Spectral and colorimetric measures in cultural Heritage

Universidad Complutense de Madrid

Daniel Vázquez Moliní

Applied Optics Complutense Group

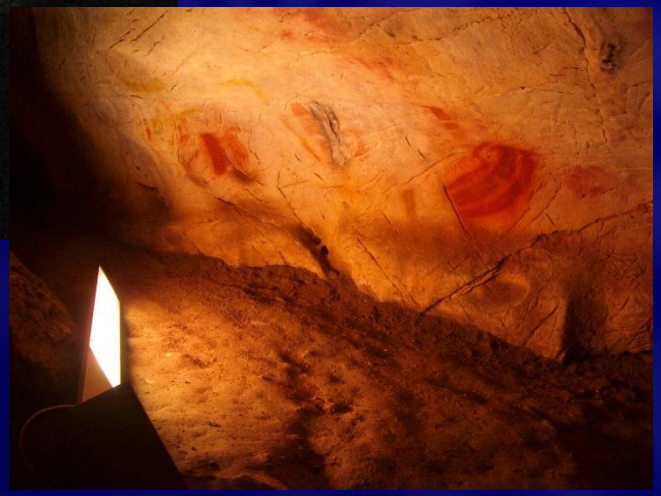
UNIVERSIDAD COMPLUTENSE DE MADRID
OPTICS AND OPTOMETRY FACULTY
Light & Color Group

Applied Optics Complutense Group

Main research lines:

1.- Spectral data adquisition

2.- Analysis and processing

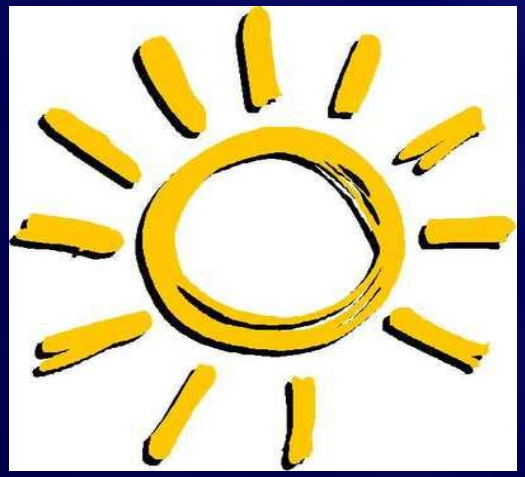


3.- Applications

Nature is a continue change under light

Now ⟷ **Future**

Perception

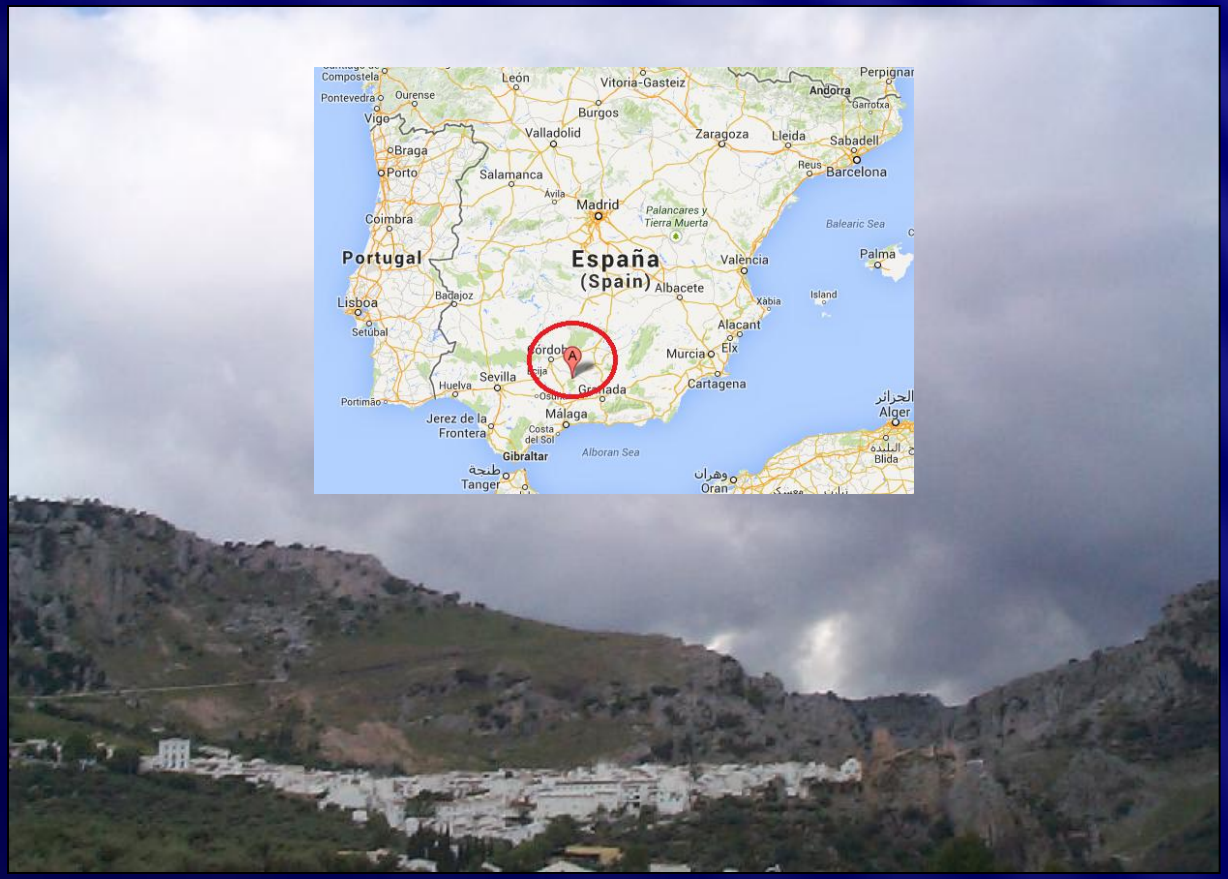


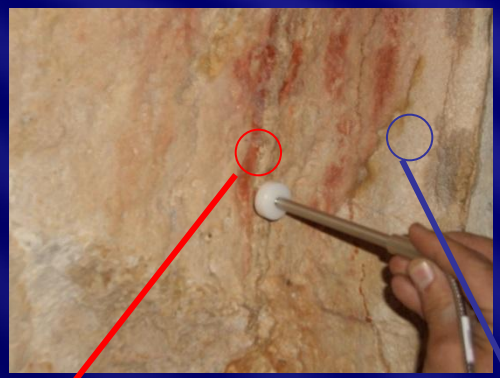
Lighting

Preservation

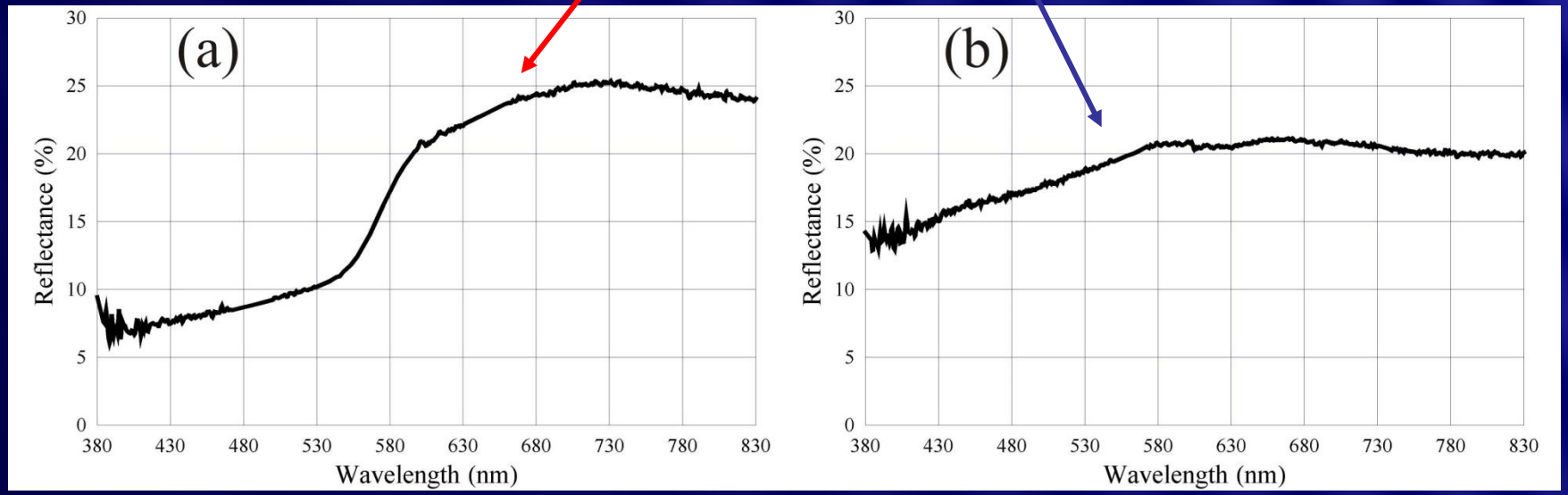
Cave of the baths (Córdoba - Spain)

2006





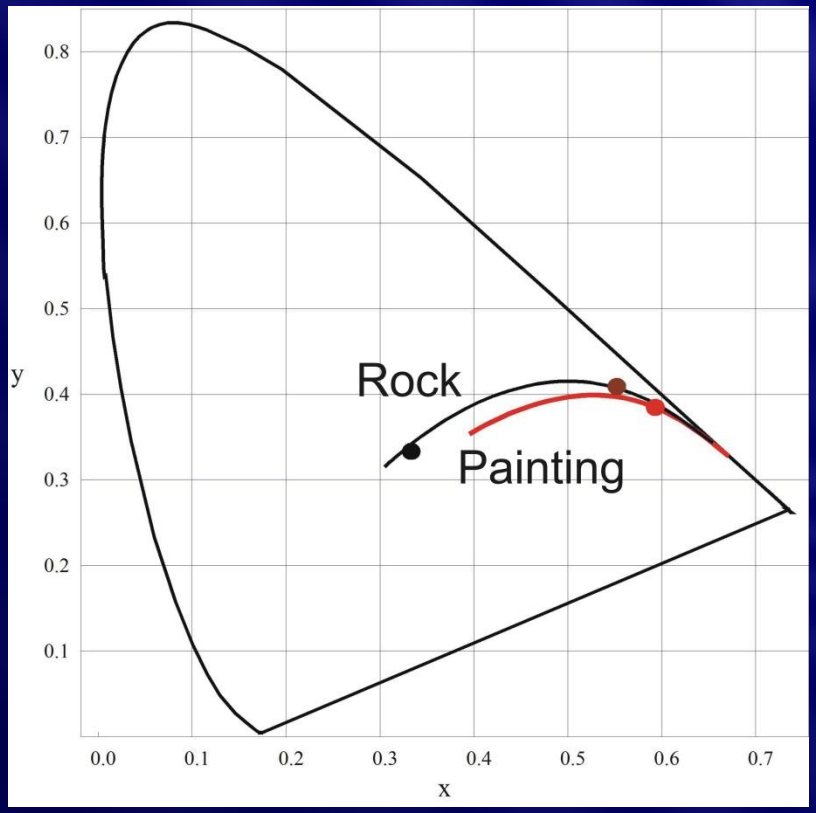
400-750nm; $\Delta\lambda$ = 5nm



a) Paint

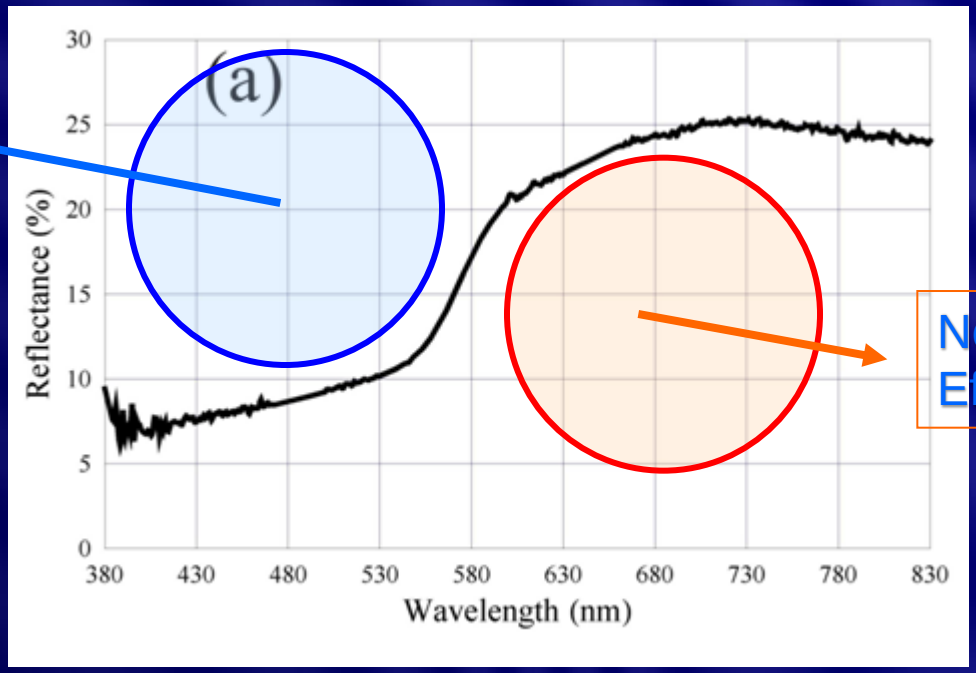
b) Rock

Variation of color with temperature of black body



from T=100 K to T=7000 K
in steps ΔT=100 K

Dangerous area
unefficient light



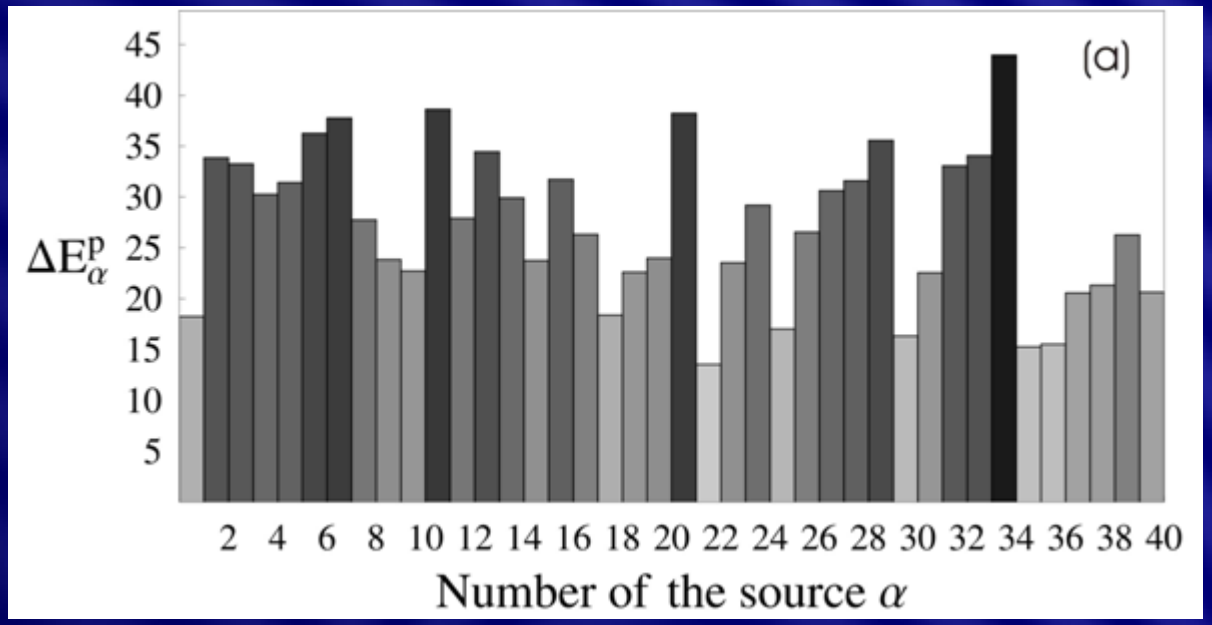
Not Dangerous area
Efficient light

Reflectance Illuminant

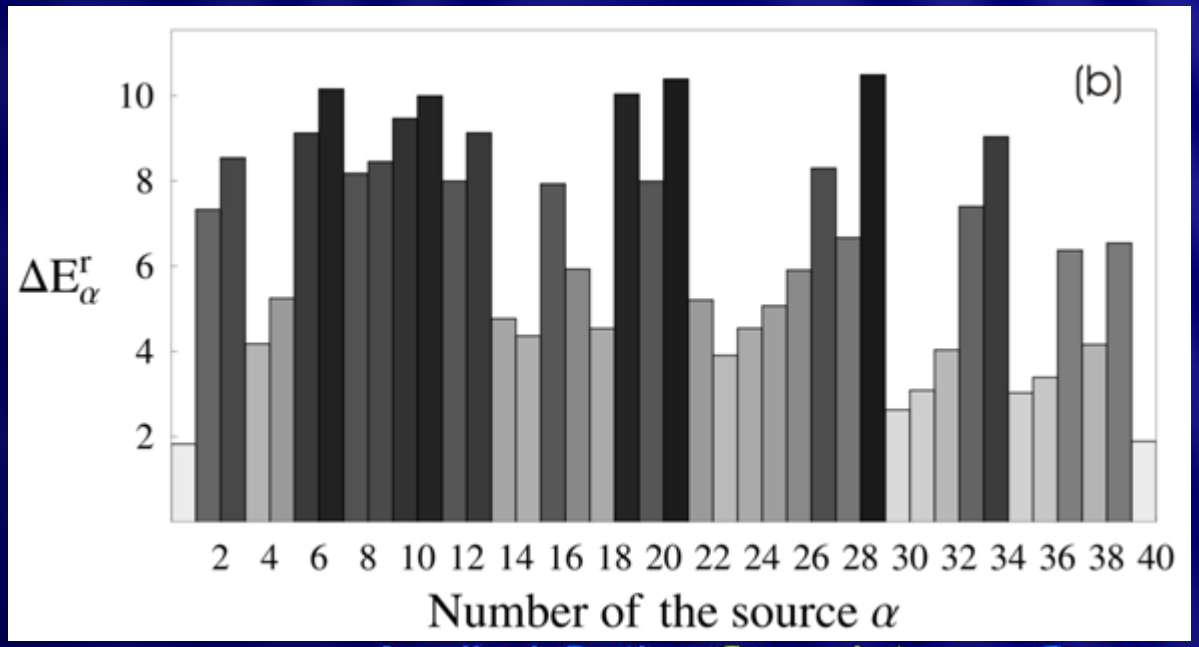
$$S_{opt}(\lambda) = \rho_p(\lambda)$$

Paint

α	Source	α	Source
1	A illuminant	21	FL3.3
2	D65 Illuminant	22	FL3.4
3	C illuminant	23	FL3.5
4	D50 Illuminant	24	FL3.6
5	D55 Illuminant	25	FL3.7
6	D75 Illuminant	26	FL3.8
7	FL1	27	FL3.9
8	FL2	28	FL3.10
9	FL3	29	FL3.11
10	FL4	30	FL3.12
11	FL5	31	FL3.13
12	FL6	32	FL3.14
13	FL7	33	FL3.15
14	FL8	34	HP1
15	FL9	35	HP2
16	FL10	36	HP3
17	FL11	37	HP4
18	FL12	38	HP5
19	FL3.1	39	Xenon lamp
20	FL3.2	40	Halogen lamp



Rock



El Castillo cave (Cantabria, Spain)

UNESCO world heritage

(2009)

Methodology

1.- spectral reflectance meassures

2.- Design criteria

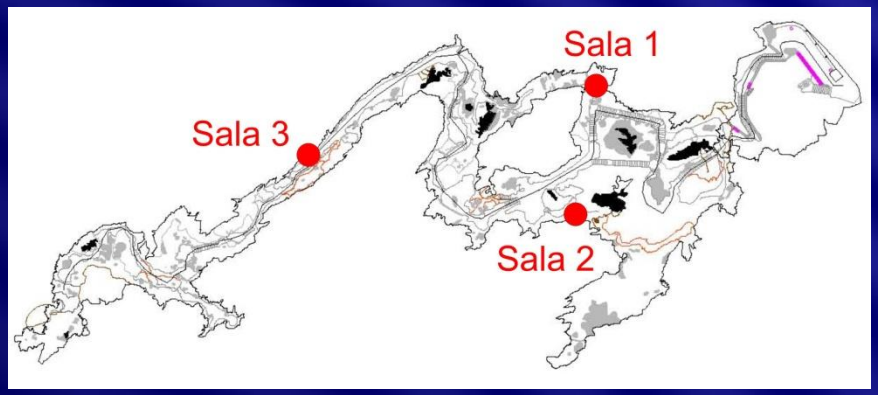
3.- Parameters definition

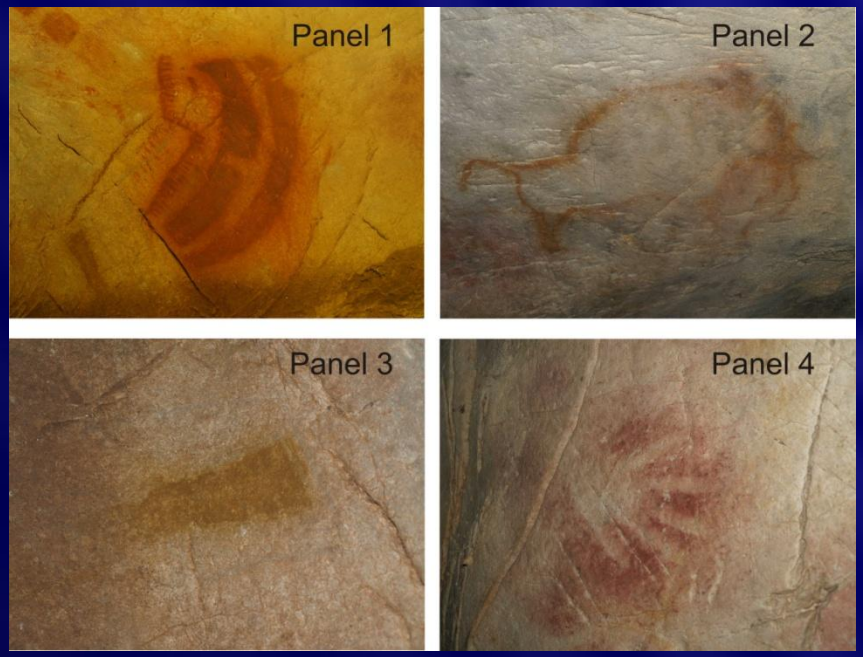
Color paint (Lab)
Color rock (Lab)
Contrast (Δlab)
Damage($w.h/m^2$)

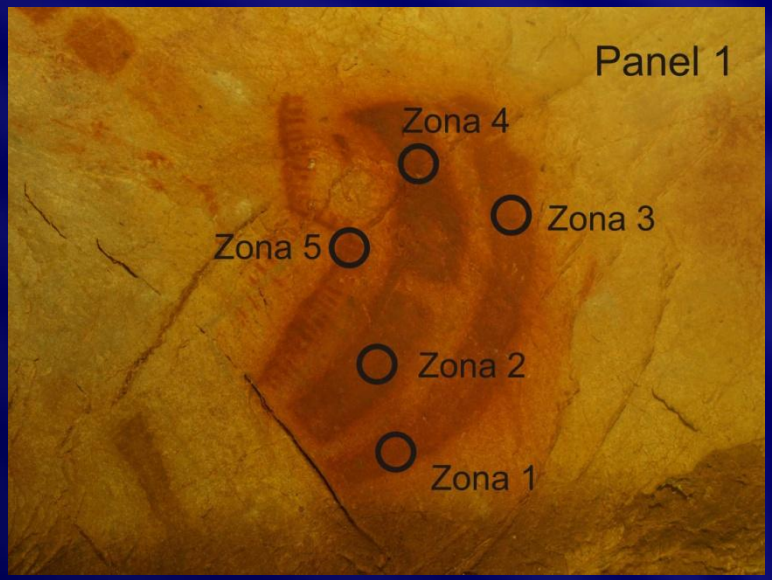
4.- priority and weight between parameters

5.- matematich function Functional

Optimized spectral distribution of light source


Sala 1
Sala 3
Sala 2


Panel 1
Panel 2
Panel 3
Panel 4



5 zones

(z=1, 2, …, 5)

10 meassures each one

(m=1, 2, …, 10)

$$\rho_{z,m}(\lambda)$$

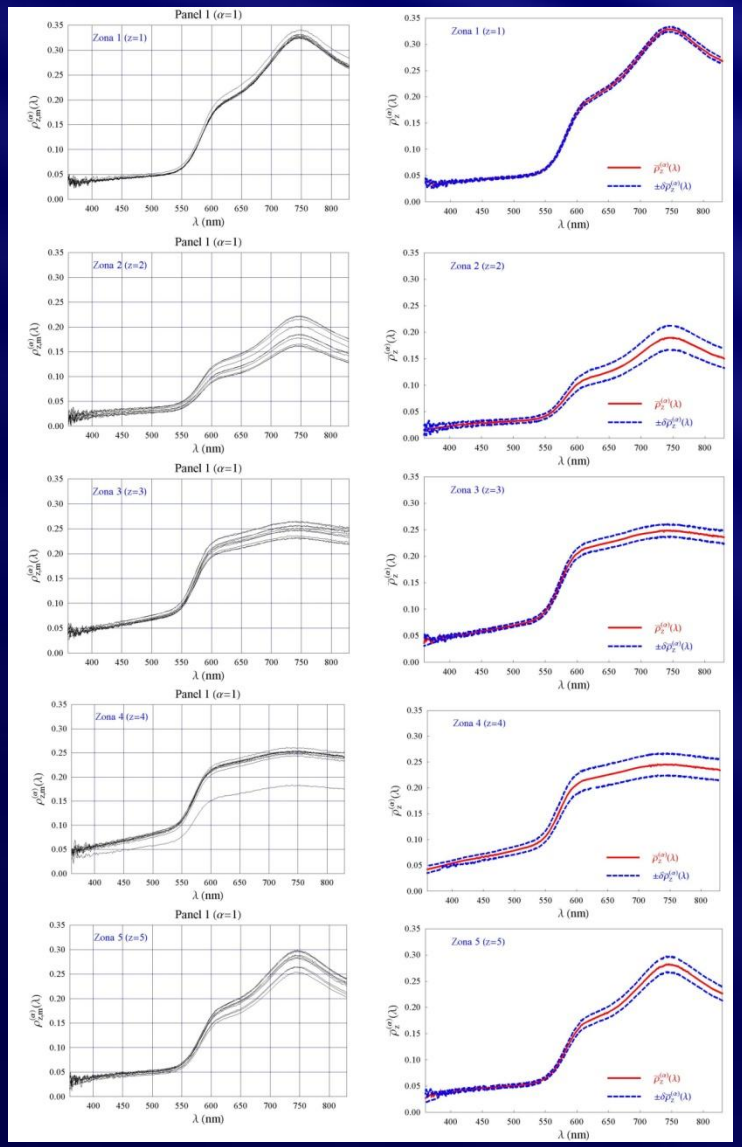
$$\bar{\rho}_z(\lambda) = \frac{1}{10}\sum_{m=1}^{10} \rho_{z,m}^{(\alpha)}(\lambda)$$

Average reflectance in each zone

$$\delta\bar{\rho}_z(\lambda) = \left[\frac{1}{10}\sum_{m=1}^{10}\left(\rho_{z,m}^{(\alpha)}(\lambda) - \bar{\rho}_z^{(\alpha)}(\lambda)\right)^2\right]^{1/2}$$

Estándar deviation

Panel 1



$$\bar{\rho}(\lambda) = \frac{1}{5}\sum_{z=1}^{5}\bar{\rho}_z(\lambda)$$

Iluminant A warm

$$\left[X_z\right]_i^A = K_A \sum_{j=1}^{M} \bar{\rho}_z(\lambda_j) S_A(\lambda_j) \hat{x}_i(\lambda_j) \Delta\lambda$$

Tristimulus each zone

$$X_i^A = K_A \sum_{j=1}^{M} \bar{\rho}(\lambda_j) S_A(\lambda_j) \hat{x}_i(\lambda_j) \Delta\lambda$$

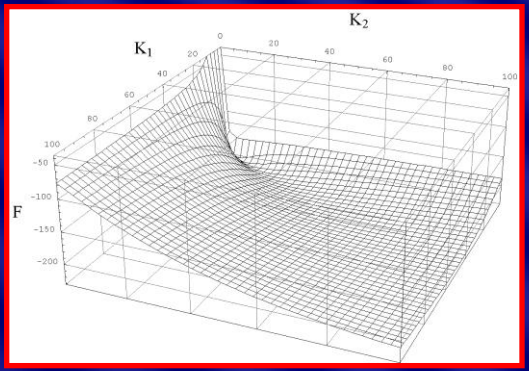
Average tirstimulus each zone

Functional 1

1

$$F_2(D, d_{c-p}, d_a) = D^2 - (d_{c-p})^2 + \sqrt{d_a}$$

High priority to D and d_{c-p} low to d_a

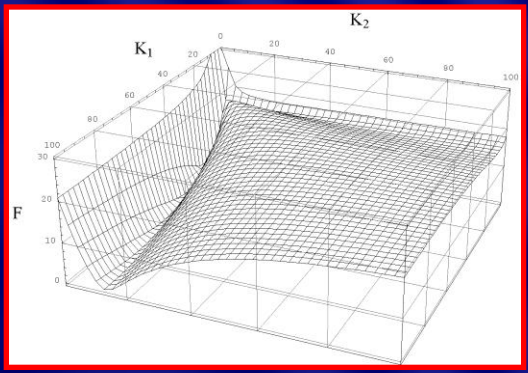


Functional 2

2

$$F_1(D, d_{c-p}, d_a) = 2D - d_{c-p} + d_a$$

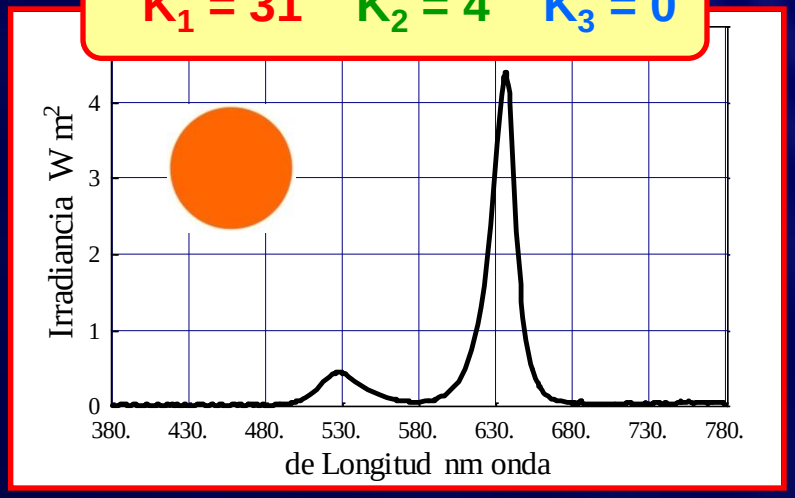
Same priority for all parameters



Light spectral distribution

2

$K_1 = 31$ $K_2 = 4$ $K_3 = 0$



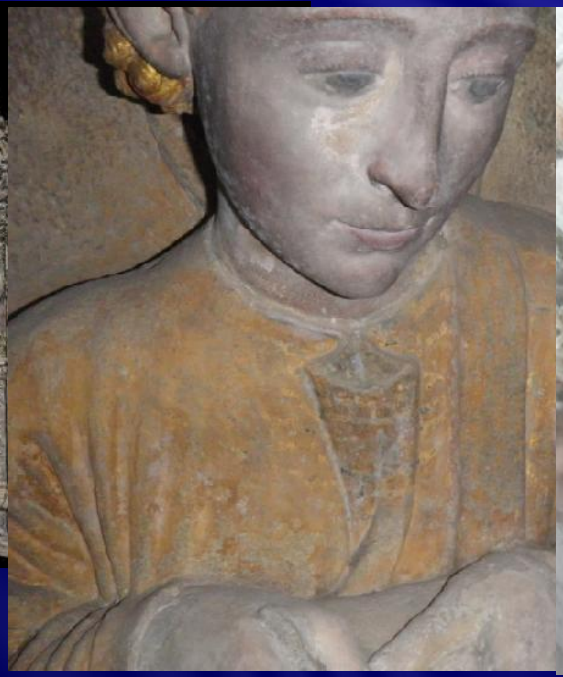
D (Damage) = 4.0 W/m²

Paint-rock distance) = 11.5

d_a(torch distance) = 3.3

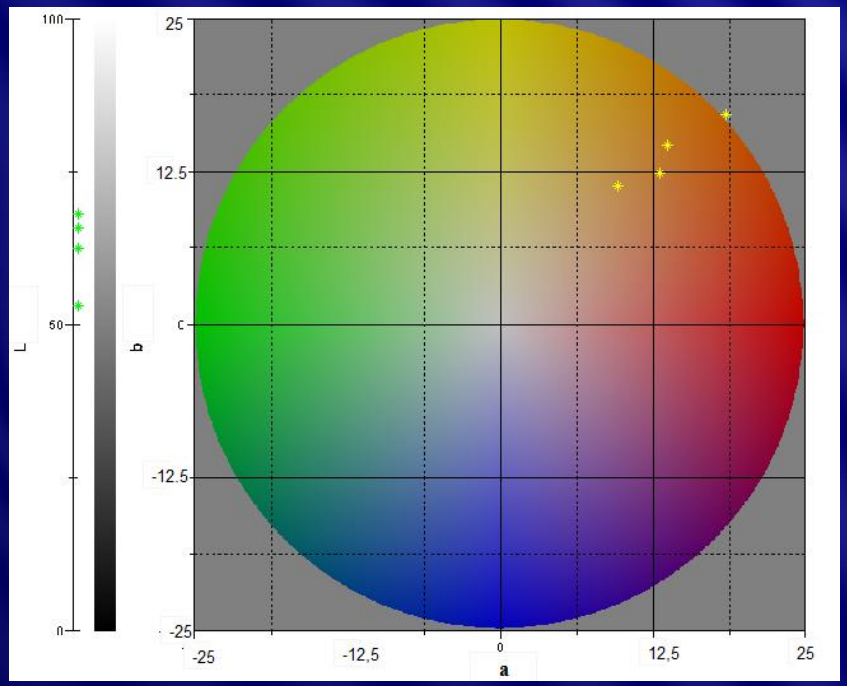
Applied Optics Complutense Group

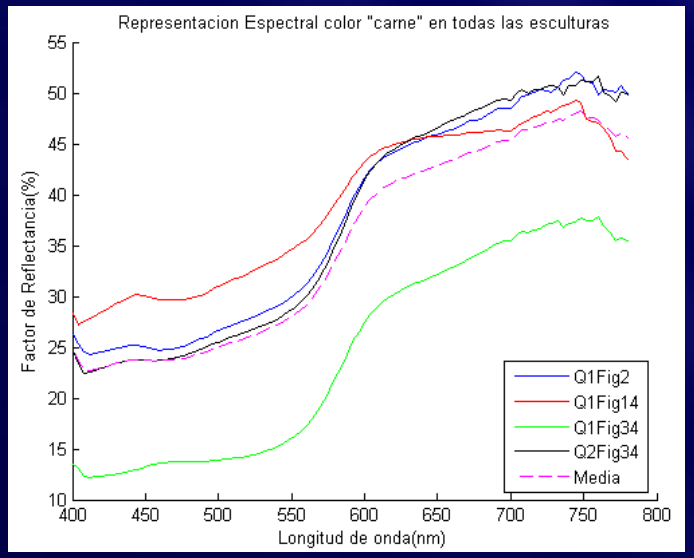
Pórtico de la gloria – Santiago chatedral



Colorimetric Analysis of different cleaning technologies

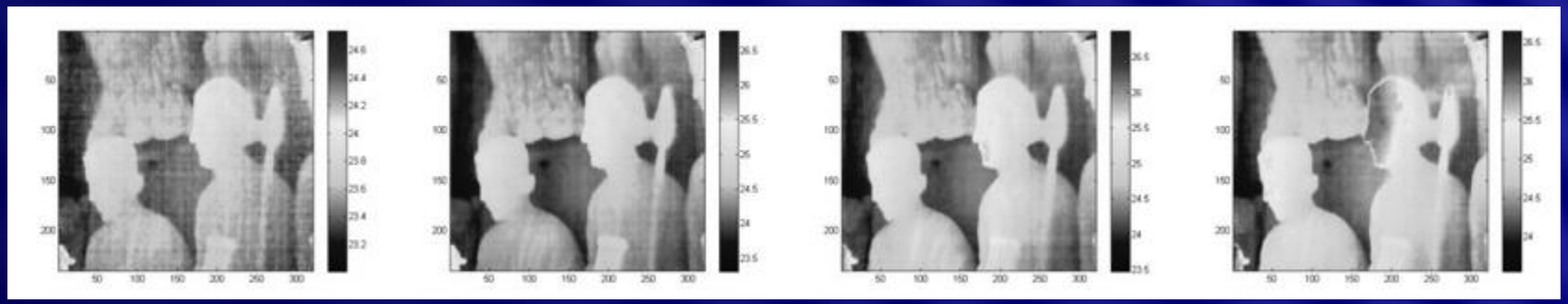
(Laser, Chimical and Mechanical)





Applied Optics Complutense Group

Daylight study: thermal and color analysis



Thermal increasing
over the day 24-7-2012

Woman in blue (Picasso)

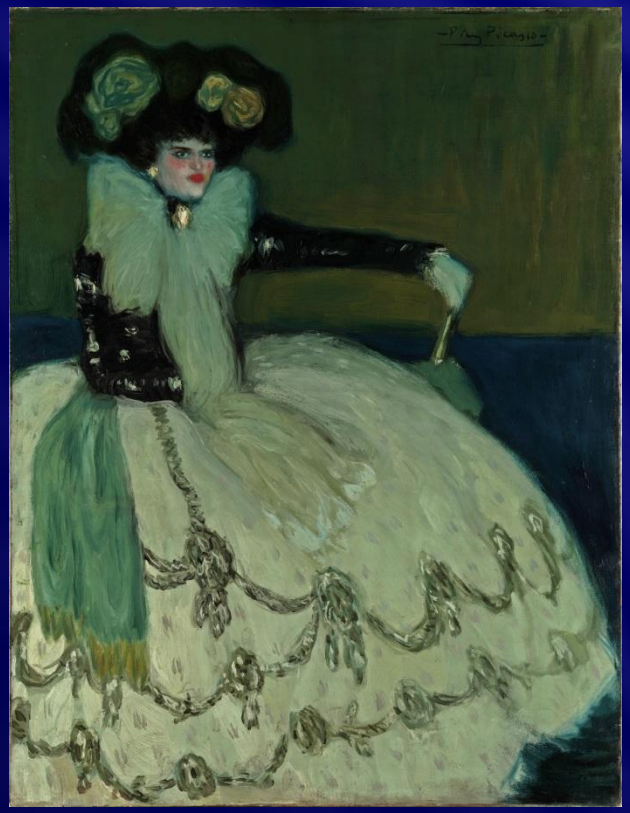
Objective:
developing an objective and simple methodology in order to evaluate color and for integration in restoration department

Requeriments:

- Easy application
- Simple data interpretation
- Control of location
- Control meassured area

Applied Optics Complutense Group

Woman in blue (Picasso)



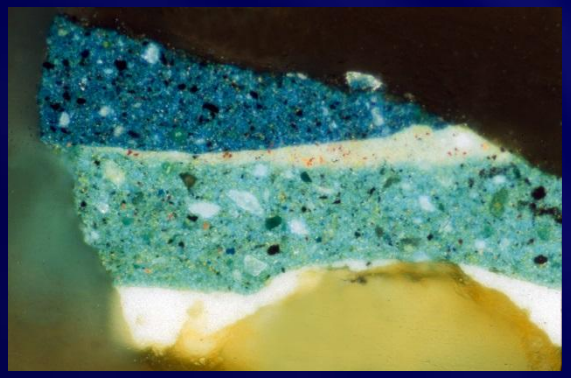
Before

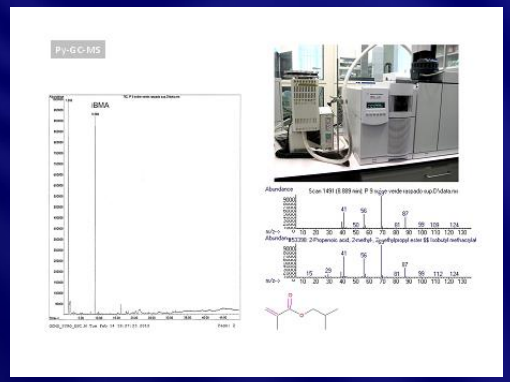
After

Applied Optics Complutense Group

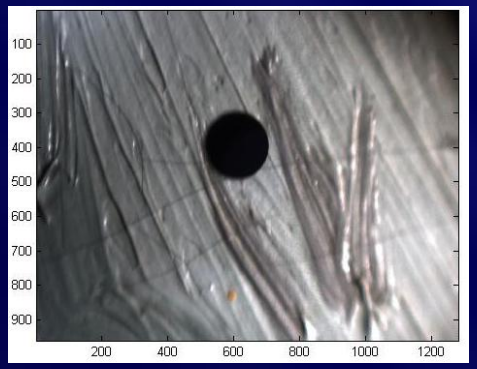
Previous characterization

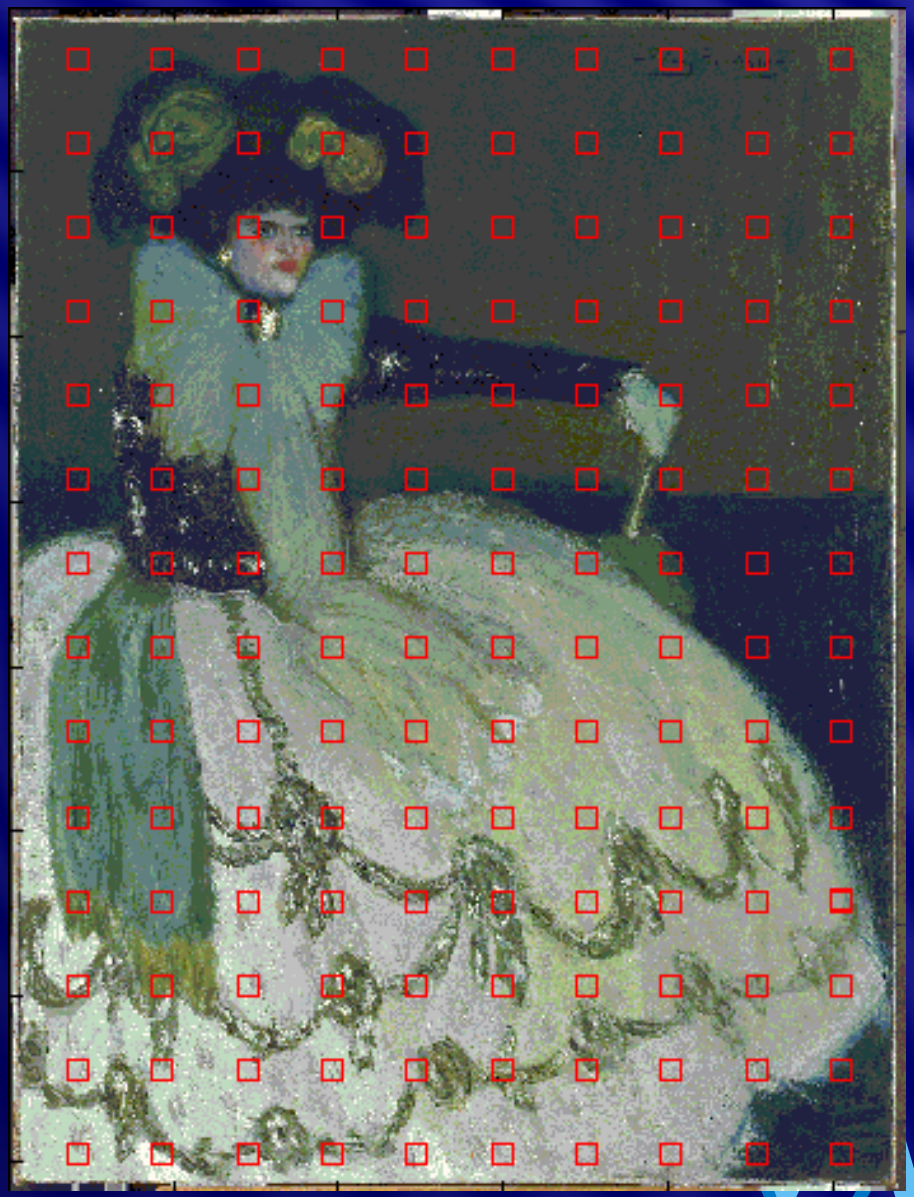
- Electronic microscopy with spectrometry in X ray (SEM-EDXS)
- IR spectrometry by fourier transform (FTIR)
- Gas cromatografy and mass spectrometry (GC-MS)
- Pyrolysis-cromatografy (Py-GC-MS)



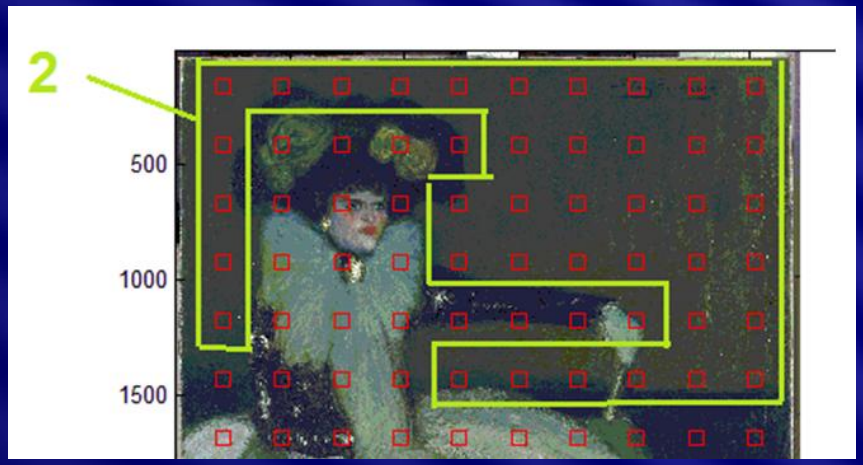


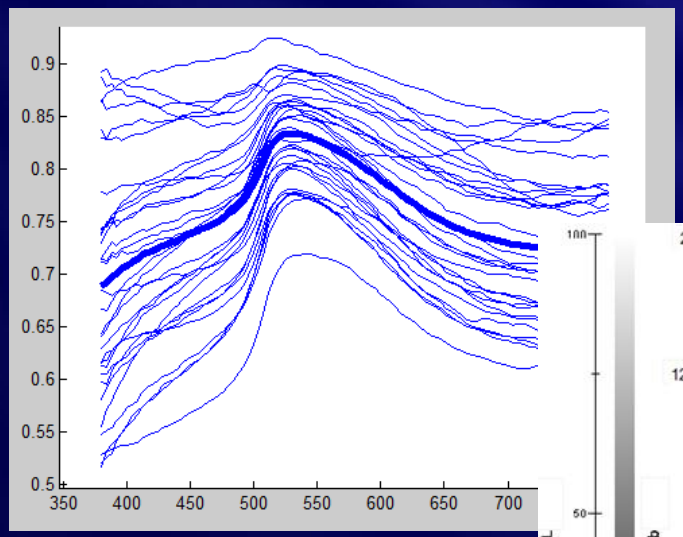
Applied Optics Complutense Group

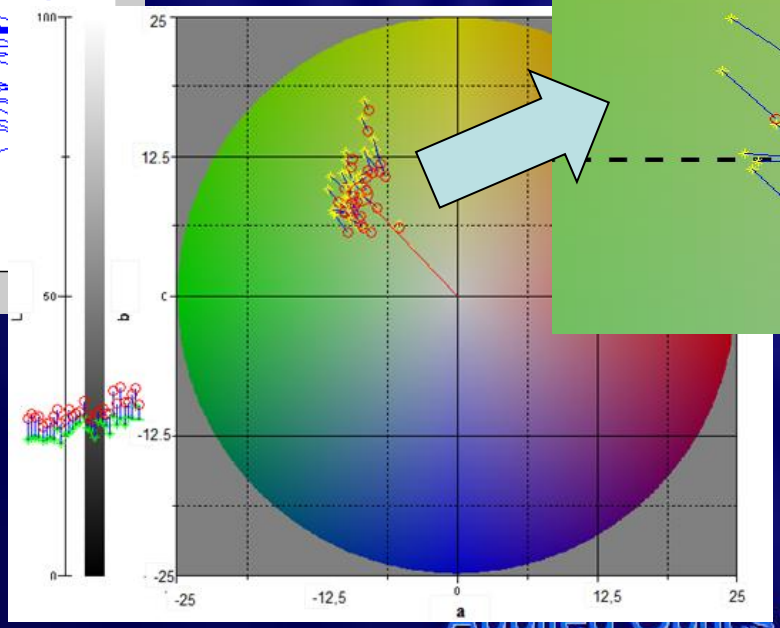


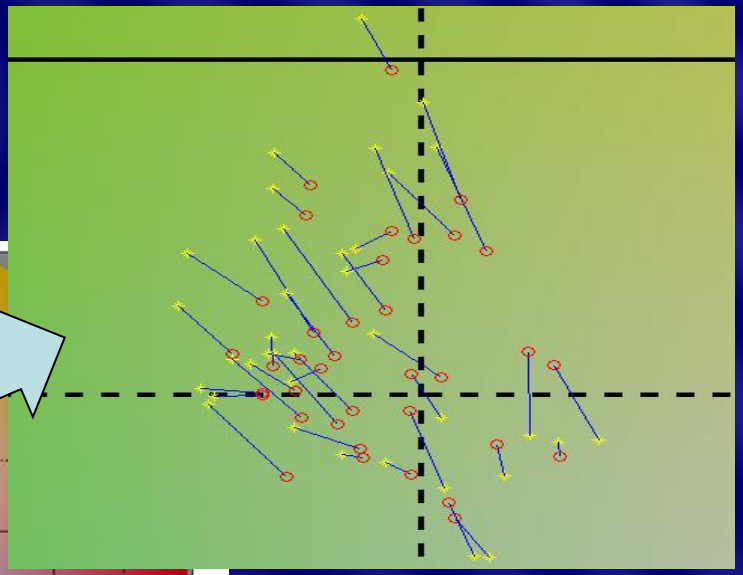


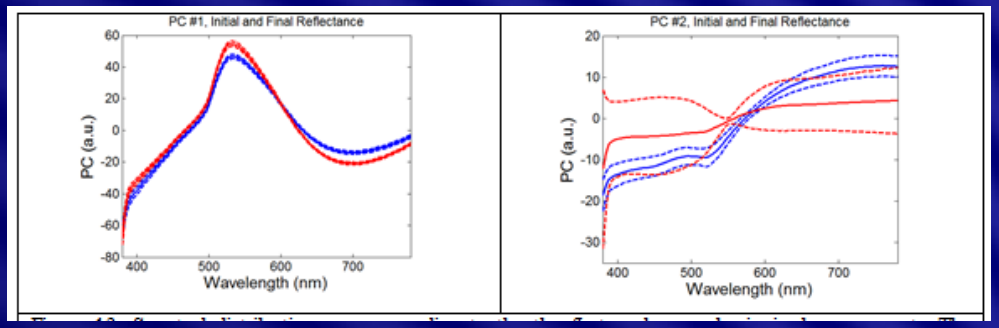
Applied Optics Complutense Group


2
500
1000
1500


0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
350
400
450
500
550
600
650
700

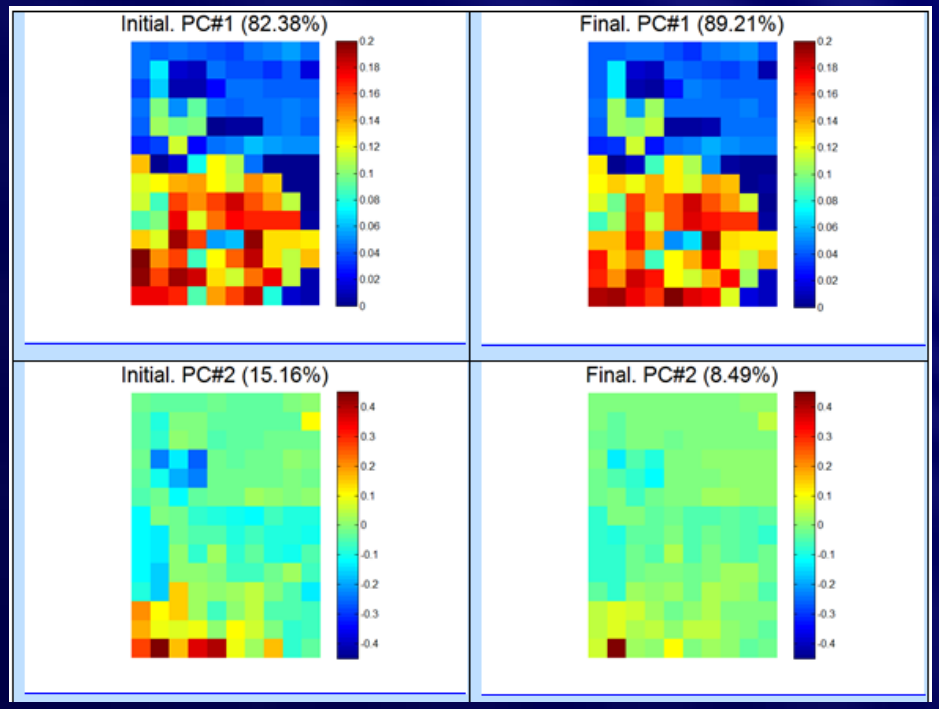

100
50
0
L
b
25
12.5
0
-12.5
-25
-25
-12.5
0
12.5
25
a





Principal Components Analysis

The first principal component has a very similar shape before and after the restoration. It shows a peak around 530 nm. However, its contribution to the total variance of the data goes from 82.38% to 89.21%.



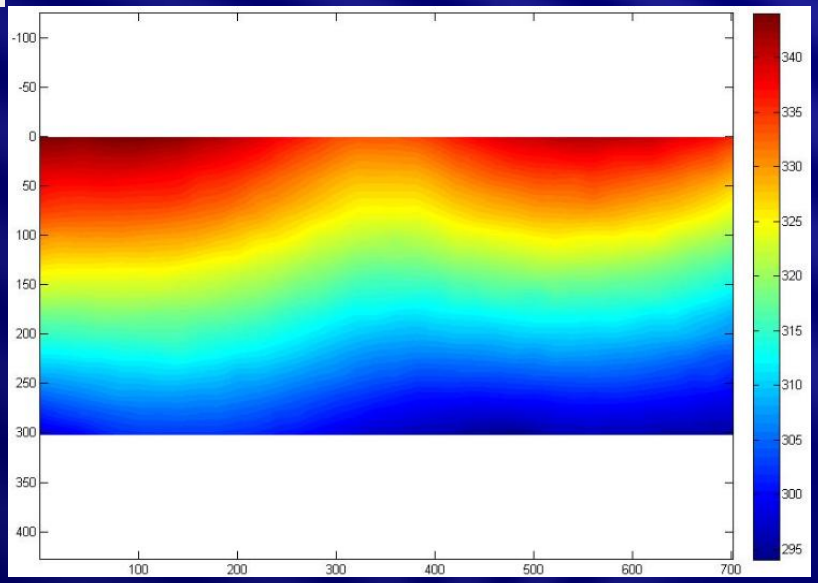
Second principal component: most of the contribution comes from specific location on the painting

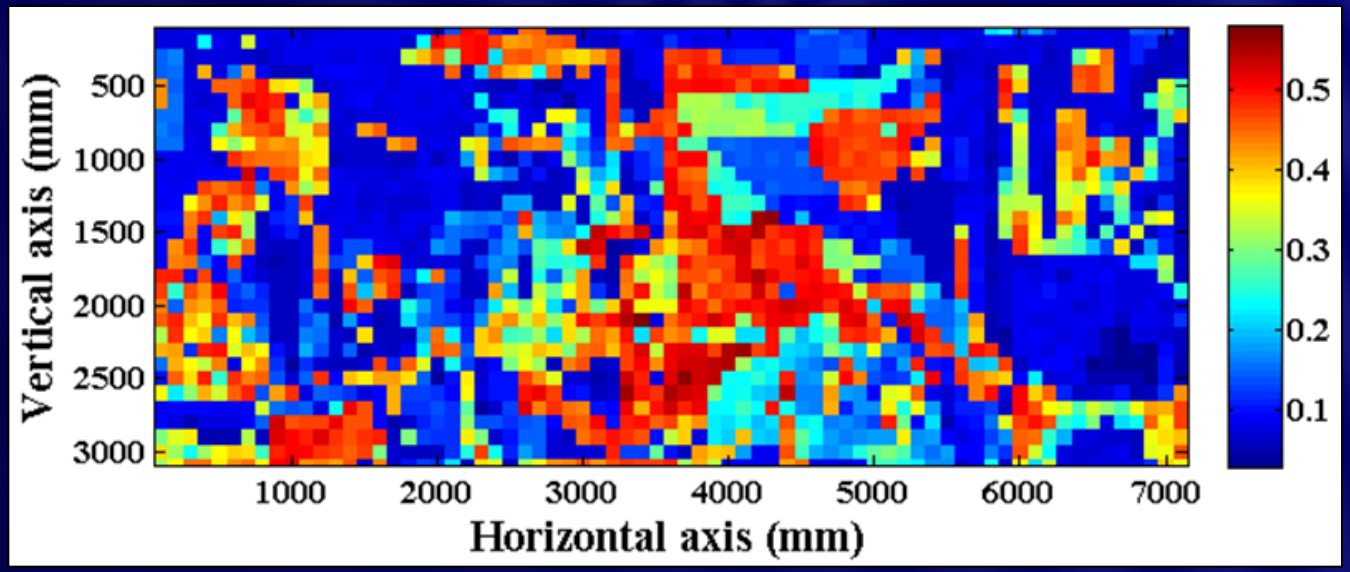
Guernica

Requeriment of the system:

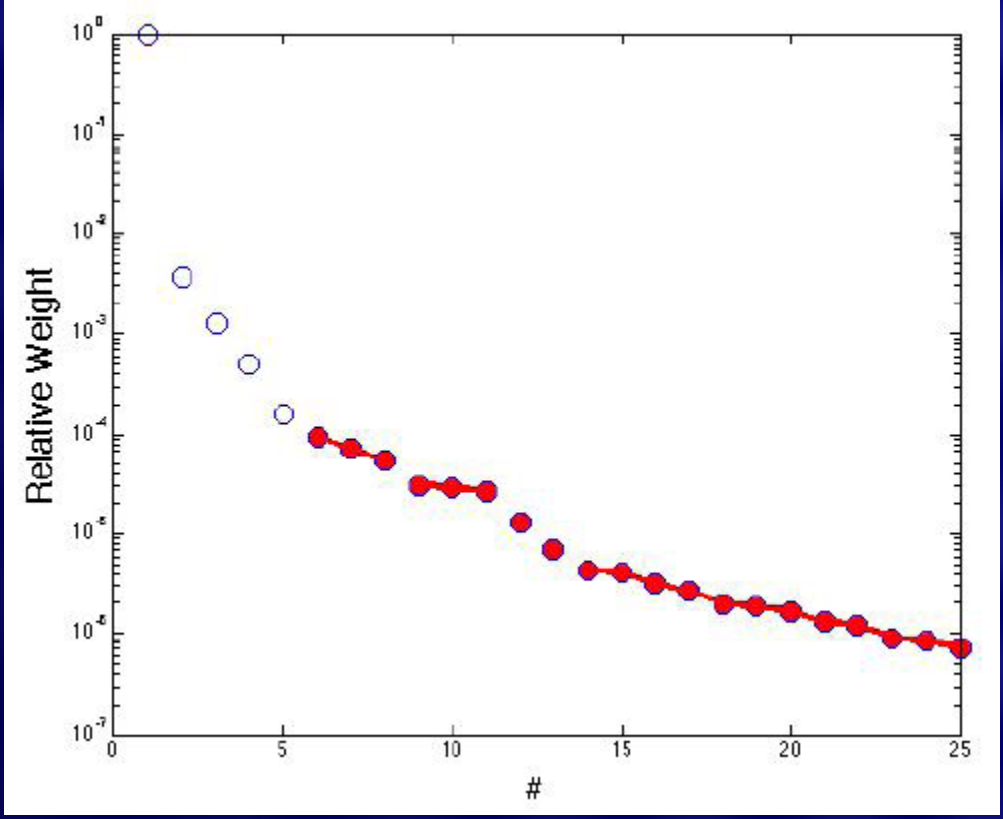
1. No contact.
2. Position refereced.
3. Orientation referenced.
4. Normalized lighting system.
5. 3D texture adapted.
6. No Time consumiption.
7. Minimal energy consumption.
8. Not expensive.

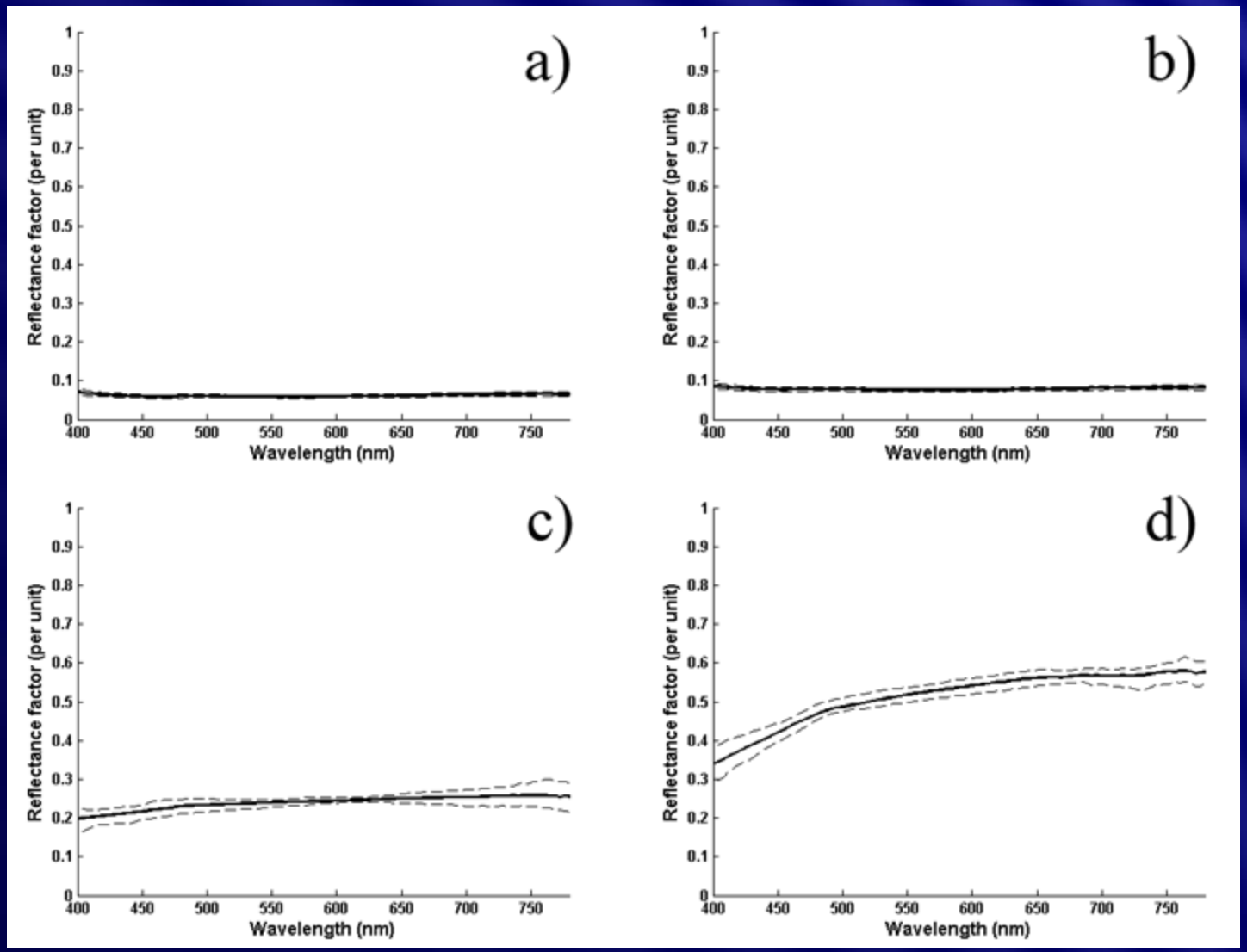
Motion accuracy system with high dimension paints :
magnetic rail 25 μm accuracy


-100
-50
0
50
100
150
200
250
300
350
400
100
200
300
400
500
600
700
340
335
330
325
320
315
310
305
300
295

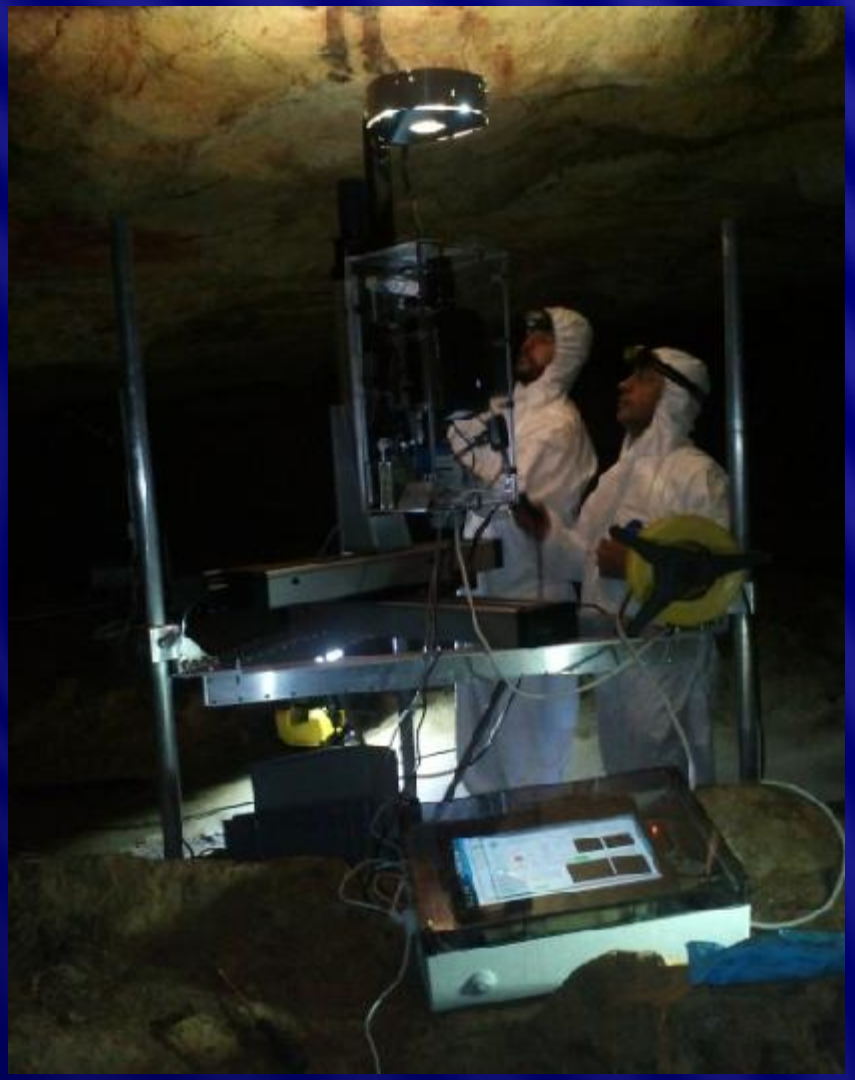

Vertical axis (mm)
500
1000
1500
2000
2500
3000
1000
2000
3000
4000
5000
6000
7000
Horizontal axis (mm)
0.5
0.4
0.3
0.2
0.1

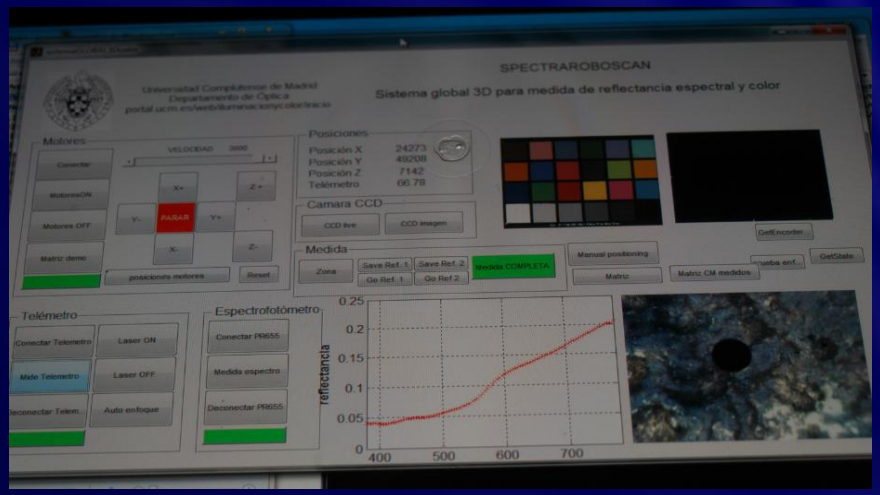
PC#1 => 99,41 %




a)
b)
c)
d)
Reflectance factor (per unit)
Wavelength (nm)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
400
450
500
550
600
650
700
750

Spectraroboscan:
IP Portable spectrometer motion system

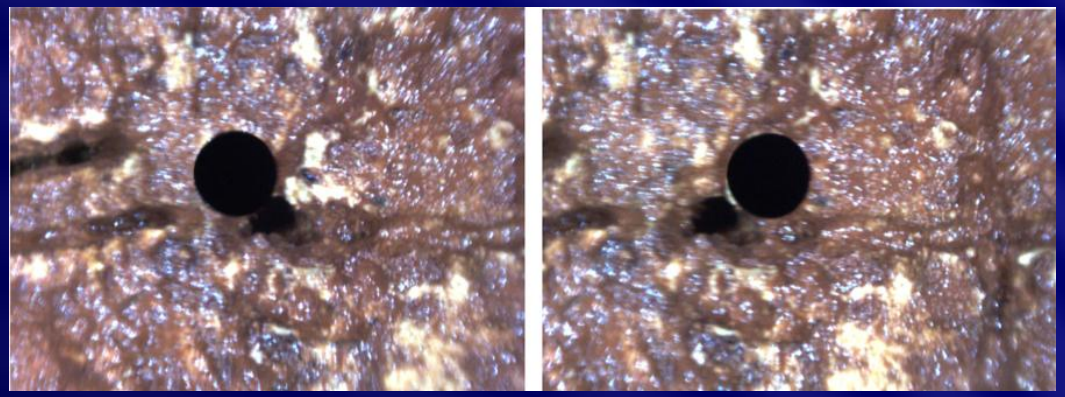


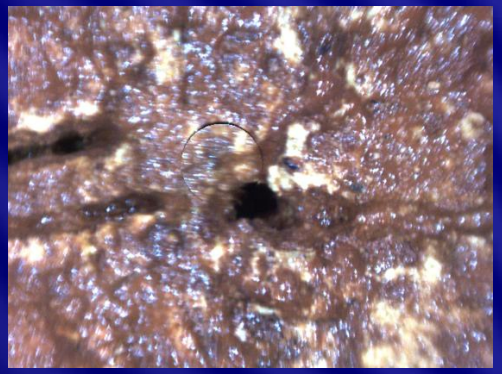


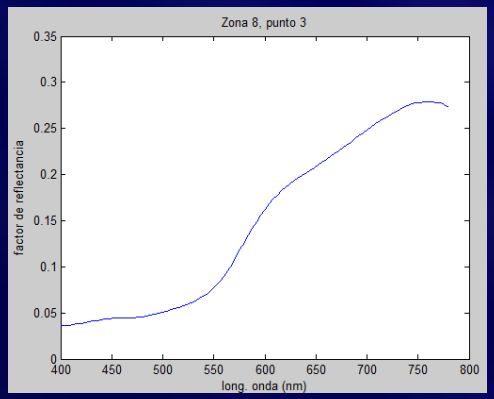
Applied Optics Complutense Group

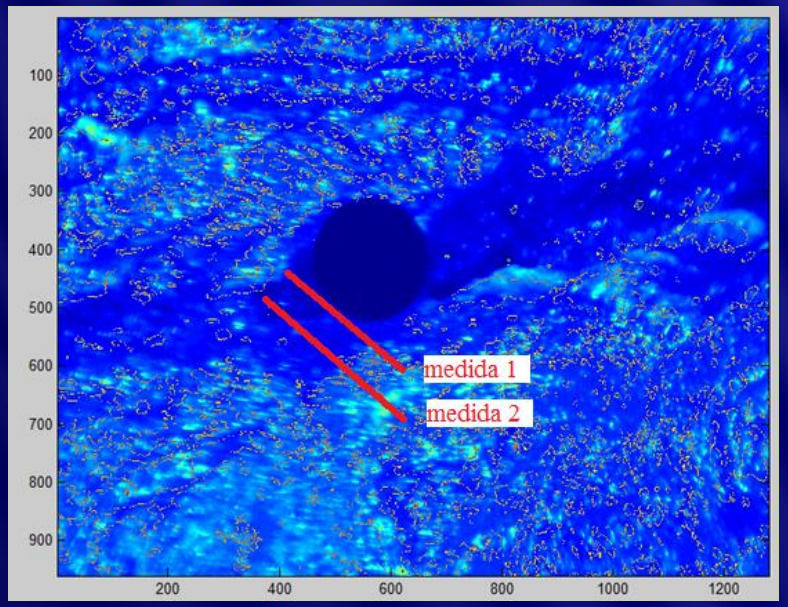
In situ callibration

Point Image proccesing









Muchas gracias !

http://portal.ucm.es/web/iluminacionycolor/inicio