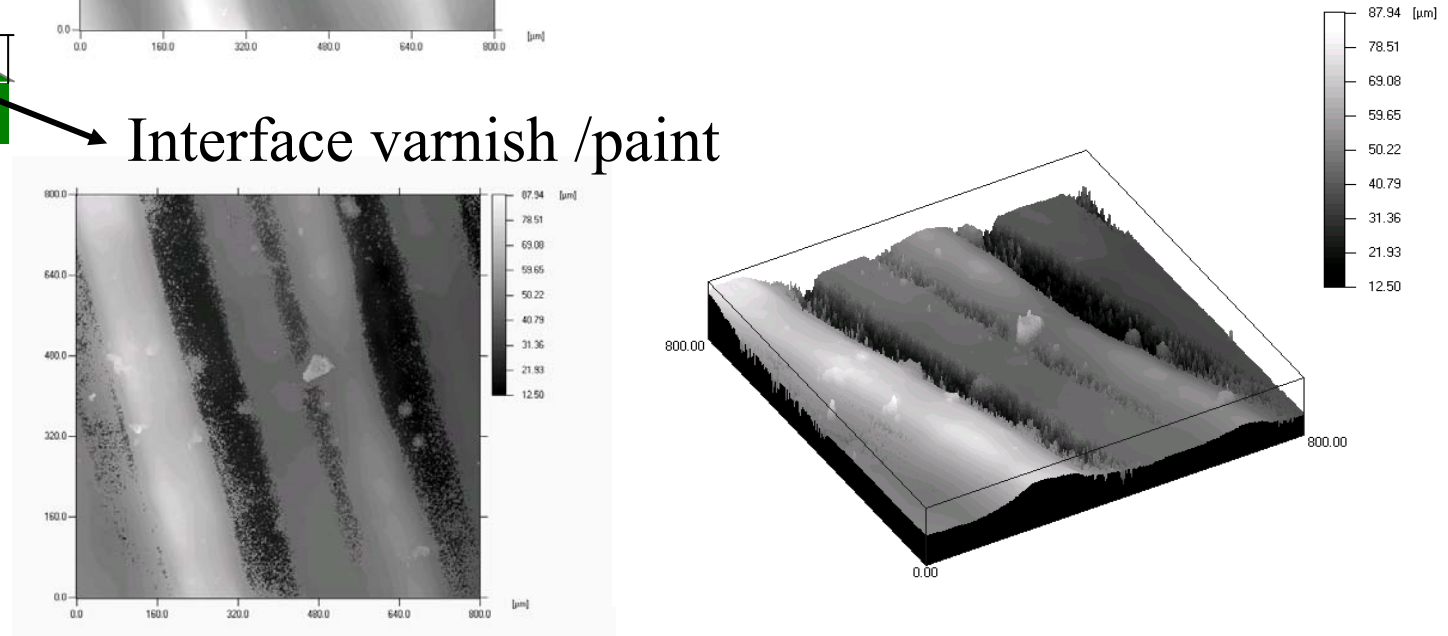
Varnishes

Topography : Interfaces imaging

Interface air/varnish



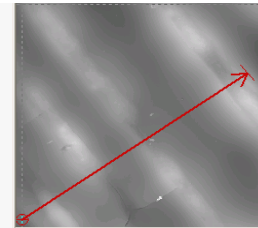
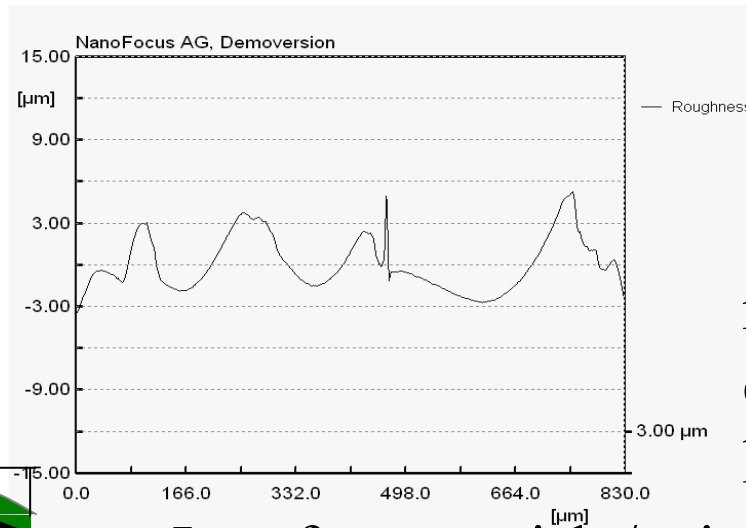
Interface varnish /paint



Varnishes

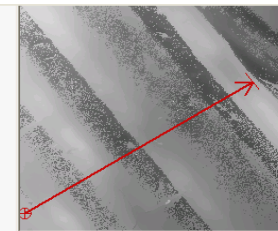
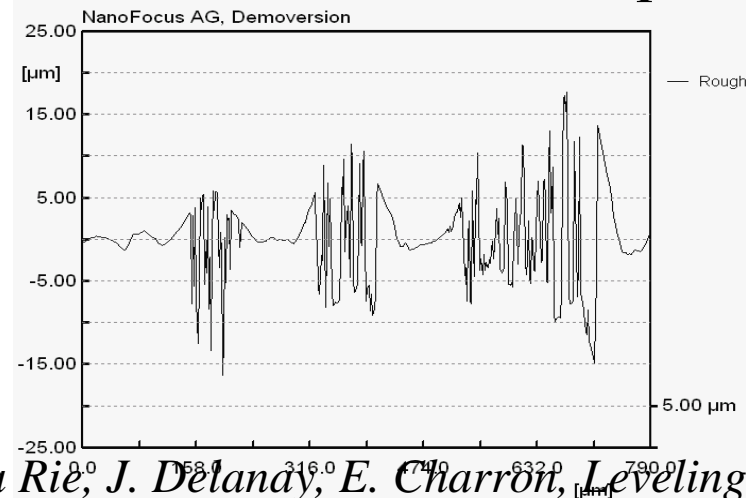
Topography : Interface profiles

Interface air/varnish



r.m.s. roughness $h = 2.0 \mu\text{m}$
 correlation length $l = 16.6 \mu\text{m}$
 $h/l = 0.1$

Interface varnish /paint

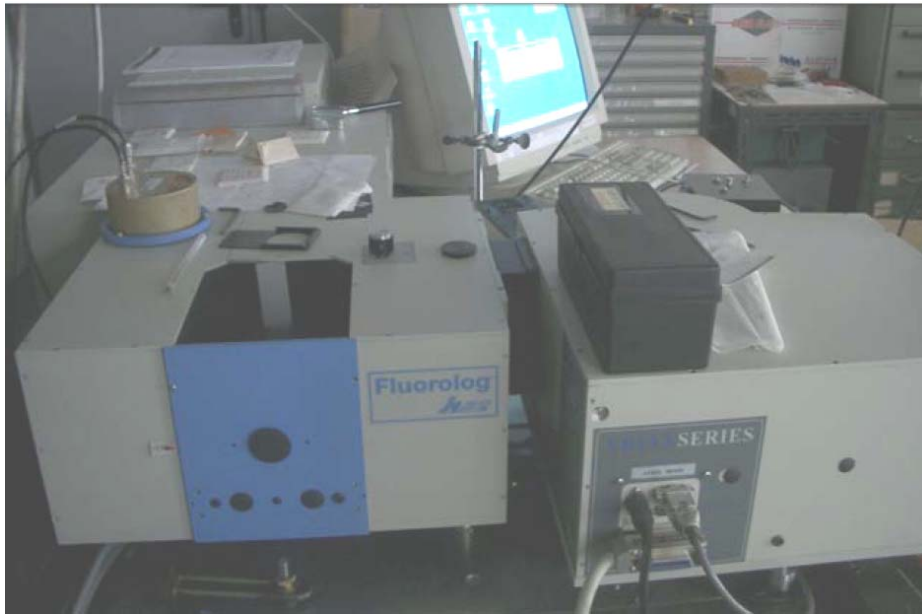


r.m.s. roughness = $4.8 \mu\text{m}$
 correlation length $l = 16.6 \mu\text{m}$
 $h/l = 0.3$

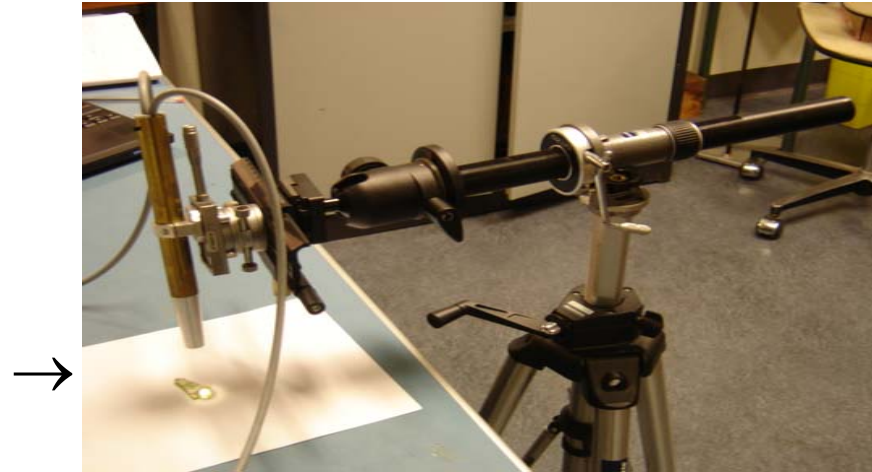
M. Elias, R. De La Rie, J. Deland, E. Charron, Leveling of varnishes over rough substrates, Opt Com 266 (2006) 586-591

Varnishes

Identification: UV fluorescence emission spectra



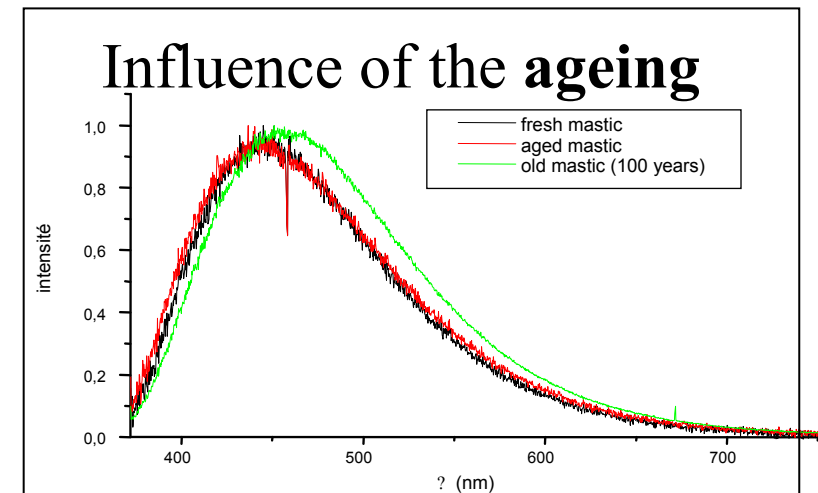
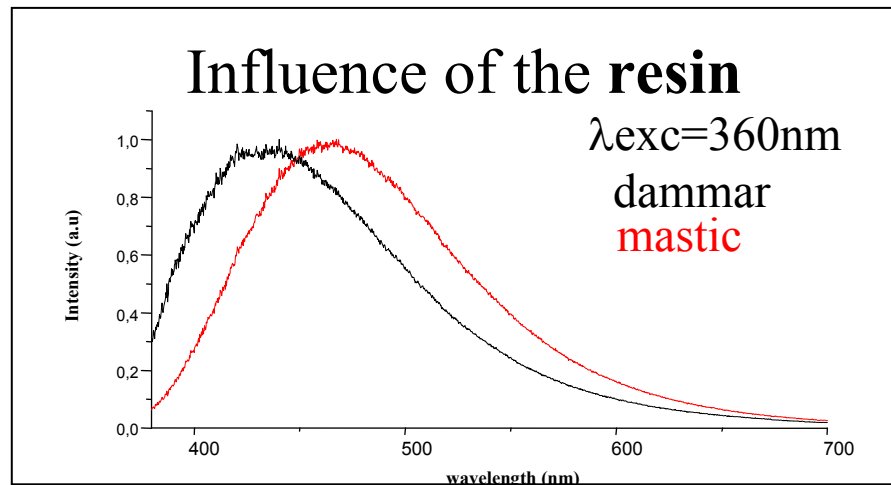
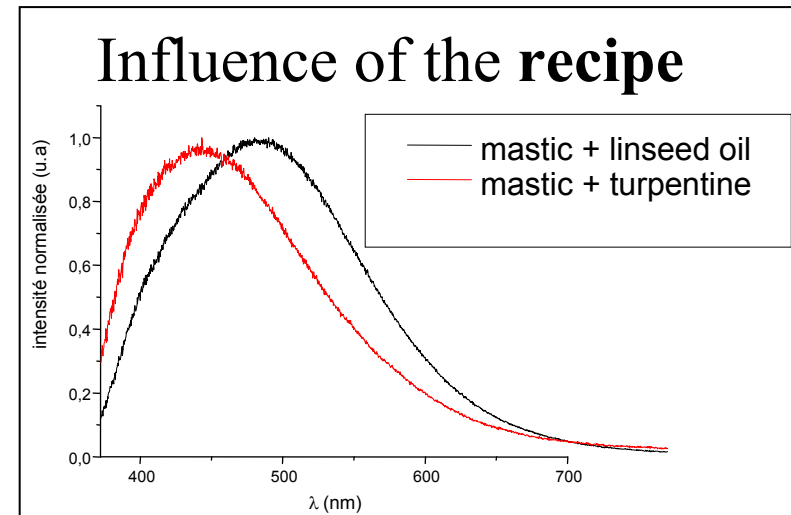
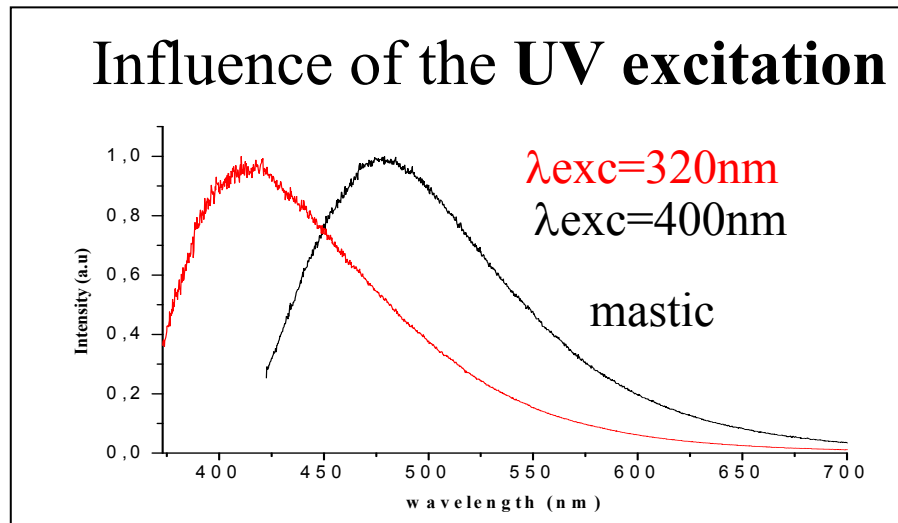
Spectrofluorimeter Jobin - Yvon



Gonio-spectrometer in back-scattering configuration
- powerful UV-LED / laser + frequency doubler
– silica optical fiber

Varnishes

Identification: UV fluorescence emission spectra



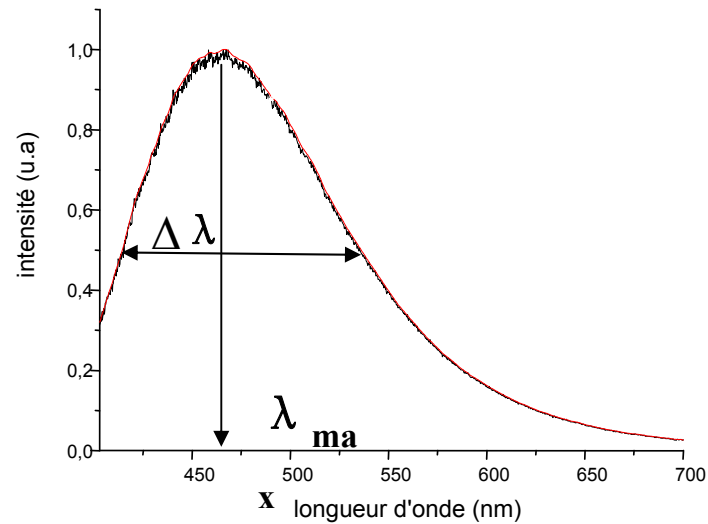
Varnishes

Identification: UV fluorescence emission spectra

Protocol: 1 database for 1 λ_{exc}

unknown spectrum \leftrightarrow spectral databes

Criteria: λ_{max} and/or $\Delta \lambda$

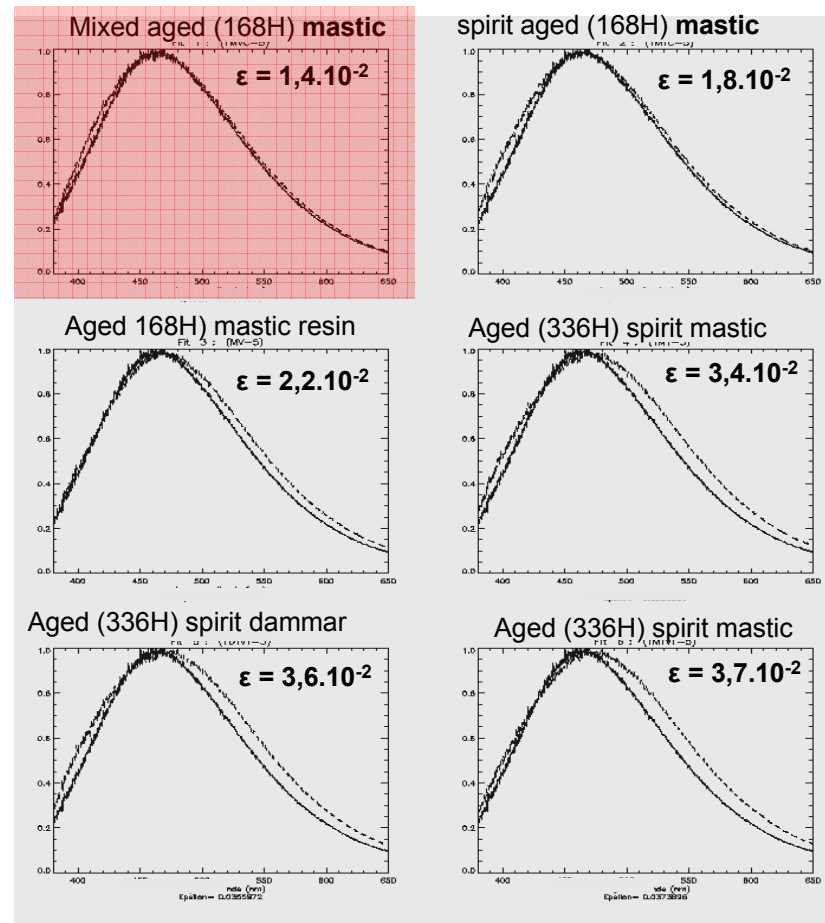


Varnishes

Identification: UV fluorescence emission spectra



La Madone Hesselin- Simon Vouet,
1640, Le Louvre



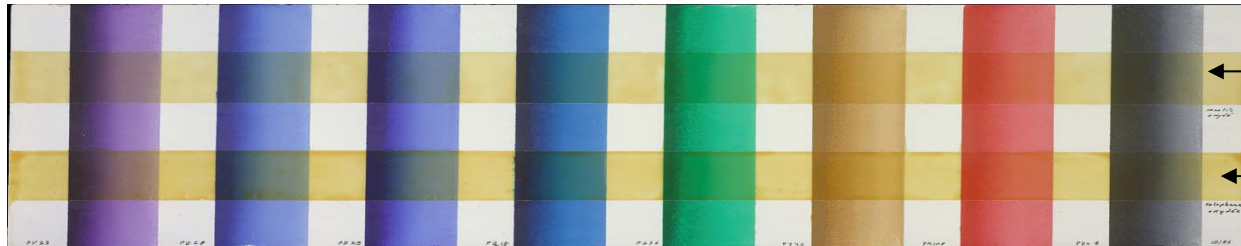
Varnish = mixed aged mastic

M. Thoury, M.Elias, J.M. Frigerio, C. Barthou "Non-destructive varnish identification by UV fluorescence spectroscopy" Appl. Spectro. (2007) [61(12)]

Varnishes

Virtual removing

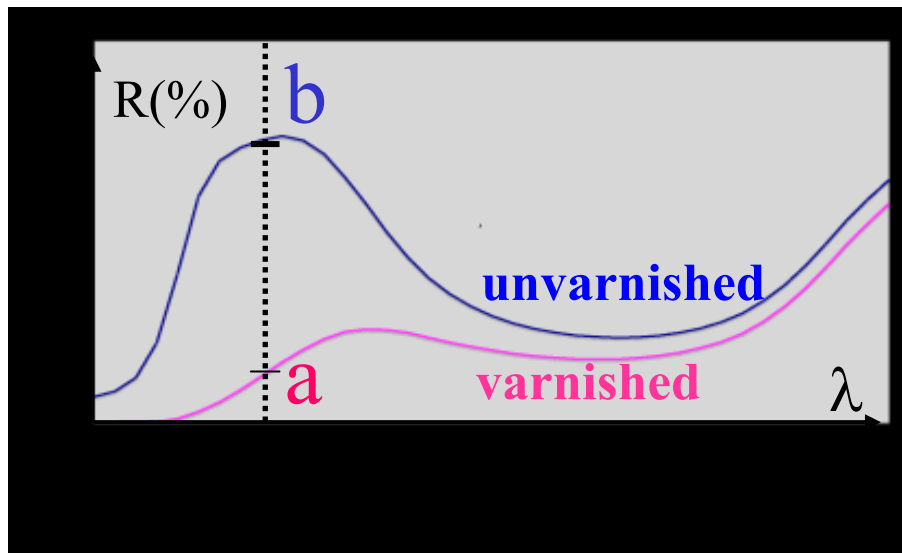
Experimental method:



← Mastic aged varnish

← Colophony aged varnish

Colour chart

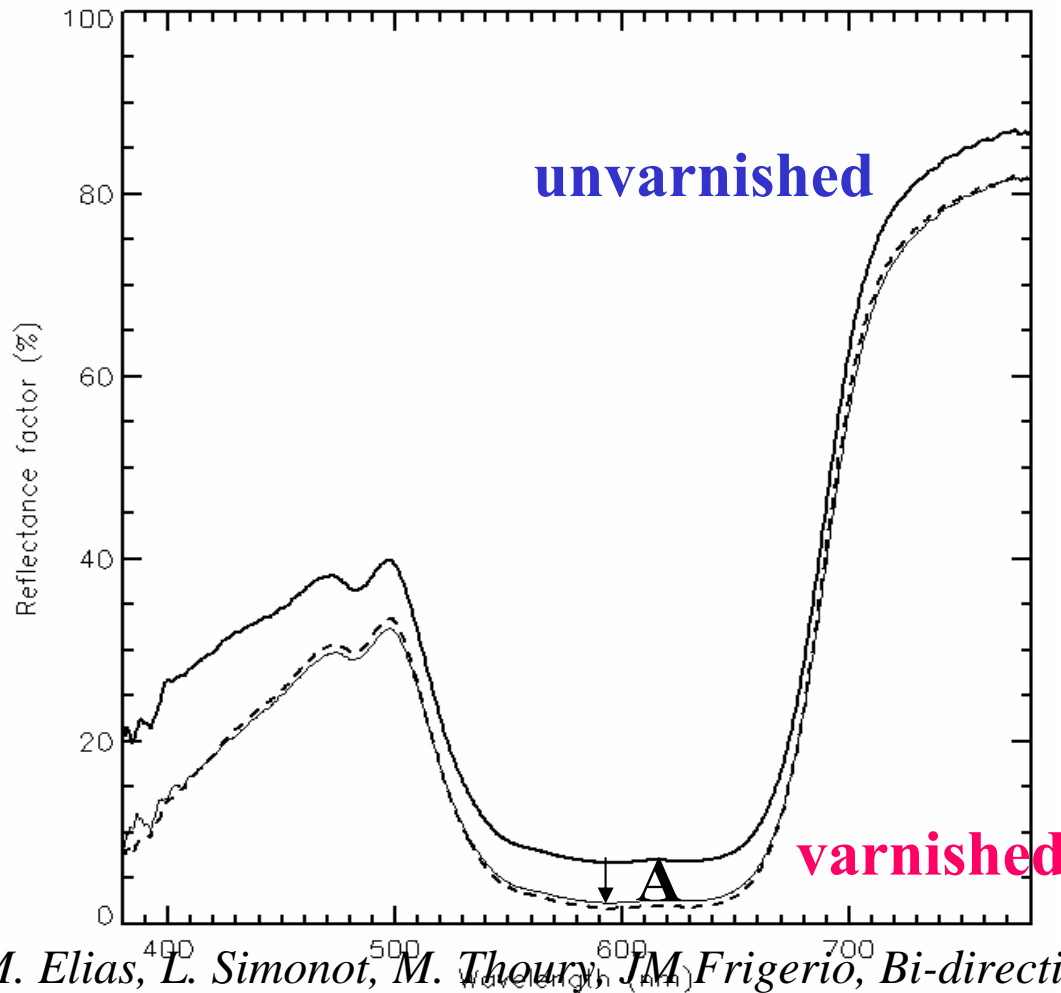


Ratio b/a applied for each λ on the recorded spectra

Varnishes

Virtual removing

Analytical method:



- surface leveling

⇒ downward translation **A**

+

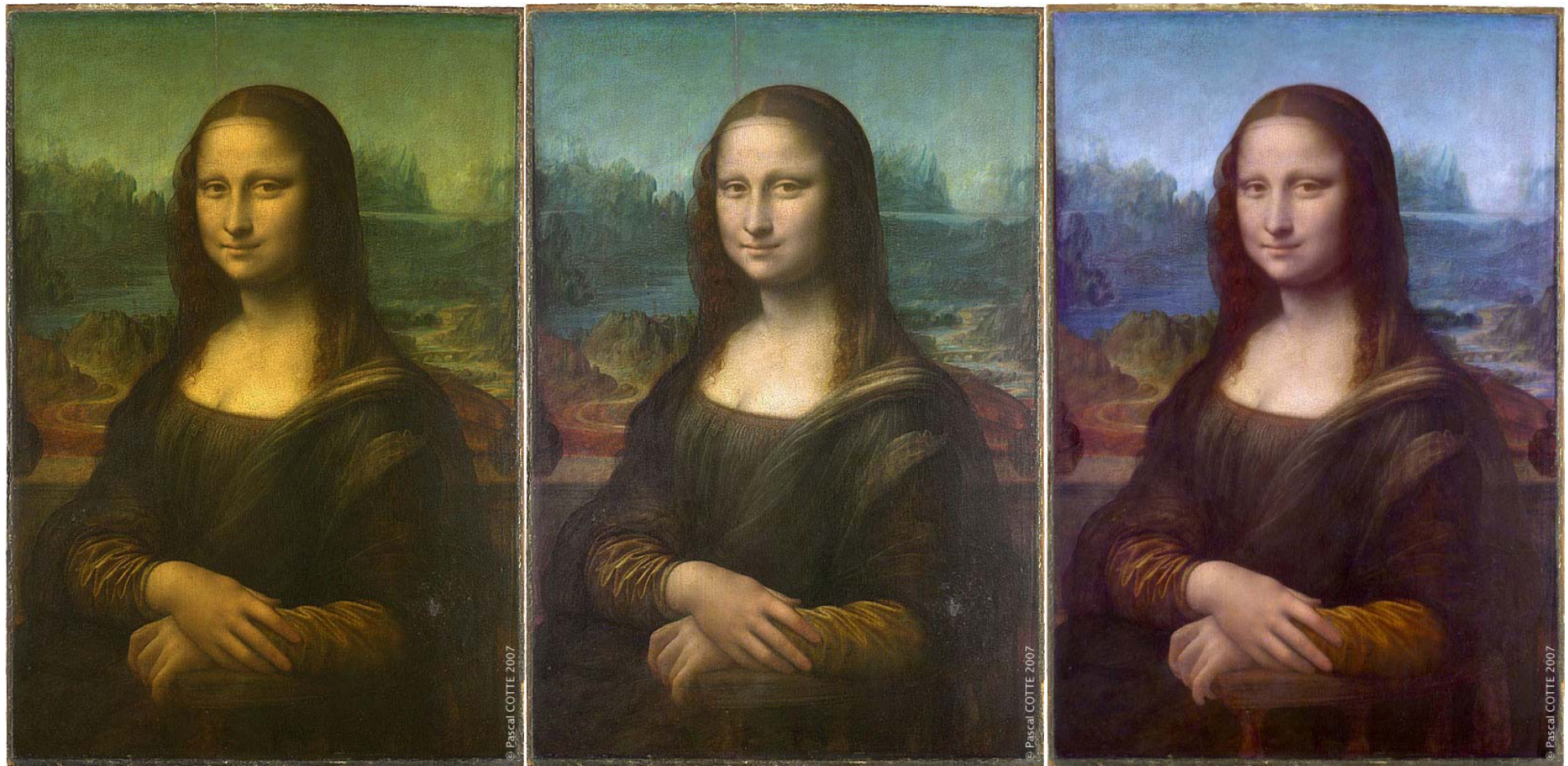
- absorption: $I = I_0 \exp(-\alpha h)$

with $\ln \alpha = -0,016\lambda + 17,2$

and $h =$ approximative
varnish thickness

M. Elias, L. Simonot, M. Thoury, JM Frigerio, Bi-directional reflectance of a varnished painting
Part 2: Influence of the refractive indices, surface state and absorption – Experiments and
simulations, *Opt. Commun.* 231 (2004) 25-33

Results for the Joconda



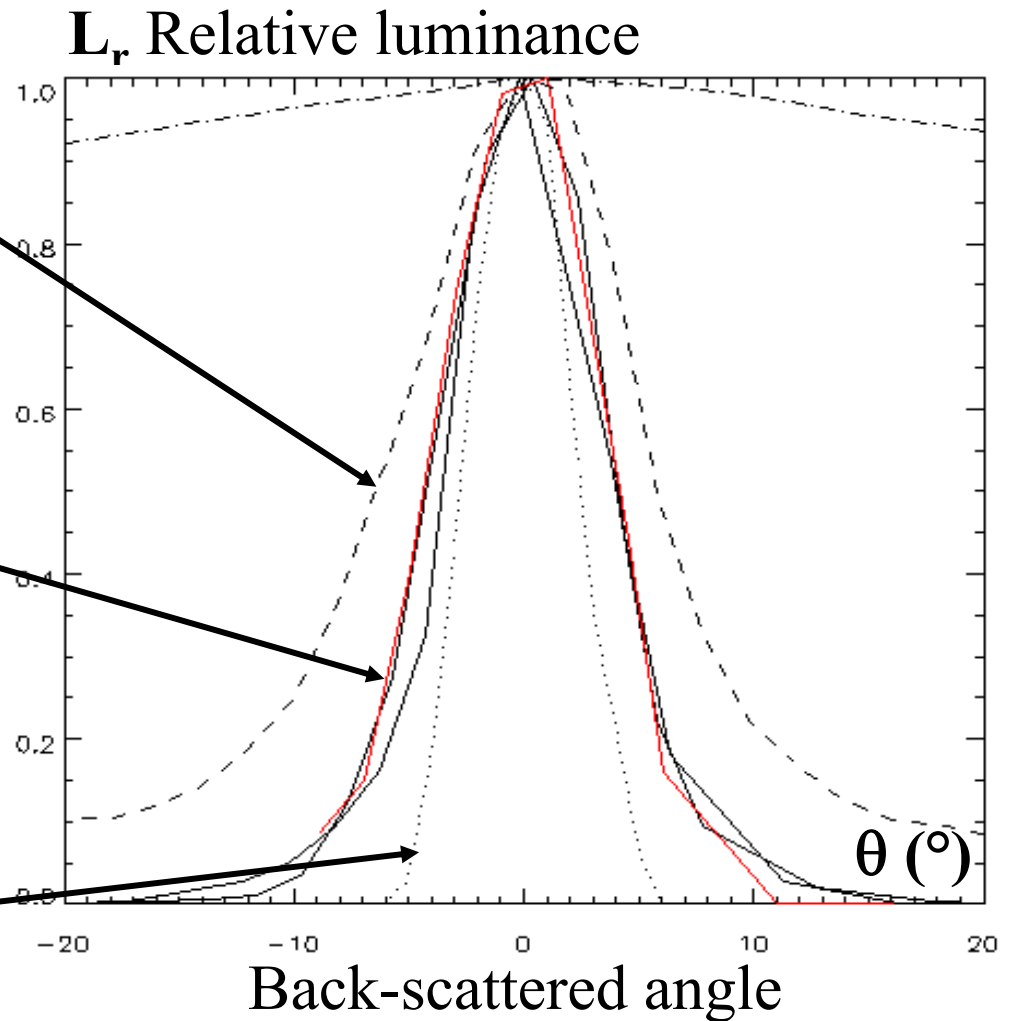
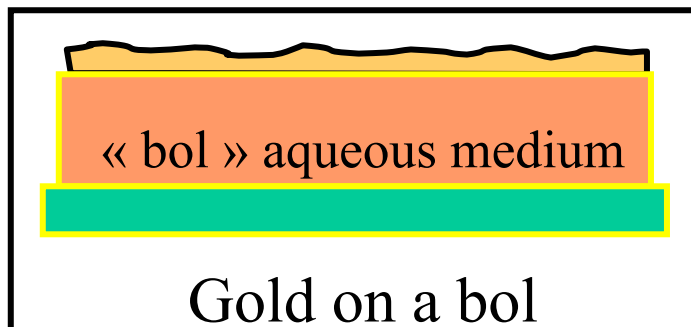
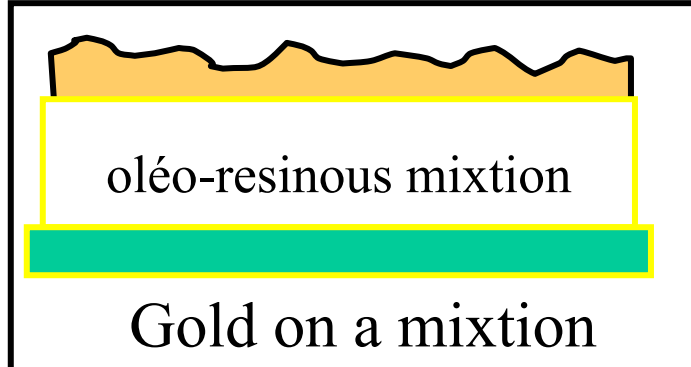
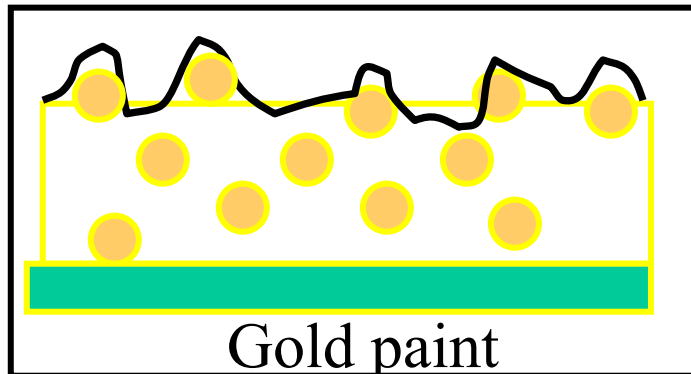
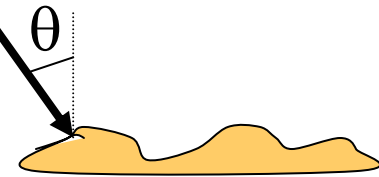
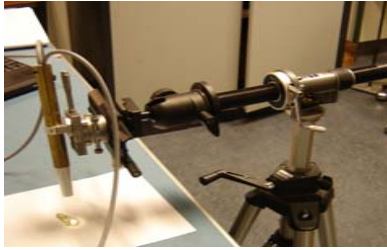
Today

After a virtual half
removing of the varnish

After a virtual varnish
removing

Artistic techniques

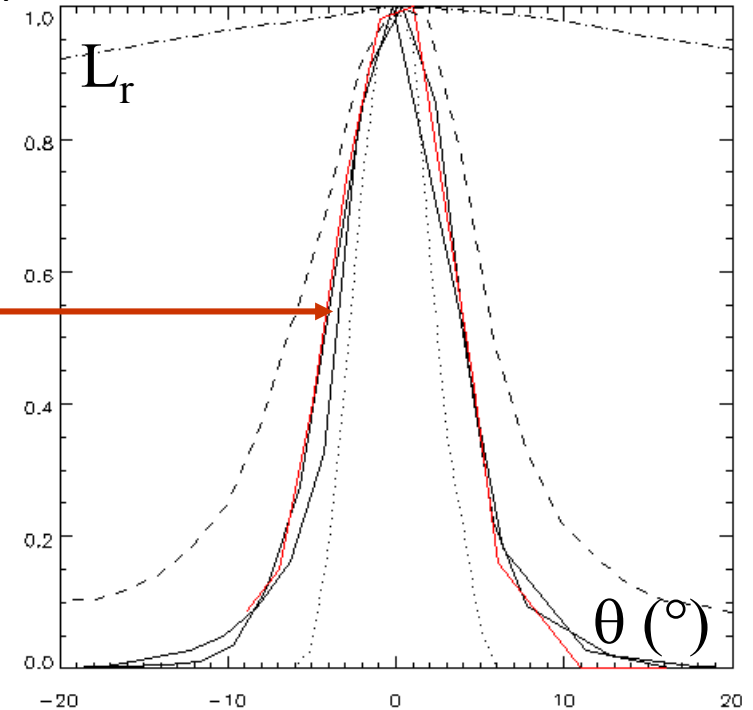
Gold techniques : goniophotometry



Artistic techniques

Gold technique : Issenheim's altarpiece - Grünewald (1510 – 1516)

Unterlinden Museum- Colmar



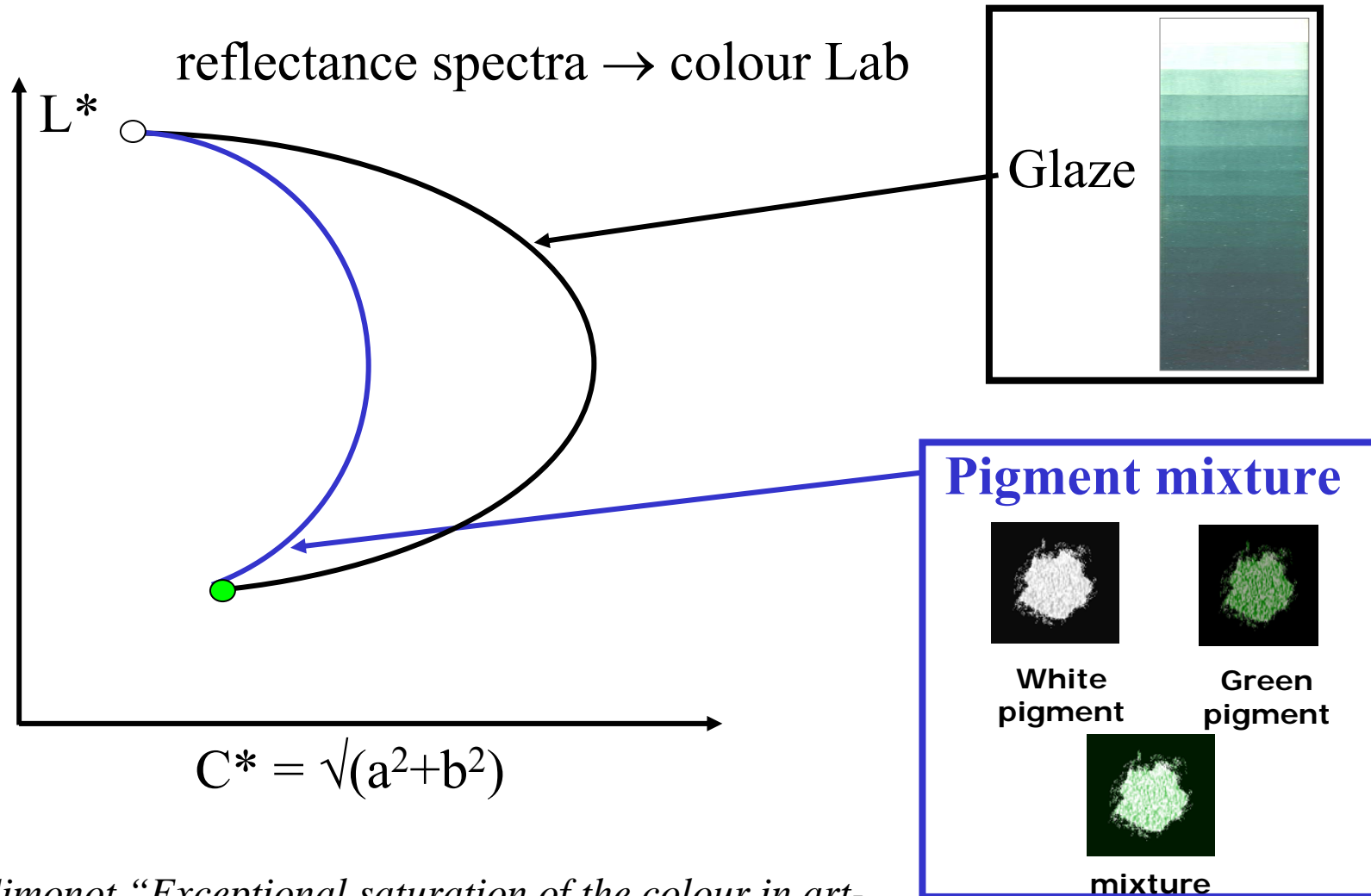
The column of the Angel's concert is made with gold on mixtion

Angels's concert

M. Elias, M. Menu, Experimental characterisation of a random metallic rough surface by spectrophotometric measurements in the visible range, Opt. Commun. 180 (2000) 191-198

Artistic techniques

Glaze and Pigment mixture



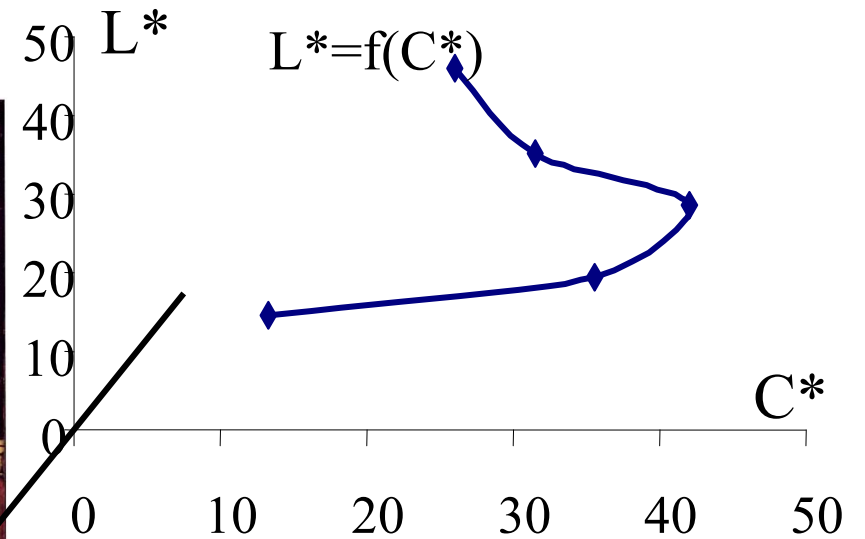
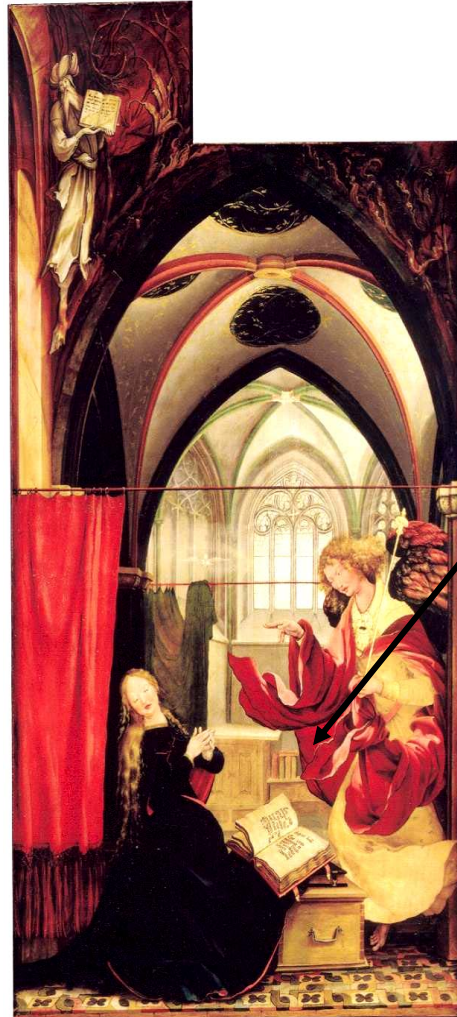
M. Elias, L. Simonot "Exceptional saturation of the colour in art-glazes explained by radiative transfer" Applied Optics 45 n°13 (2006) 3168-3172

Artistic techniques

Glaze and Pigment mixture

Issenheim's altarpiece - Grünewald (1510 – 1516)

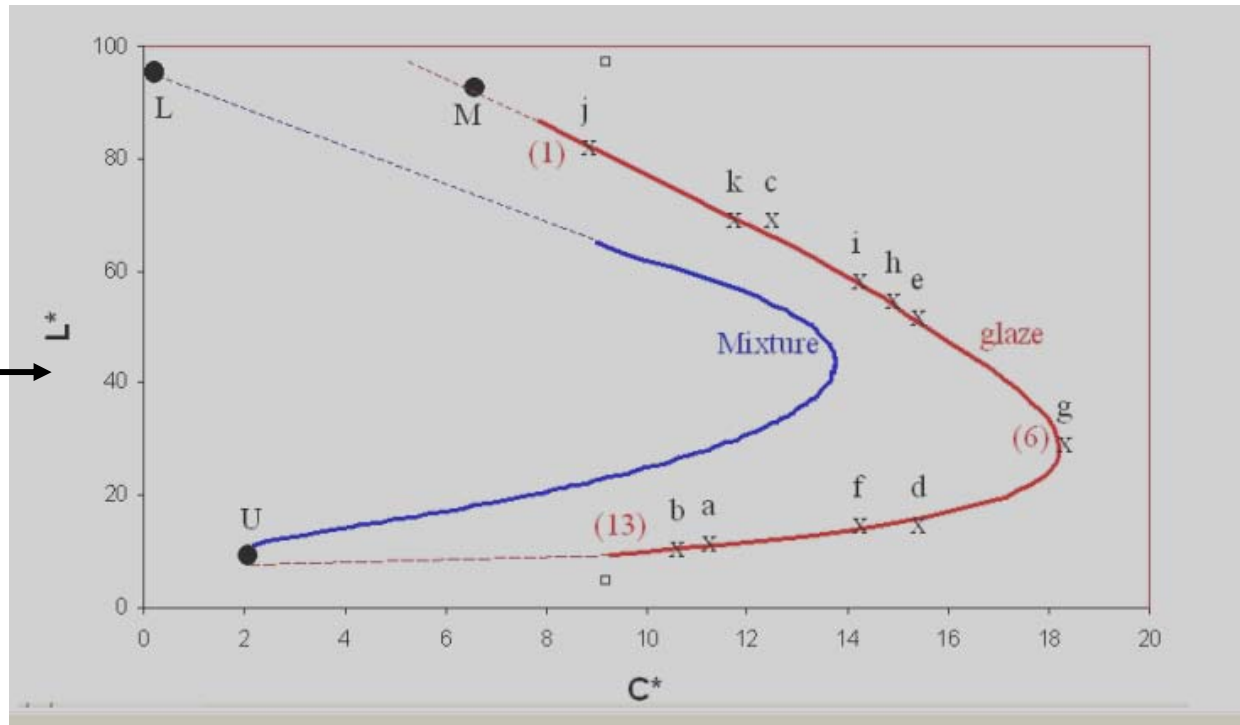
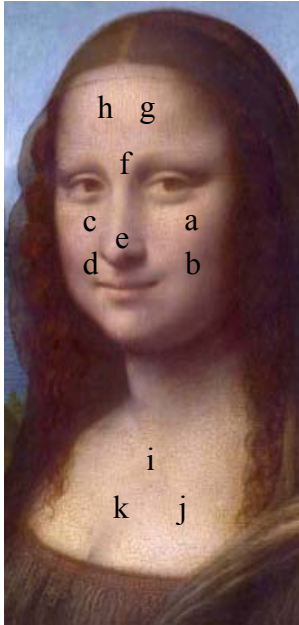
Unterlinden Museum- Colmar



Grünewald used a glaze technique in Gabriel's drape

Artistic techniques

Glaze and Pigment mixture



Léonardo used a glaze technique around 1505

Is the Lady with Ermine (Cracocia) made of a glaze ?

You are invited in the **European City of Science**
Grand Palais – Paris – the 14-16th of November 2008

« Le musée des œuvres revisitées »



Thank for your attention