

White Light Contains All Colours: The Myth of Whiteness and the Spectral Life of Artworks

Irina Ciortan

Colourlab 

PERCEIVE

Perceptive Enhanced Realities of Colored collections
through AI and Virtual Experiences

 **NTNU**

Norwegian University of
Science and Technology

① CONTRAPPOSTO

Weight on one leg, creating a natural S-curve in the body.



DORYPHOROS
(SPEAR-BEARER)
Polykleitos, c. 450 BCE

② PUDICA

A modest pose, often used by female figures to cover themselves.



VENUS PUDICA
Roman copy after Greek original, c. 1st century BCE

③ ADLOCUTIO (ORATOR POSE)

Raised arm and open gesture used by orators to address an audience.



STATUE OF AUGUSTUS
(PRIMA PORTA)
Roman, c. 20 BCE

④ FIGURA SERPENTINATA

A dynamic twisting pose with the body coiled in a spiral, full of tension and movement.



LAOCOÖN AND HIS SONS
Agesandros, Polydoros, Athenodoros, c. 1st century CE

⑤ CROUCHING VENUS

A seated or crouching pose, often to cover the body or in moments of rest.



VENUS GENITRIX
("VENUS THE MOTHER")
Roman copy, c. 1st century CE

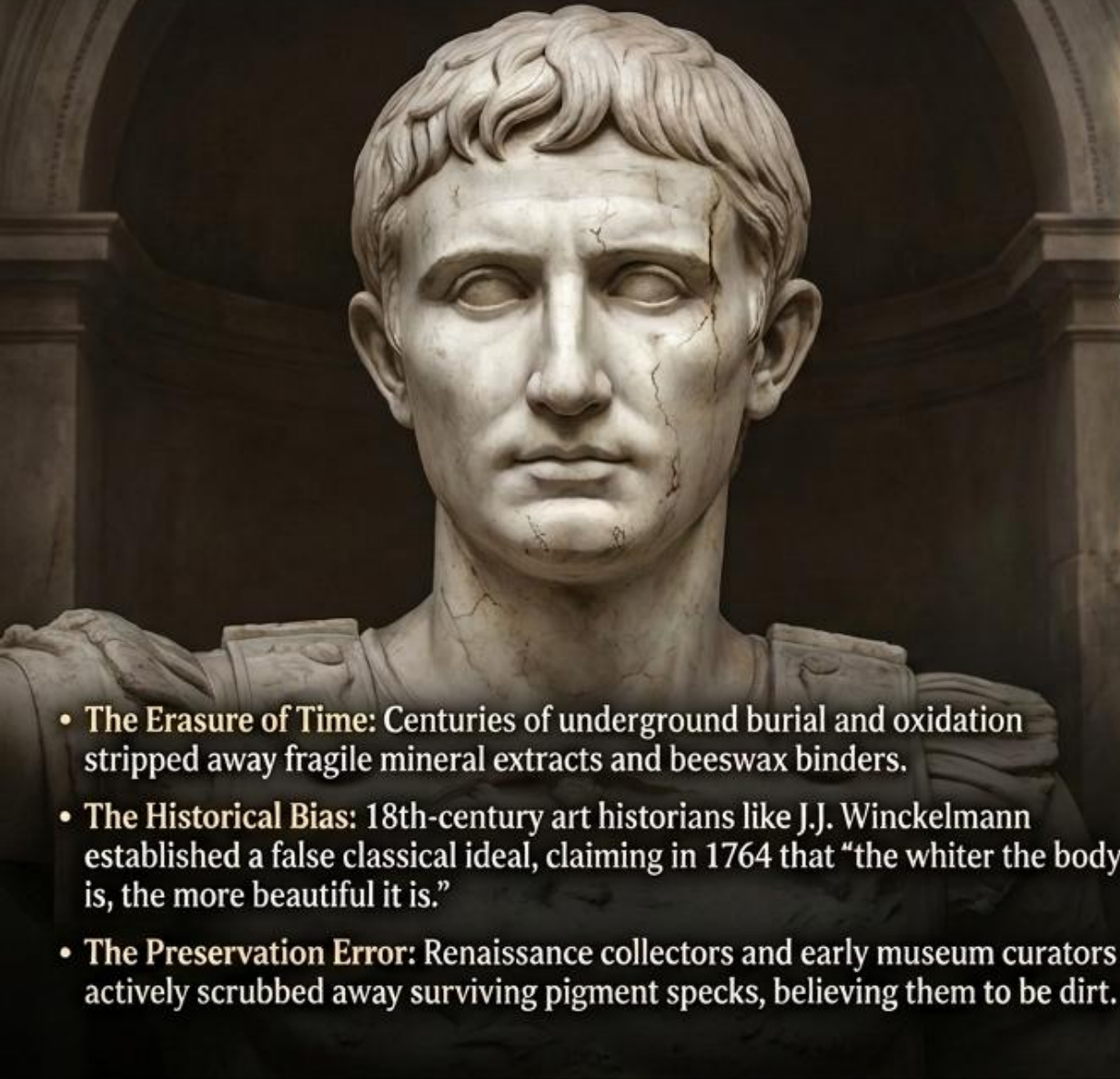
⑥ HEROIC RESTING POSE

The hero rests after battle or labor, leaning on a support, showing strength and calm.



HERCULES
(FARNESE HERACLES)
Roman copy, c. 2nd century CE

The White Marble Ideal



- **The Erasure of Time:** Centuries of underground burial and oxidation stripped away fragile mineral extracts and beeswax binders.
- **The Historical Bias:** 18th-century art historians like J.J. Winckelmann established a false classical ideal, claiming in 1764 that “the whiter the body is, the more beautiful it is.”
- **The Preservation Error:** Renaissance collectors and early museum curators actively scrubbed away surviving pigment specks, believing them to be dirt.

The Polychrome Reality



- **The Spiritual Canvas:** Greek and Roman sculptors considered unpainted marble ugly; color was necessary to serve as a container for the living spirit.
- **The Vivid Palette:** Ancients utilized vivid primary shades derived from mineral extracts.

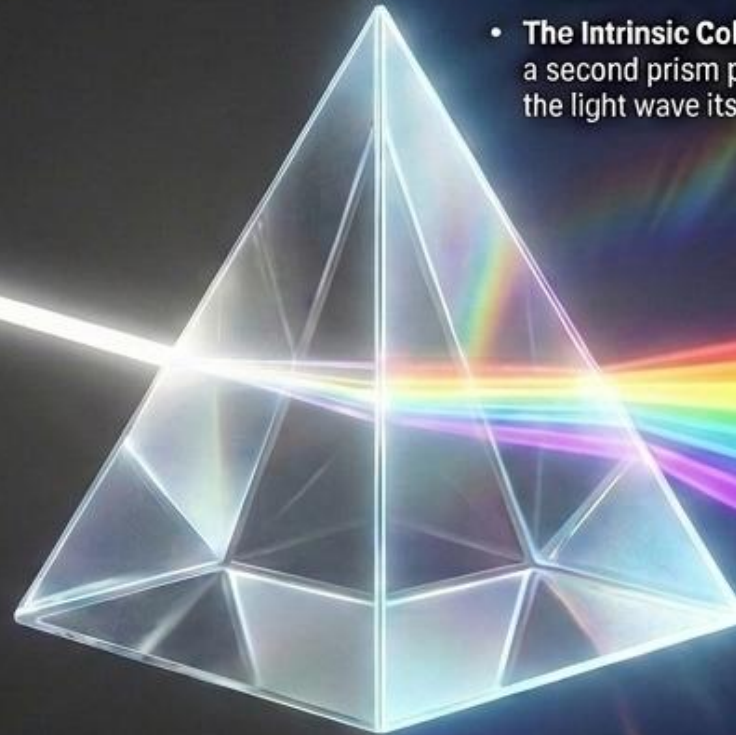
What remains today is not the artist's intent, but the skeleton of antiquity.³

Pre-Newtonian Optics

- **The Illusion of Purity:** Thinkers like Descartes and Hooke believed white light was instantaneous, simple, and homogeneous.
- **The Color Corruption Theory:** Colors were thought to be physical modifications or 'corruptions' of white light—mixtures created by adding darkness to light.

Newton's 1704 Opticks

- **The Dispersion Reality:** Through his crucial prism experiment, Newton proved that white light is actually a composite mixture of all visible wavelengths.
- **The Intrinsic Color:** Passing a dispersed color through a second prism proved color is an intrinsic property of the light wave itself, not a modification by the glass.

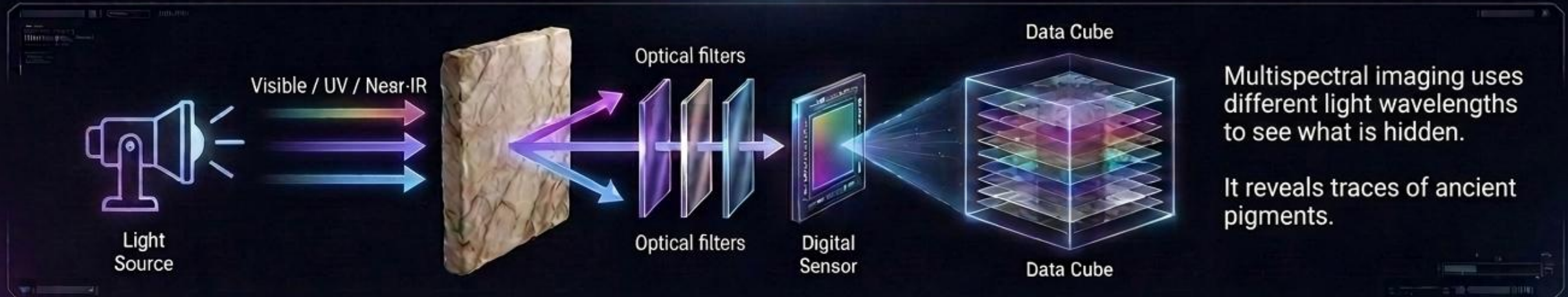


Analogy: "White" marble hides its original painted colors,



just as 'white' light hides a spectrum of wavelengths.

Multispectral Imaging: Seeing Colours That Time Erased



The Luminescent Ghost



- **Egyptian Blue:** The first synthetic pigment, created around 3200 BC.
- It emits a powerful, invisible light in the near-infrared when exposed to visible light.
- This technique, VIL, shows it was used for shading and under-drawings.

3D Spatial Mapping



- Photogrammetry creates a 3D model of the sculpture's surface.
- Multispectral data is then mapped onto this 3D model to show where pigments are located.



This technology allows us to reconstruct the original colors of the statues.

Traditional colour reconstruction pipeline

1. Identification of residual traces

2. Repainting physical copies

3. Digitally manual coloring of defined areas in image editing softwares

4. Digitally stretching and deforming images of comparative artworks (i.e. using other sculptures or mummy portraits) showing similar paint layers

Repaints of physical copies – started with mid 19th century



Polychrome plaster cast of the so-called Bluebeard (or Three-Body Man), created by a Danish artist Anne Marie Carl-Nielsen (1863–1945) featured in the “Farben Sehen” exhibition (March 13-17 2024)

Siotto, E., & Cignoni, P. (2024). Digital methods and techniques for reconstructing and visualizing ancient 3D polychromy—An overview. *Journal of Cultural Heritage*, 68, 59-85.

“Gods in Colour” project

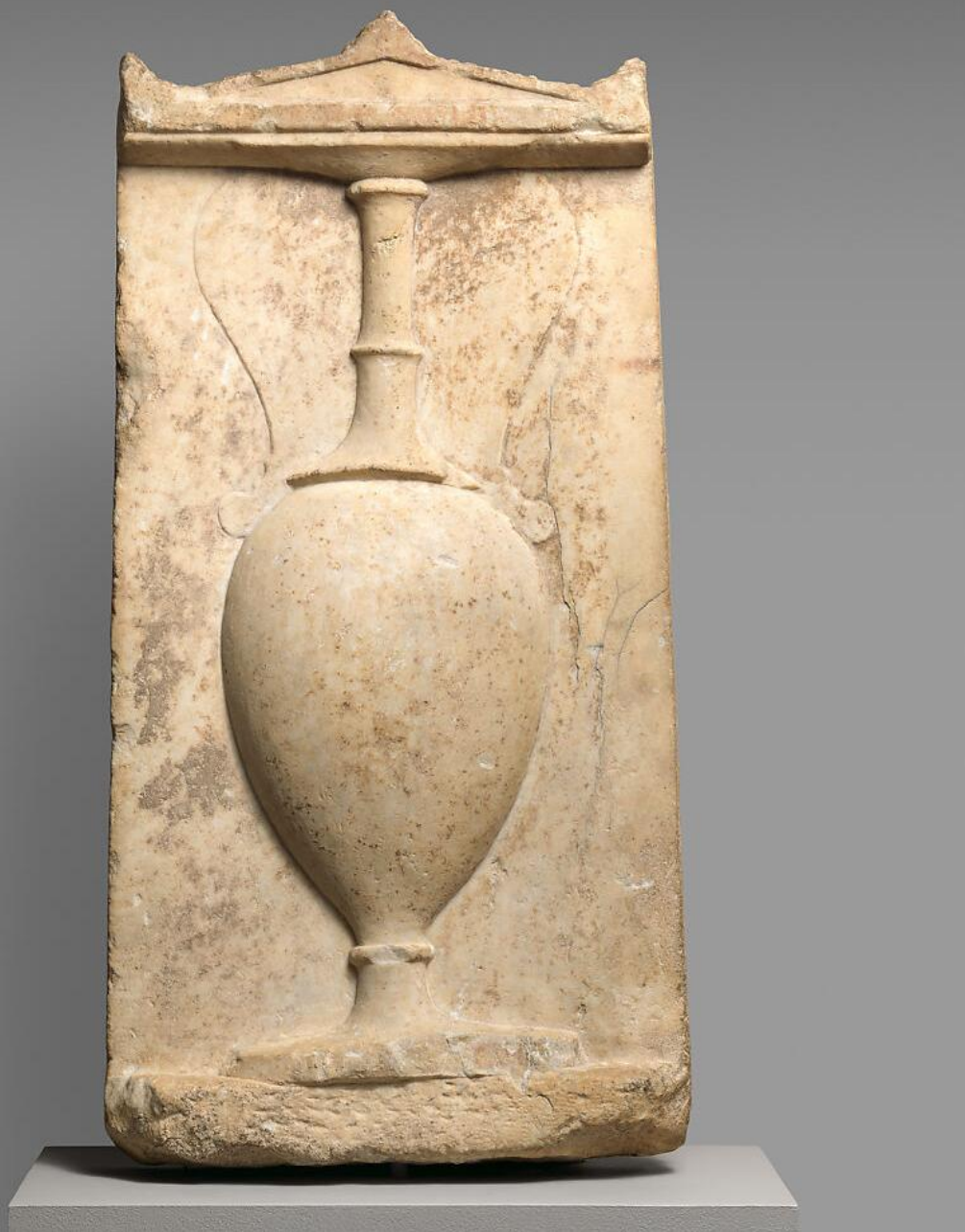
- Since 2001/03, physical reconstructions of lost polychromy were brought to life by Vincenz Brinkmann and Ulrike Koch-Brinkmann
- “Bunte Götter” or “Gods in Color” travelling exhibition
- Showcased over 100 painted sculptures at Frankfurt’s Liebieghaus Museum
- 1:1 replicas
- Re-included in the **Chroma: Ancient Sculpture in Color** at the MET (July 5 2022 - March 26, 2023)



Marble
capital
and finial
in the form
of a sphinx
Greek,
Attic
ca. 530
BCE



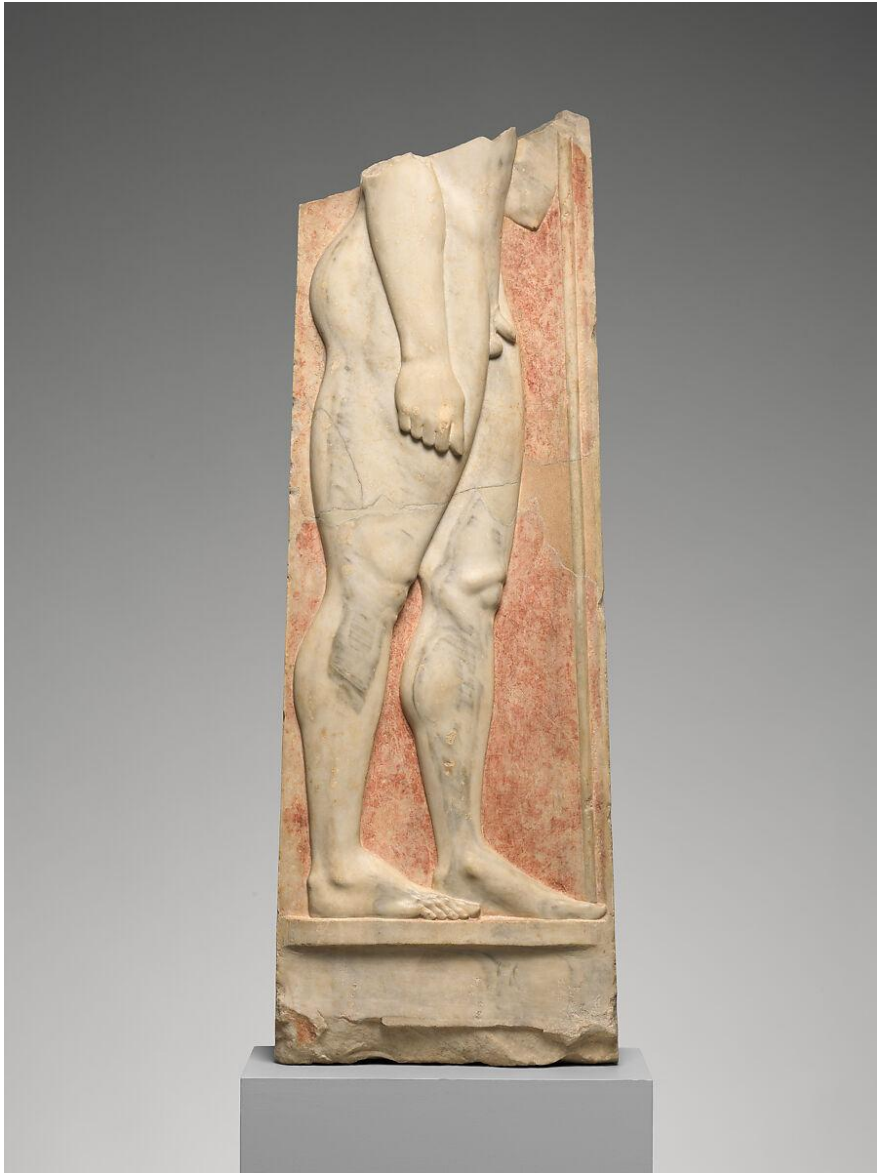
Reconstruction
of a marble
finial in the form
of a sphinx
©Vinzenz
Brinkmann
Ulrike Koch-
Brinkmann



Fragment of the marble stele (grave marker) of a youth,
Greek, Attic, ca. 530 BCE



Colour
reconstruction,
©Vinzenn Brinkmann
Ulrike Koch-
Brinkmann
2009



Fragment of the marble stele (grave marker) of a youth
Greek, Attic
ca. 530 BCE



Colour reconstruction,
© Vinzenz Brinkmann
Ulrike Koch-Brinkmann
2006



Researchers demonstrate the process of applying color to the Treu Head, from a Roman sculpture of a goddess, made in the second century A.D. Ancient sculptures were often painted with vibrant hair colors and skin tones. Photograph by Mark Peckmezian for The New Yorker



Study 1 of the color scheme of the so-called Treu Head,
© Vinzenz Brinkmann, Ulrike Koch-Brinkmann
2014/ 2020



Giovanni Verri, 2010 – digital
colour reconstruction



Beauty brought to life in vivid colour

Ancient Palmyra's painted lady is digitally reconstructed from traces of pigments for new exhibition at Ny Carlsberg Glyptotek

ANTIQUITIES & ARCHAEOLOGY

COPENHAGEN. Harald Ingholt, a Danish archaeologist, was on his third campaign of excavations at Palmyra, in present-day Syria, in 1928, when his team unearthed a half-length portrait of an unknown woman made between AD190 and 210 in a tomb dubbed Qasr

The following year Ingholt presented *The Beauty of Palmyra* and around a dozen other sculptures to Copenhagen's Ny Carlsberg Glyptotek, a museum built on the collection of the Carlsberg brewery scion Carl Jacobsen, where the archaeologist was also a curator. Today, the Glyptotek's collection of Palmyrene tomb sculptures is the largest outside Syria.

The Beauty of Palmyra has begun to yield some of its secrets. For the past 18

a team reconstructing how the tomb sculpture may originally have looked. The research, financed by the Carlsberg Foundation, will be featured in *The Road to Palmyra*, an exhibition opening on 20 September at the Glyptotek and celebrating the return of the museum's tomb sculptures from a year-long loan to the J. Paul Getty Museum in California.

The researchers' work began with a digital reconstruction of the sculpture's

Glyptotek, the British Museum and the Louvre, Brøns says.

The next step was to establish the pigments used to paint the skin, hair, jewels and textiles. Using X-ray fluorescence, the team identified the chemical composition of paint patches, which were well preserved due to the sculpture having been underground for nearly two millennia. Most of the colours turned out to be local earth pigments, including red and yellow ochre. The researchers also found madder lake, which fluoresces with a coral colour under ultraviolet light. "For such a fine and elaborate portrait, the pigments weren't at all precious," Brøns says.

The team also employed visible induced luminescence, used to identify a pigment known as Egyptian blue that was in use from the third millennium BC. "What was intriguing is that we didn't find any on *The Beauty of Palmyra*, despite its widespread use in the ancient world at that time," she says.

Some of the other works in the Glyptotek's tomb sculpture collection appear to have applications of lapis lazuli from

From left, *The Beauty of Palmyra* today, with reconstituted elements, and in the final stage of digital reconstruction

Once established, the pigments were incorporated in the reconstruction to create a video bringing *The Beauty of Palmyra* back to life. As a final touch, her jewels were reset digitally with the types of precious stones found in excavations at Palmyra.

Still, the project involved some guesswork. "It was easy to say, 'Make the jewellery look gold', but areas such

The sculpture had been underground for nearly two millennia

as her eyes had no traces of colour left," Brøns says. The Los Angeles County Museum of Art has a funerary portrait from Palmyra with inlaid black-glass eyes, so the team followed that example.

©Harry Seymour in the Art Newspaper, 2020

Judean Pillar Figurines

LET THERE BE LIGHT

RELIGHTING AND RECOLORING ANCIENT ARTIFACTS



ABOUT THIS SITE »

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THINK ABOUT RELIGION »

False color texture map was made by applying [DStretch](#) image processing to the texture map made from the original photographs.



<https://laurmcco.github.io/judeanpillarfigurineexhibit/>

Athena reveals her true colours

- Produced by Black Math in 2021
- In collaboration with **Museum of Fine Arts** in Boston
- <https://www.mfa.org/video/athena-reveals-her-true-colors>



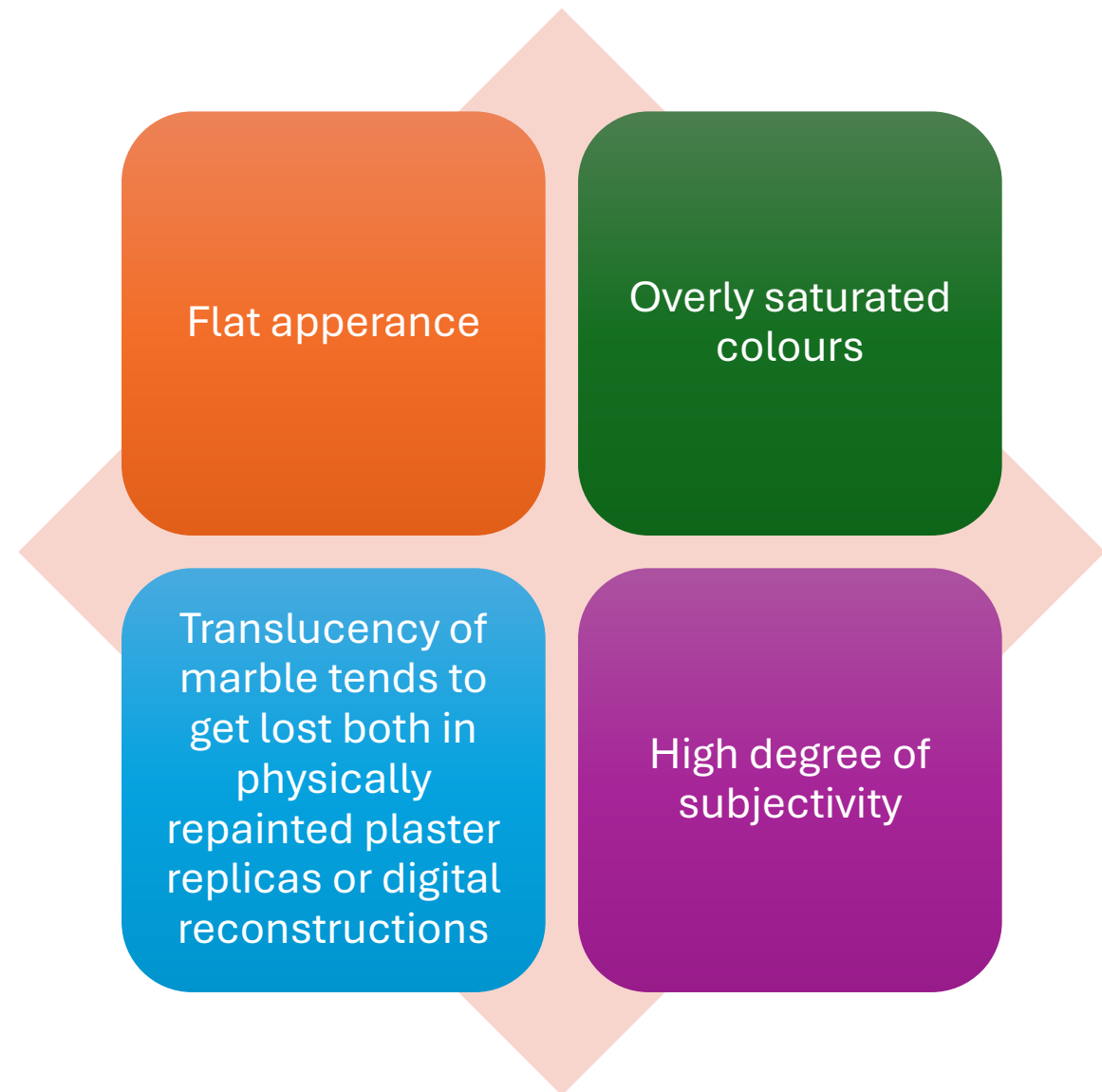
How would you describe the aesthetics of the colour reconstructions so far?



<https://www.menti.com/alygqfrj4qum>

Code: **8603 9616**

Quality of traditional techniques

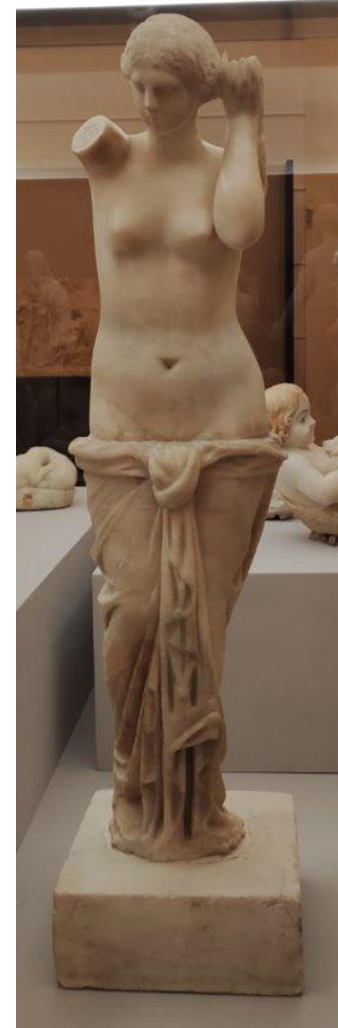
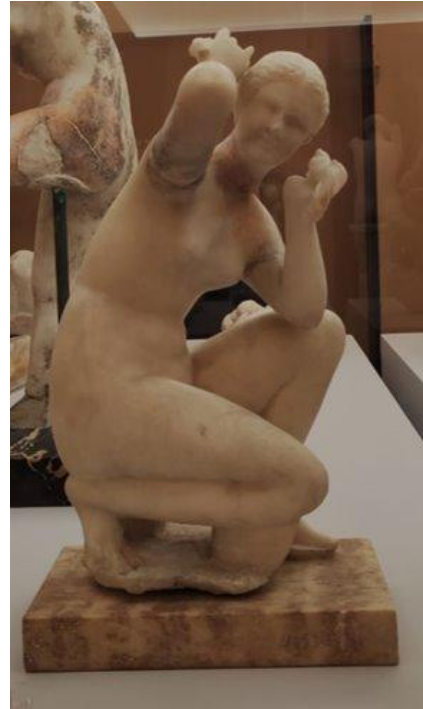
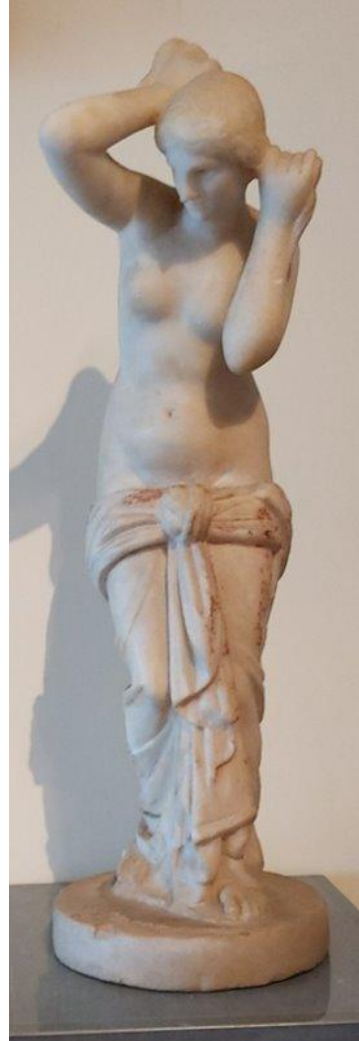




Perceptive Enhanced Realities of Colored collections
through AI and Virtual Experiences

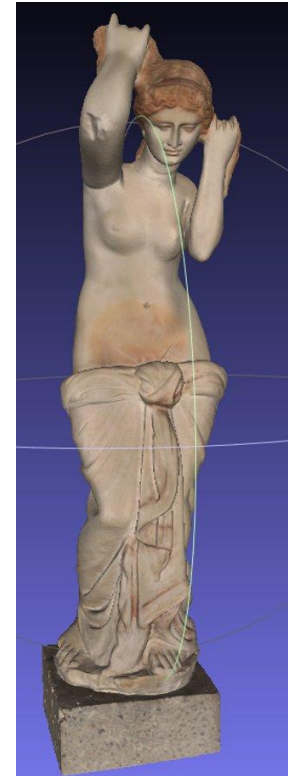
Aimed at creating a new way to perceive, preserve, curate, exhibit, understand and access coloured museum collections, promoting their re-appropriation. These collections are fragile and in danger.

Lost Polychromy scenario - Venus Anadiomene at MANN



Aim

- Digitally reconstruct original colour of the Venus Anadiomene statues at the MANN museum



Physically- based colour reconstruction pipeline

1. Identification of polychromy traces
(data collection)

2. Experimental fabrication of mock-ups

3. Capturing measurements and digital
modelling of mock-ups

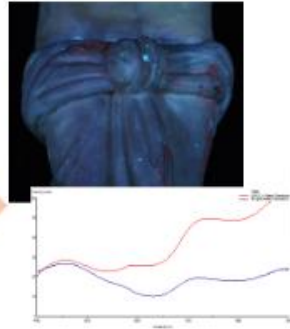
4. Atlas-based segmentation of a
sculpture based on a 3D model

5. Application of mock-up models as
shaders

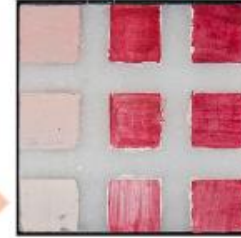
Venus Anadyomene



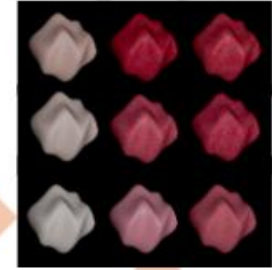
Identification of polychromy traces



Fabrication of mock-ups



SVBRDF modelling



3D model - photogrammetry



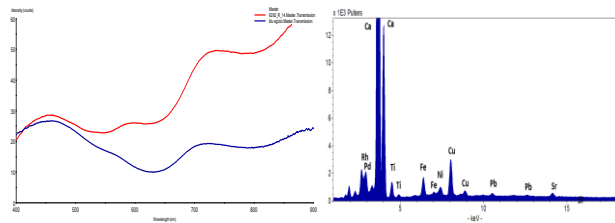
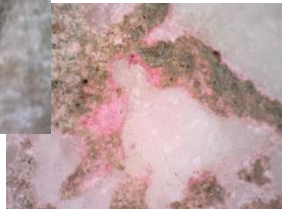
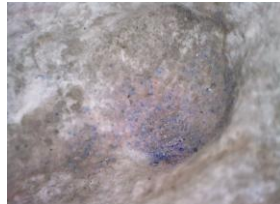
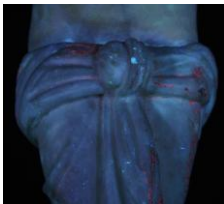
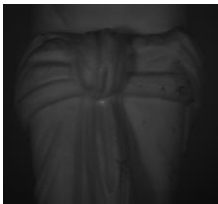
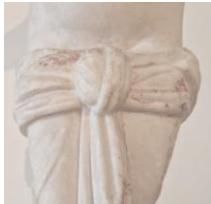
Atlas-based segmentation



StyleShade - Reconstruction

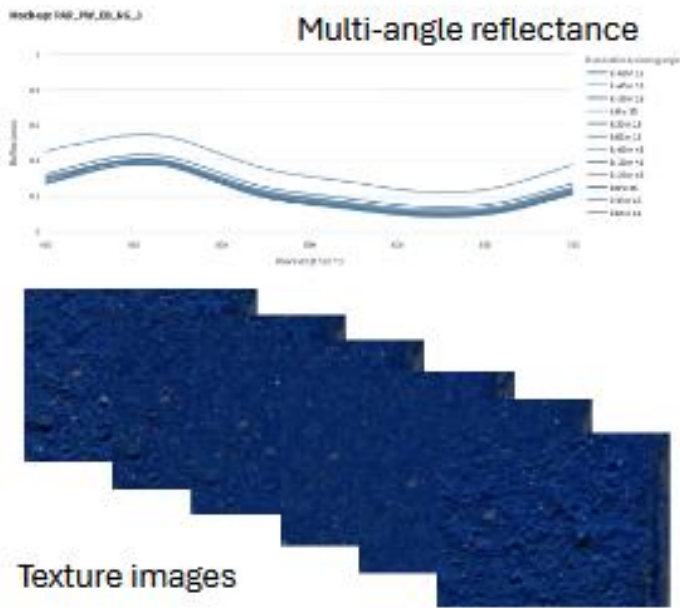
Paros marble - No preparatory layer, red lake, egyptian blue and calcium carbonate mixed with Punic wax, one paint layer on the top.

Data Acquisition

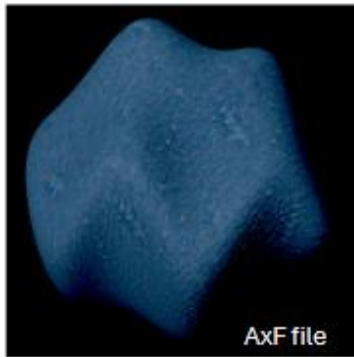


PREPARATION OF
CONTROLLED MOCK-UPS

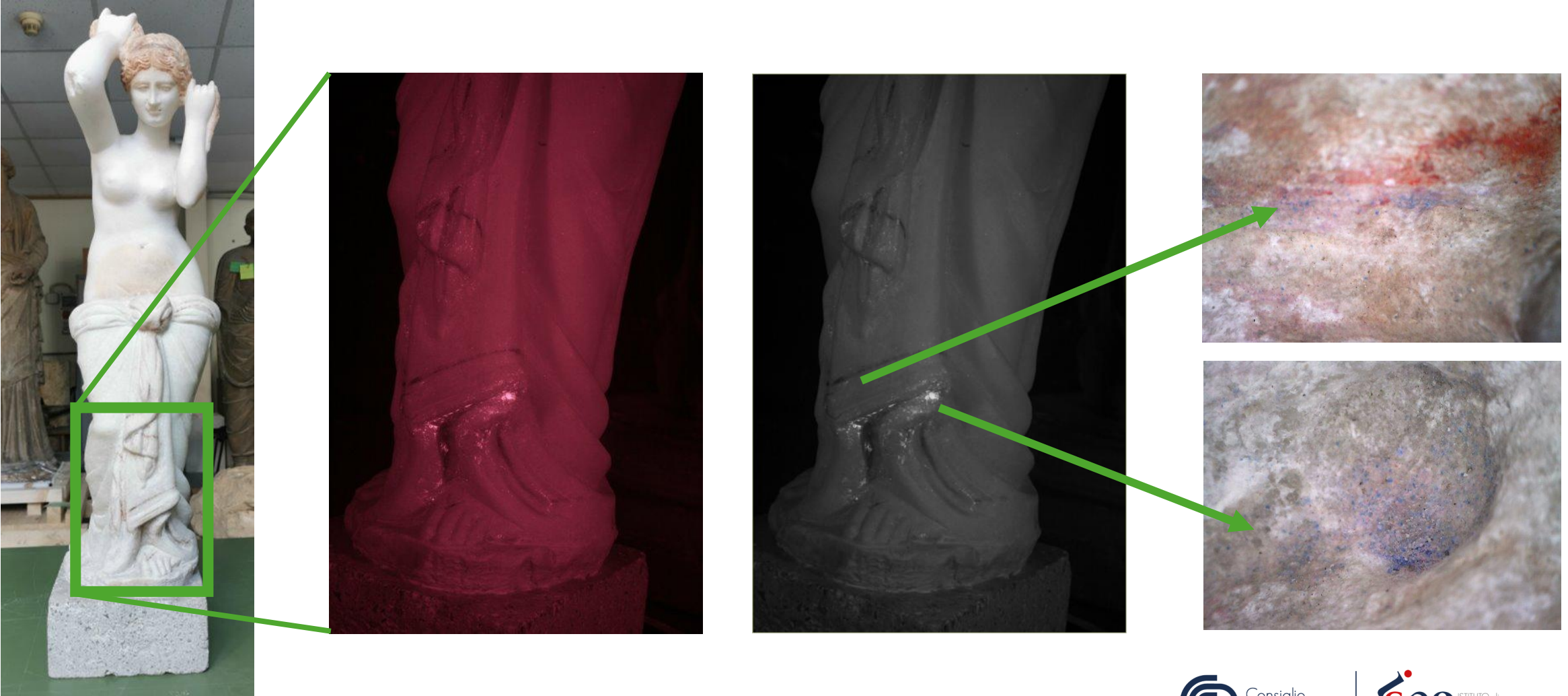
Measurements



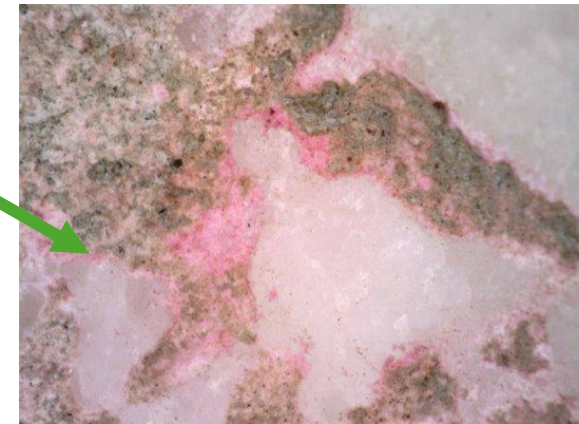
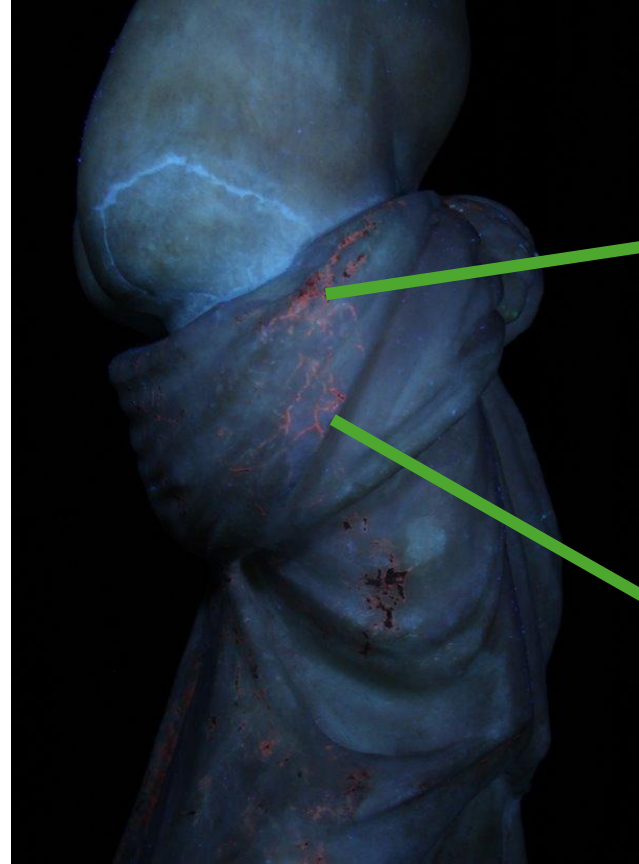
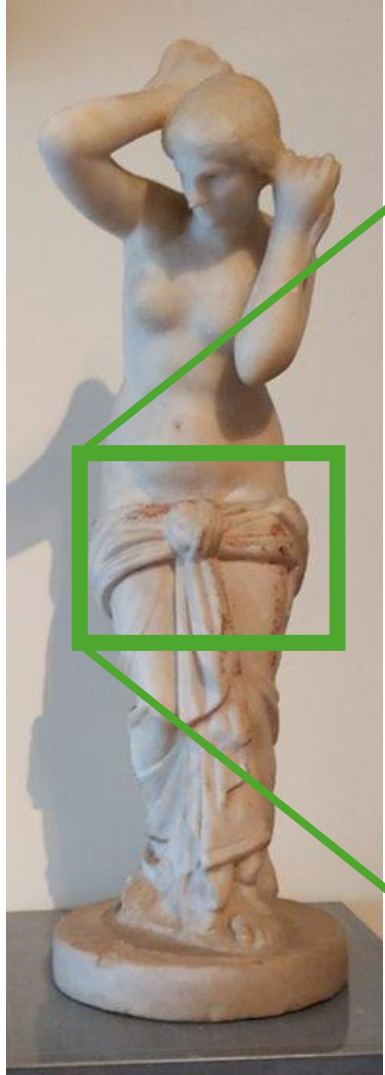
Modelling



Material and pigment identification: visible induced infrared luminescence (800-1700 nm)



Material and pigment identification: ultraviolet induced luminescence



Mock-up design

	No ground	Lead white	Calcium carbonate
1 layer			
2 layers			
3 layers			

- Raw materials:

- Type of marble
 - Pentelic
 - Paros
- Pigment
 - Egyptian blue
 - Red ochre
 - Yellow ochre
 - Madder lake
 - Cinnabar
- Ground layer
 - Lead white
 - Calcite
- Binders
 - Egg tempera
 - Wax

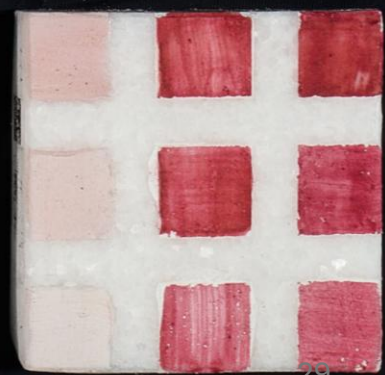
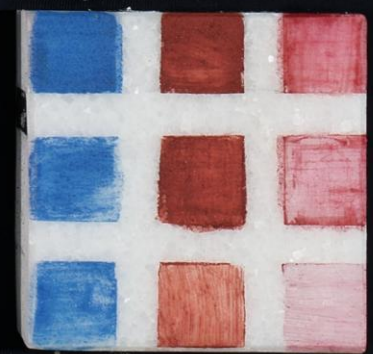
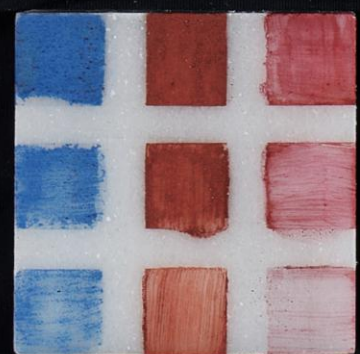
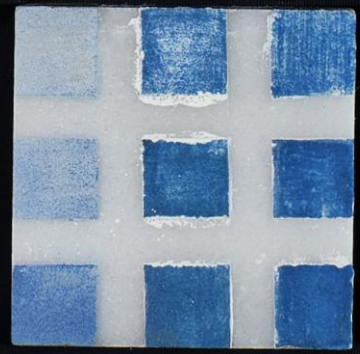
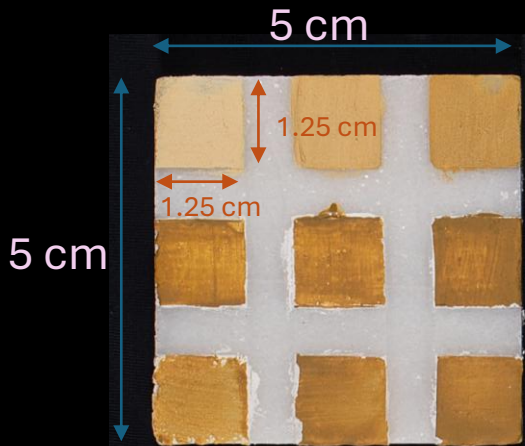
- Parameters:

- Type of marble
- Type of pigment
- Number of layers
- Granulometry
- Mixture with ground layer
- Binary layers
- Binder

Mock-up fabrication

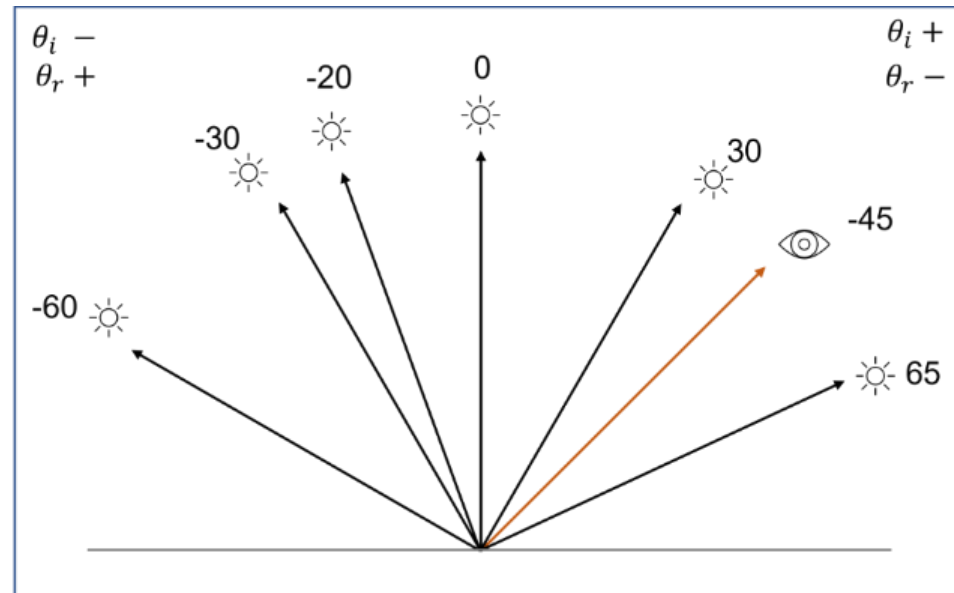
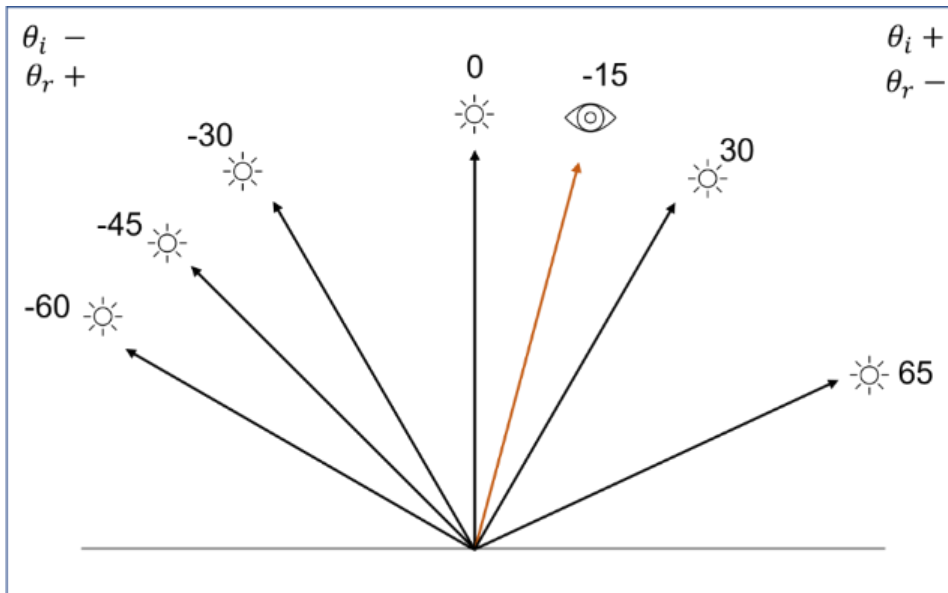
- Based on interpretation of analytical data and ancient recipes





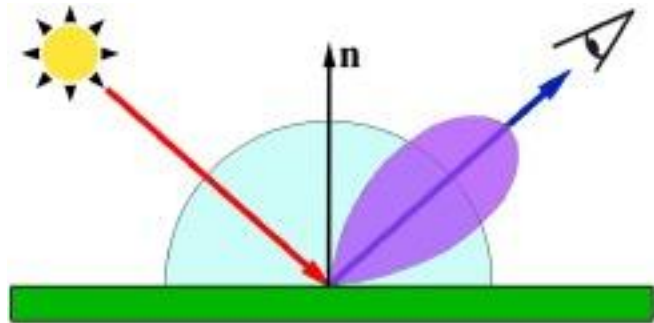
Bidirectional measurements and texture images

- X-Rite MA-T12 multiangle spectrophotometer
- 12 reflectance spectra [380 780] nm
- 6 texture images



SVBRDF modelling with PANTORA

- Spatially varying bidirectional reflectance distribution function



(a) Basic reflection models



(b) Diffuse



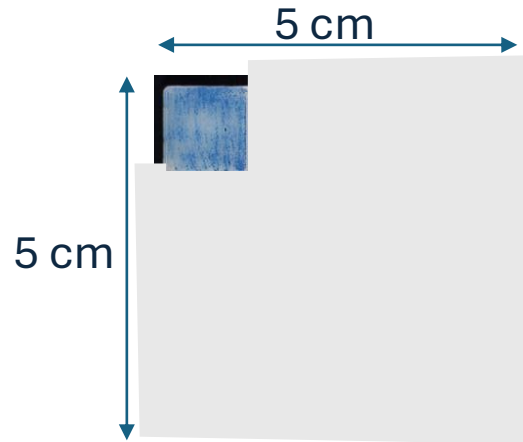
(c) Glossy



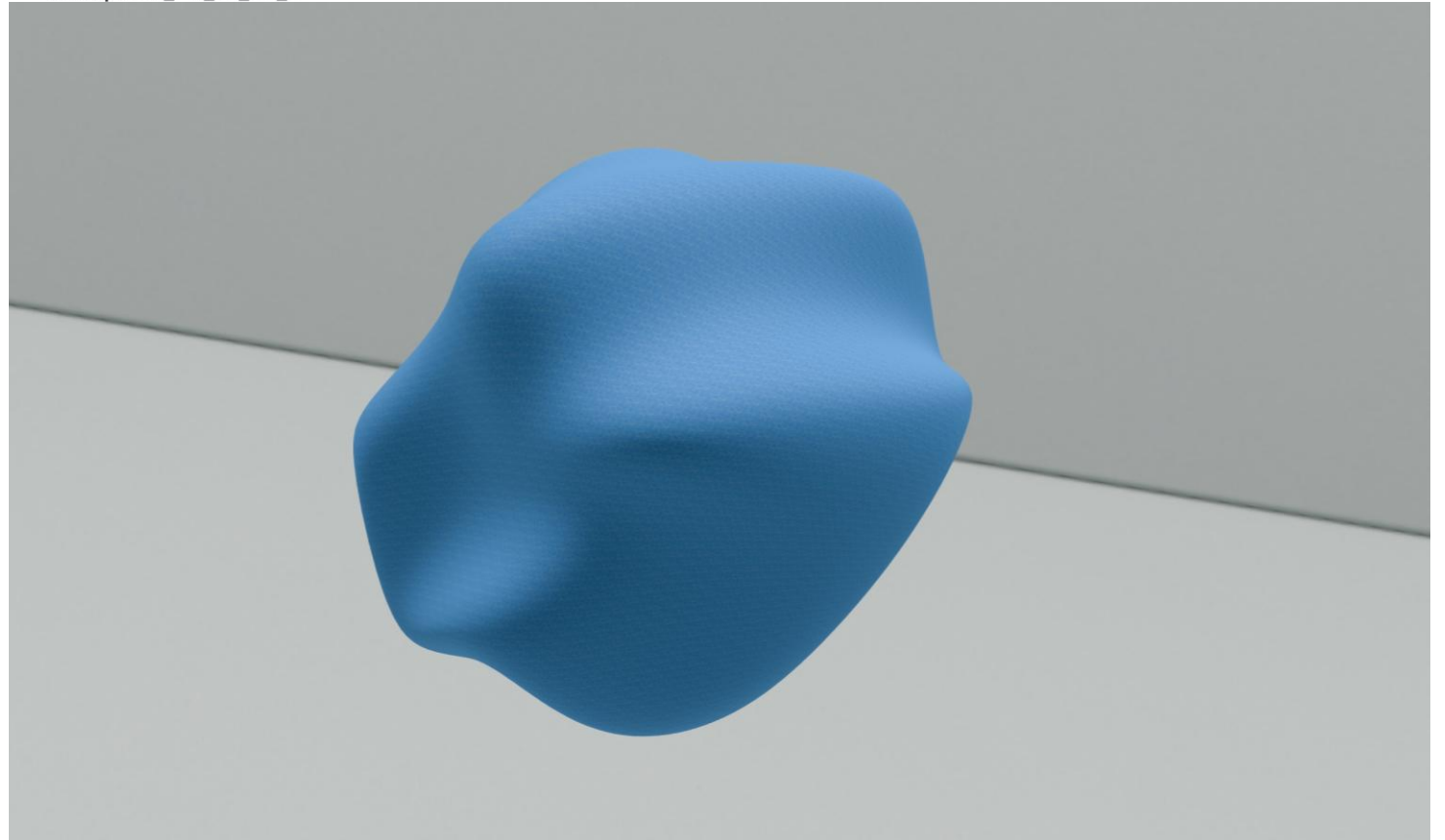
(d) Specular

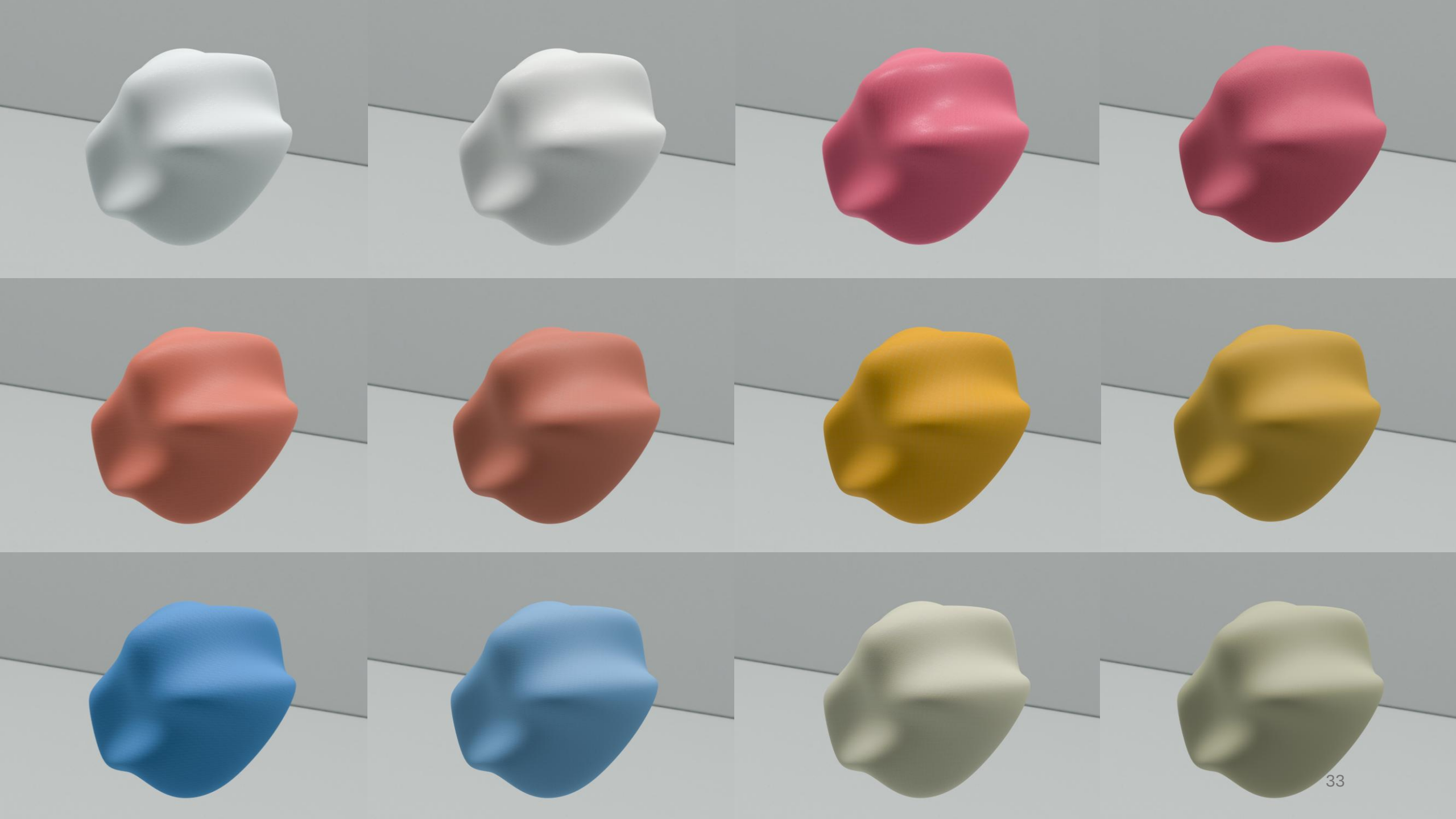
Guarnera, D. (2016)

Paros marble, 1 layer of Egyptian blue with Punic wax binder, no ground layer



Mock-up: PEN_PW_EB_NG_1





Polychromy database

<https://ancientpolychromy.streamlit.app/>

Credits:

- Donata Magrini, Roberta Iannacone (CNR, ISPC), Yoko Arteaga (NTNU): mock-up fabrication.
- Yoko Arteaga (NTNU): measurements
- Lu Xu (NTNU): website
- Petros Stravoulakis, Sophia Sotiropoulou (FORTH): purchasing marble

Single mock-up multiangle reflectance

Reflectance spectra of single mock-up. The mock-ups have been named using the following convention: Marble_Binder_Pigment_Ground_nLayers.

Texture images

Texture images of mock-up. The mock-ups have been named using the following convention: Marble_Binder_Pigment_Ground_nLayers. More information in the Home page.

Mock-up: PEN_PW_GE_CC_2



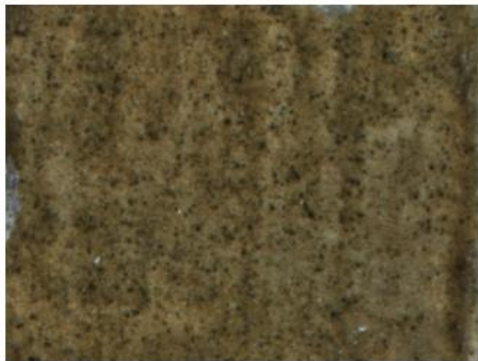
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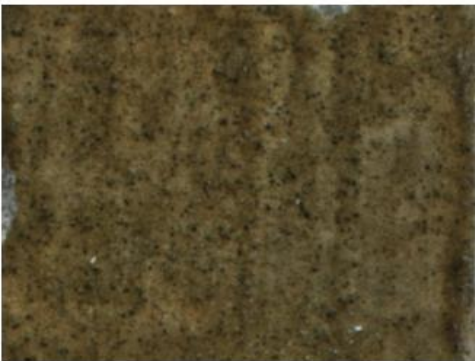
illumination angle: -45 viewing angle: 15



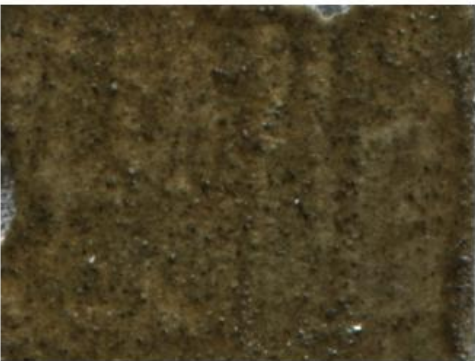
illumination angle: -30 viewing angle: 15



illumination angle: 0 viewing angle: 15

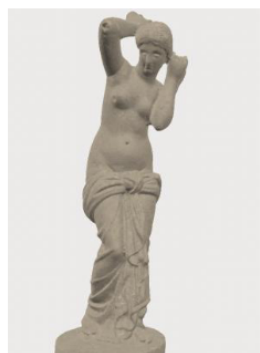


illumination angle: 30 viewing angle: 15

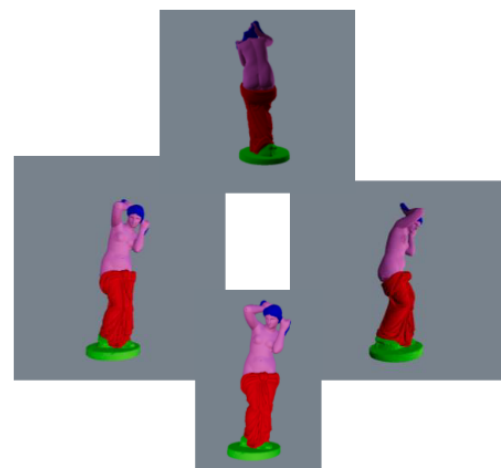
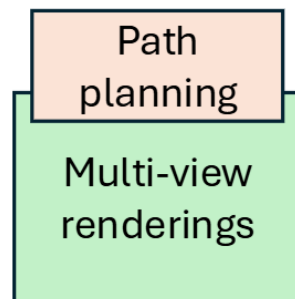


illumination angle: 65 viewing angle: 15

✓	PEN_PW_GE_CC_2	Pentelic	Punic wax	green earth	Calcium carbonate	2	34
	PEN_PW_GE_NG_3	Pentelic	Punic wax	green earth	No ground	3	
	PEN_PW_GE_MC_1	Pentelic	Punic wax	green earth	Mixed with calcite	1	



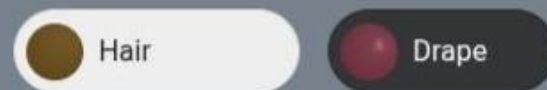
3D model



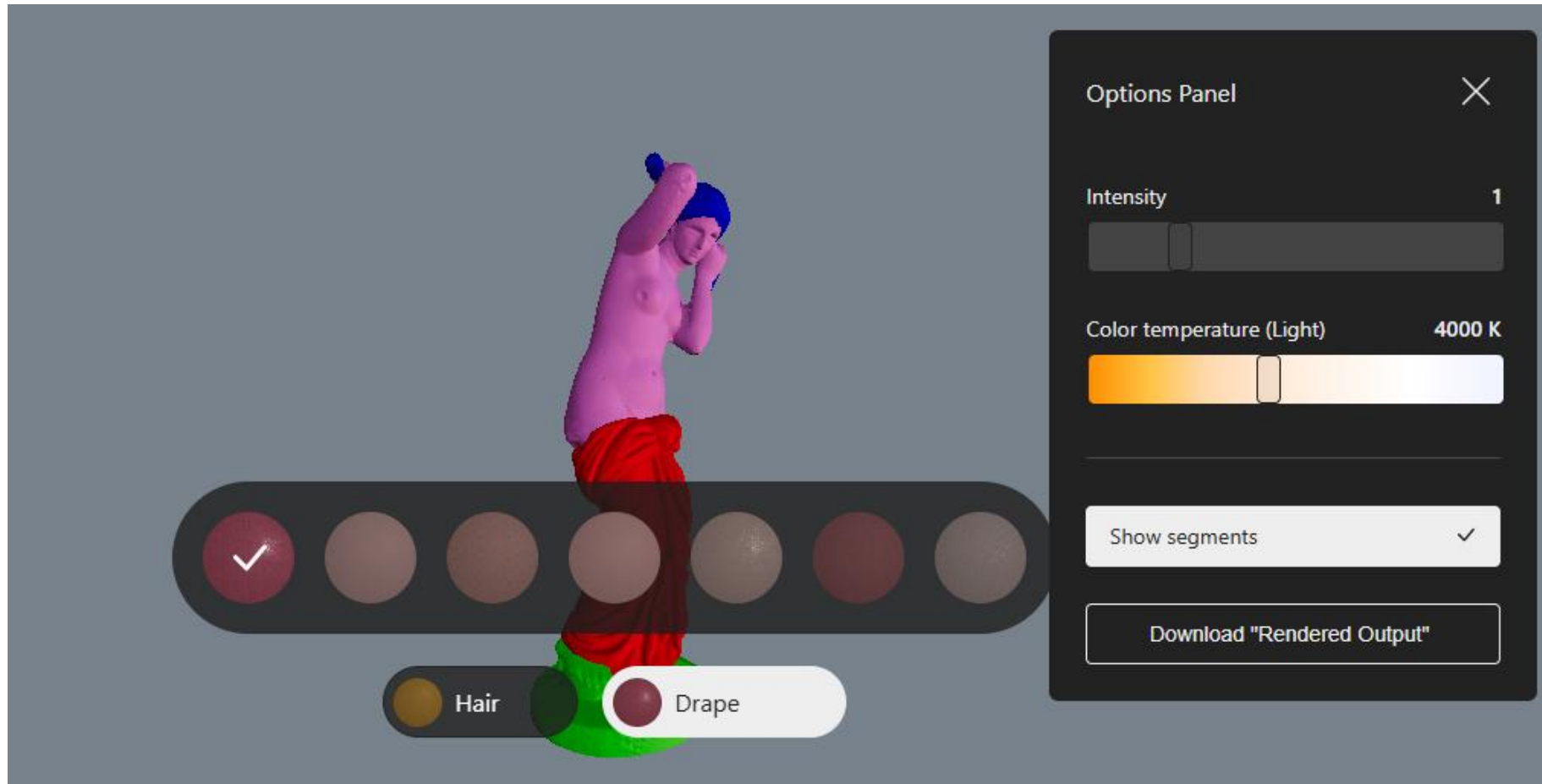
AI assisted multi-view
segmentation



2D parameterized
segmentation map over
the 3D surface
(Segmentation atlas)



StyleShade3D – online visualization tool for the colour reconstruction



<https://perceive-tools.igd.fraunhofer.de/venus/>



Options Panel

×

Intensity

1

Color temperature (Light)

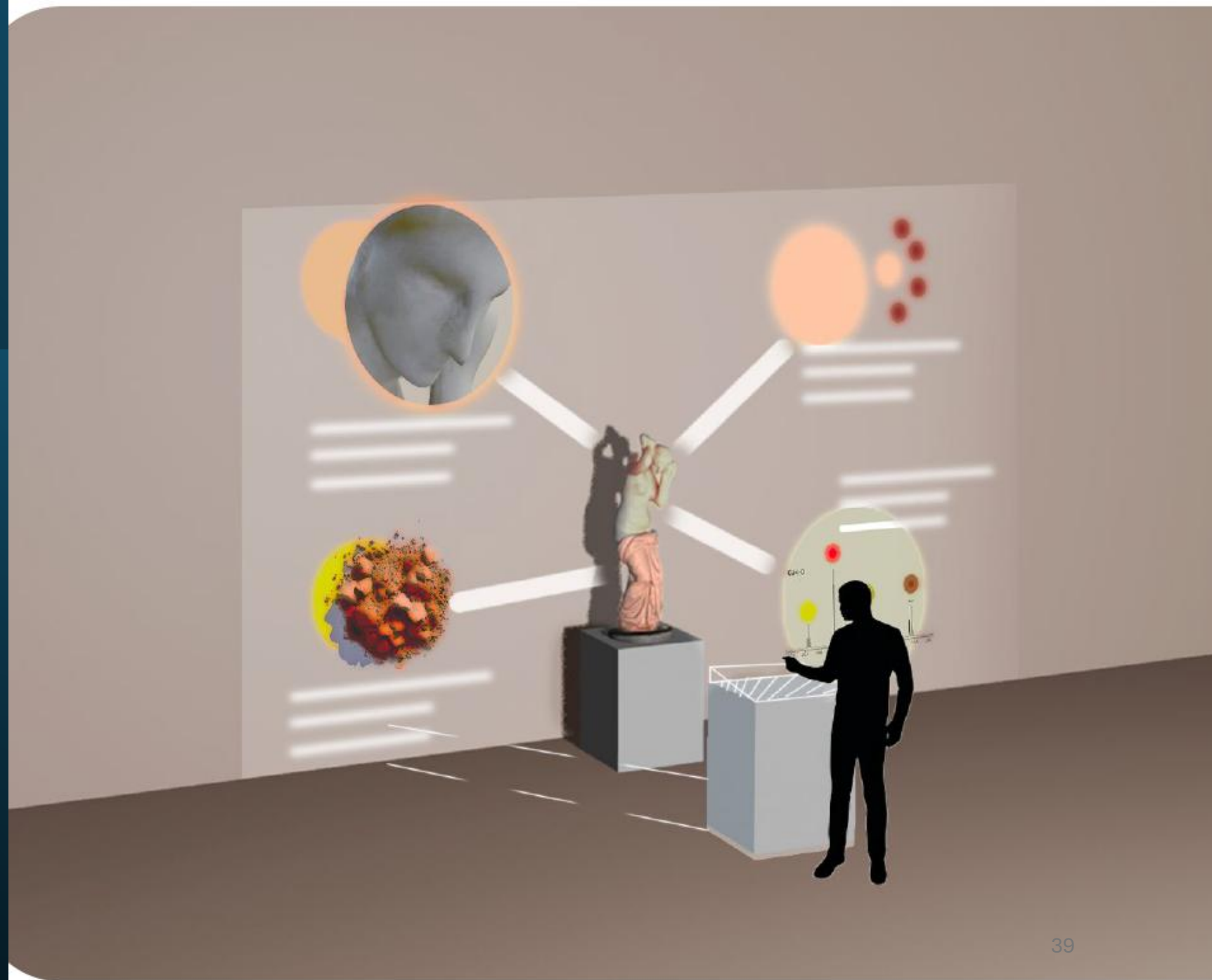
4000 K

Show segments

☐

Download "Rendered Output"

Exhibition
**“Echoes of
Colour”**,
Digital
Heritage
Siena, 2025



ECHOES OF COLOURS

The interactive projection

Echoes of Colours brings the visitor into the scientific investigative journey, applied to the research attempt to reconstruct the original polychromy of the statue of Venus Anadyomene.

In the interactive experience visitors are asked to **lift one of three objects and observe the complexity of the colour reconstruction process**, in accordance with their increasing weights. Lifting each object activates a projection mapped on the statue. The sequence demonstrates in stages how the process is demanding both scientific rigor and interpretive humility.

Stages of the Experience

1

Chaos

From uncertainty to possibility

The projection shows the chaos of countless hypothetical colourings, reflecting the vast unknown of the lost polychromy.

2

Research

From sources to selection

Diagnostic results, pigment analyses, and historical sources converge to limit the field to a set of plausible options.

3

Reconstruction

Towards a reconstructed vision

The final hypothetical colour palette, informed by scientific evidence and mock-up tests, emerges on the statue, offering a glimpse of how the sculpture might have appeared in the 1st AD.



The weights

The weight of the objects serves as a metaphor for the effort and responsibility intrinsic to the act of taking care: to "lift" the past requires dedication, critical attention, and sustained inquiry. Reconstructions are not definitive, but the result of an open, careful and updatable process based on evidence, sources and comparison.

La proiezione interattiva

Echoes of Colours conduce il visitatore all'interno di un percorso di indagine scientifica, applicato al tentativo di ricostruire la policromia originale della statua di Venere Anadyomene.

I visitatori sono invitati a **sollevare uno di tre oggetti e a osservare la complessità del processo di ricostruzione cromatica**, in relazione al loro peso crescente. Ogni oggetto infatti attiva una proiezione mappata sulla statua. La sequenza mostra, per fasi, come il processo richieda sia rigore scientifico sia umiltà interpretativa.

Fasi dell'esperienza

Caos

Dall'incertezza alla possibilità

La proiezione offre l'immagine del caos causato dalle innumerevoli ipotetiche colorazioni, e riflette l'incognita della policromia perduta. Senza analisi non ci sono dati, senza dati non c'è ricostruzione.

Ricerca

Dalle fonti alla selezione

I risultati diagnostici, le analisi dei pigmenti e le fonti storiche convergono per restringere il campo a un insieme di opzioni plausibili.

Ricostruzione

Verso una visione ricostruita

La palette cromatica finale basata su prove scientifiche e test emerge, offrendo uno scorcio di come la scultura poteva apparire nel I secolo d.C.

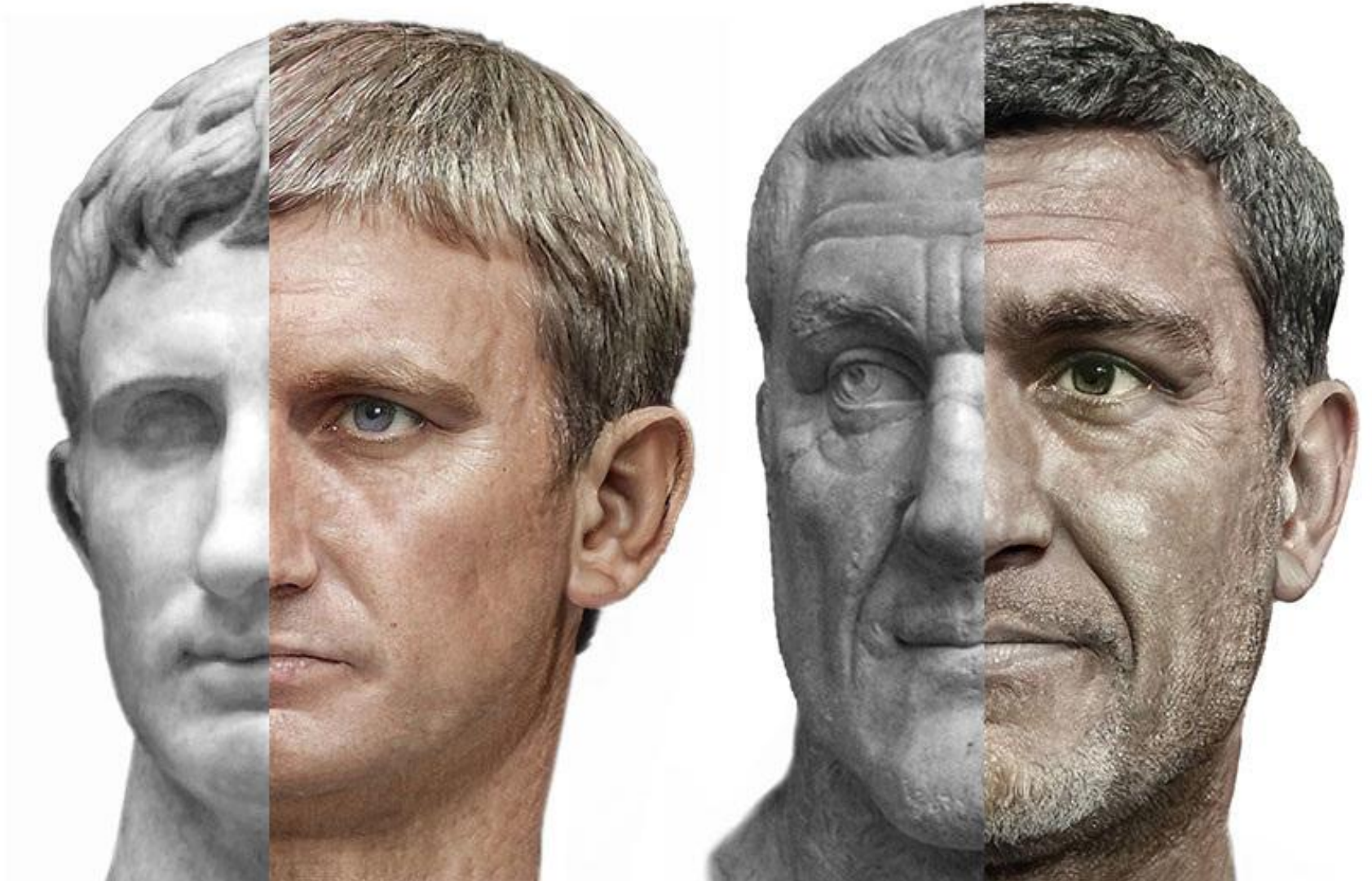
I pesi

Il peso degli oggetti funge da metafora dello sforzo e della responsabilità insiti nell'atto del "prendersi cura" che richiede dedizione, attenzione critica e indagine costante. Le ricostruzioni non sono definitive ma il risultato di un processo aperto e aggiornabile sulla base di dati, fonti e confronti.



AI-powered technique & Roman Emperor Project

- **Artbreeder** by Daniel Voshart
- Generative AI (GAN)
- Historical photographs
- Photo editing
- Comparable to the **deep fake** technology





AUGUSTUS
27BC - 14AD



TIBERIUS
14 - 37



CALIGULA
37 - 41 +



CLAUDIUS
41 - 54 +



NERO
54 - 68 +



GALBA
68 - 69 +



OTHO
69 +



VITELLIUS
69 +



VESPASIAN
69 - 79



TITUS
79 - 81



DOMITIAN
81 - 96 +



NERVA
96 - 98



TRAJAN
98 - 117



HADRIAN
117 - 138



ANTONINUS PIUS
138 - 161



LUCIUS VERUS & MARCUS AURELIUS
161 - 169



161 - 180



COMMODUS
177 - 192 +



PERTINAX
193 +



DIDIUS JULIANUS
193 +



SEPTIMIUS SEVERUS, CARACALLA & GETA
193 - 211



198 - 217 +



+ 211



MACRINUS & DIADUMENIAN
217 - 218 +



218 +



ELAGABALUS
218 - 222 +



SEVERUS ALEXANDER
222 - 235 +



MAXIMINUS THRAX
235 - 238 +



GORDIAN I & GORDIAN II
238 +



238 +



PUPIENUS & BALBINUS
238 +



238 +



GORDIAN III
238 - 244 +



PHILIP THE ARAB & PHILIP II
244 - 249 +



247 - 249 +



DECIUS
249 - 251 +



HERENNIUS ETRUSCUS
249 - 251 +



HOSTILIAN
251



TREBONIANUS GALLUS & VOLUSIANUS
251 - 253 +



253 +



AEMILIAN
253 +



253 - 260 +



253 - 268 +



258 - 260 +



CLAUDIUS GOTHICUS
268 - 270





Summary & conclusions

- Traditional techniques
 - Pro: physical replicas, real-size
 - Cons: artificial, not realistic enough, subjective
- Physically-based models and automatic segmentation
 - Pro: loyal to material's appearance, more objective
 - Cons: resource heavy
- AI techniques using neural nets
 - Pro: creative and progressive
 - Cons: low level of authenticity

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Acknowledgement to all PERCEIVE partners



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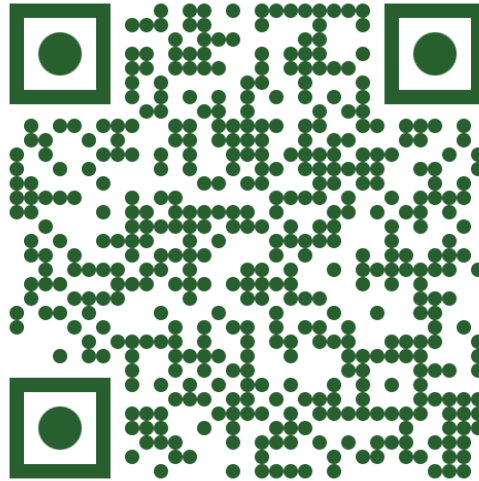
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CHICAGO



MuLaX tool



Polychromy database



Let there be light project