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Non-invasive diagnostic techniques for studying the *Coronation of the Virgin* altarpiece by Michele di Matteo

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Abstract **– This paper focuses on the study of the *Coronation of the Virgin* altarpiece by the Bolognese painter Michele di Matteo (1410-1469).**
In the field of diagnostics and conservation of cultural heritage, non-invasive techniques are increasingly used to study and understand works in depth. Only through these techniques is it possible to preserve the integrity of the work itself.
The aim of this preliminary study is therefore to investigate the pictorial composition of the work in a completely non-invasive and non-destructive manner to obtain useful information on the restoration methods that have been applied to the altarpiece over the years, and, where possible, to evidence the differences before and after cleaning.
For this purpose, colourimetric and visible reflectance analysis in addition to multispectral imaging techniques were employed.
Further analyses are necessary to better understand the composition of the work. Indeed, portable X-ray fluorescence (XRF) and iperspectral imaging measurements are ongoing, whose application could be useful to obtain information on the elements and compounds that make up the pigments used to paint and decorate the artwork.

I. INTRODUCTION

The *Coronation of the Virgin* is a painting on panel signed by the Bolognese painter Michele di Matteo (1410-1469) (Fig.1). The bibliography that refers to the author suggests training in the late Gothic Bolognese climate, where he acquired the most innovative and international techniques [1].

Fig. 1. Visible image of the altarpiece before the restoration.

The rough wooden board is composed of a single panel (92x72 cm and 2.5 cm thick) and has no crossbeams. On the verso it is possible to observe the presence of marks left by a planer and various imperfections of the board. This indicates the choice of a material that was perhaps reused, or whose preparation was not particularly accurate. Numerous woodworm galleries and flicker holes due to a xylophagous attack can be observed. Several cracks are also present, the most critical one being at a knot on the recto. By simply observing the work macroscopically, it is also possible to determine the presence of canvas between the wooden support and the preparation layer; this could in fact be canvas used in the past to create a cushioning layer between the wood and the plaster preparation. The preparation, therefore, is expected to be made of gypsum and animal glue, while the painting technique, was done in tempera or oil tempera. Finally, the work also has gilding, especially at the haloes and the crown.

In the field of diagnostics and conservation of cultural heritage, non-invasive techniques are increasingly being used to study and understand artwork in depth. It is only through these methods that the integrity of the work itself can be preserved [2,3].

With the present research, the aim is therefore to attempt to study the pictorial composition of the work in a completely non-invasive and non-destructive manner and to obtain useful information on the restoration methods that have been applied to the altarpiece over the years, and where possible, to observe some differences before and after the cleaning process.

Colourimetric analysis and multispectral imaging were used for the investigation.

The spectrophotometer, and thus the colourimeter was used to obtain reflectance spectra in the visible range and to calculate the colourimetric coordinates of the analysed points before and after restoration. Multispectral imaging techniques, on the other hand, were used to obtain useful, immediate, and non-invasive information on the surface composition of the board.

In the future, the application of portable XRF will also make it possible to obtain the recognition of the elements that make up the pigments used to paint and decorate the artwork.

II. EXPERIMENTAL

Visible reflectance analyses have been performed by means of a Konica Minolta CM 2300d portable spectrophotometer. The instrument was calibrated using its 100% reflective white reference and a 0% reflective calibration box. Visible reflectance spectra were recorded in the 400-700 nm wavelength range. The measurements refer to the CIE L*a*b* chromaticity diagram to the Normal recommendation 43/93 [4] where L* is luminosity or lightness, which varies from black (value = 0) to white (value = 100); a* ranges from +a* (red) to –a* (green), and b* varies from +b* (yellow) to –b* (blue). The measurement conditions were specular component included (SCI) and all the measurements were conducted straight on the altarpiece's surfaces.

Multispectral imaging technique was carried out using a multispectral camera with a 28 Mpixels APS-C BSI sensor 28mm 1:2.8 lens and a set of sources and high-pass or low-pass filters as follows: 365nm LED UV source for UV Fluorescence and UV Reflection; 440nm Blue LED source for Blue induced Fluorescence; Visible/IR source with Tungsten filament for IR Reflection 950 and 1070 nm; Red source for Visible Induced Luminescence; No UV no IR "hot mirror" filter for Visible and UV-induced Fluorescence; High-pass filter 950 nm for IR reflectography; High-pass filter 850 nm for Visible Induced Luminescence; Narrow Band IR filter 1060-1080 nm for IR reflectography; Yellow filter.

All available sources and filters were used to obtain the images, but in the results and discussion, we will mainly consider the UVL, IRR and IRRFC techniques, as they provided the most satisfactory and useful information for the purpose of this paper.

III. RESULTS AND DISCUSSION

Using the colourimeter, it was possible to carry out the analysis on 18 points both before and after the restoration to understand whether there were any colourimetric differences (Fig.2) [5].

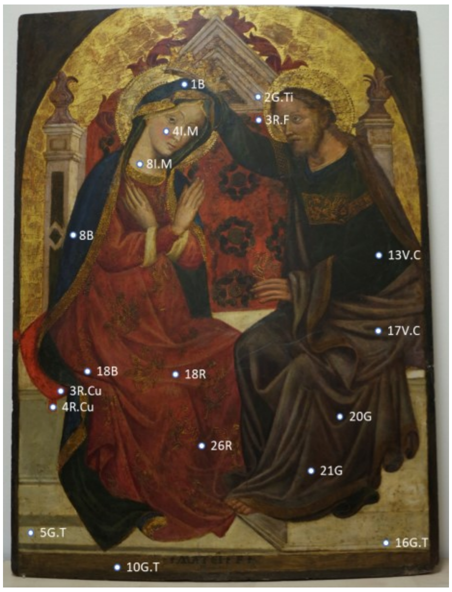

Fig. 2. Scheme of the 18 points analysed by colourimetry.

In particular, it is possible to observe three different red points 3R.F, 26R, 3R.Cu taken from the background behind the figures, the Virgin's robe and the pillow on which the Virgin sits respectively.

Observing Fig.3, it is indeed possible to understand how the analysed points were brighter after restoration. More specifically, points 3R.F and 26R, after cleaning, vary in their luminosity slightly, while maintaining the same hue. In particular, the L*(D65) coordinate (luminosity) of point 3R.F varies from 31.38 to 33.59 and that of point 26R varies from 29.21 to 30.35. The variation in the luminosity of point 3R.Cu is much more appreciable. In fact, the value of the L*(D65) coordinate varies from 33.30 to 39.42. Overall, the cleaning of the artwork has thus given it brightness and intensity.

For the sake of completeness, the colourimetric coordinates values (ΔL*, Δa* Δb, ΔE*) of the most representative points are reported in Table 1. In particular, in addition to the three red points described above, all the selected points were: 1B on the head of the Virgin, 8B on the shoulder of the Virgin, 18.B on the lower part of the Virgin's robe, 4I.M on the face of the Virgin, 8I.M on the neck of the Virgin, 18.R on the red robe of the Virgin, 13V.C and 17 V. C on the upper part of the Christ's robe, 20G, 21G on the lower part of the Christ's robe, 2G.Ti on the tympanum decoration on the upper background behind the figures, 16G.T and 5G.T respectively the points at the bottom right and left corners of the panel, 10G.T point to the left of the bottom signature, 4R.Cu on the pillow where the Virgin sits.

Table 1. Colorimetric coordinates (ΔL, Δa*, Δb*, ΔE*) calculated for the analysed areas before and after restoration.*

	ΔL*	Δa*	Δb*	ΔE*
8B	4,86	1,80	6,19	8,07
8I.M	3,61	1,39	2,24	4,47
3R.F	2,21	1,77	0,87	2,96
26R	1,14	3,01	2,12	3,85
13V.C	0,90	1,00	0,14	1,35
21G	0,41	1,09	1,53	1,92
10G.T	1,58	0,50	0,83	1,85
3R.Cu	6,12	10,62	6,31	13,79

The reflectance spectra in the visible spectrum also provide information about the pigment itself [6-8]. In fact, from these spectra (Fig.4a) the three points analysed show to be different and this difference is even more visible through the calculation of the first derivative [7,9,10] (Fig.4b). Looking at the peak of the derivative, in fact, it is possible to perceive how they diverge and thus differ. This is especially true for samples 3R.F and 26R, where with the derivative the difference is more appreciable.

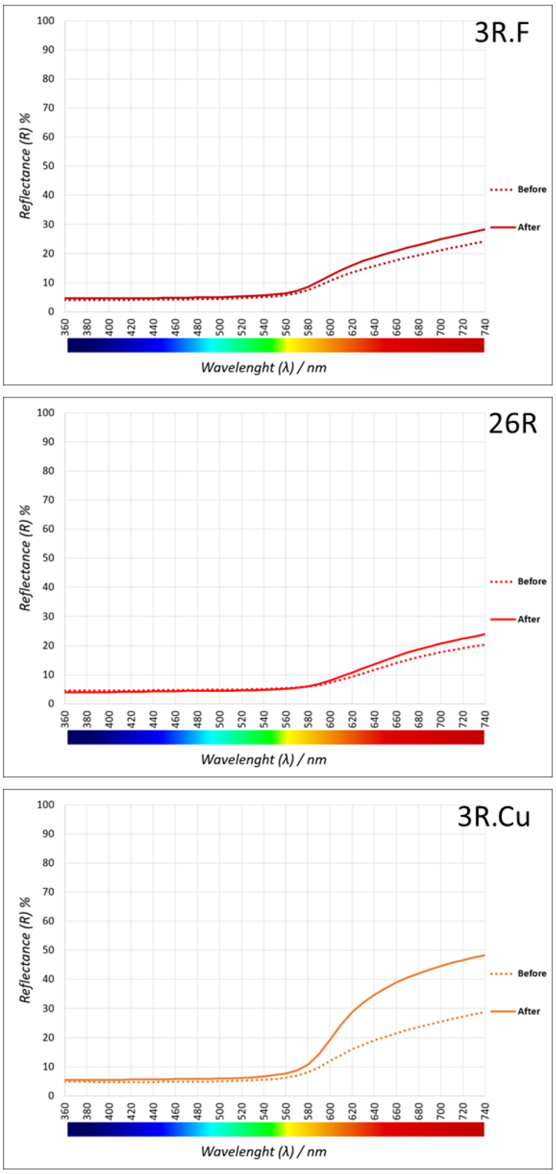

Fig. 3. Spectra in reflectance of selected red points before and after the restauration.

Multispectral imaging techniques, on the other hand, were useful to observe the entire surface of the panel. Obviously, the technique, as already mentioned, is particularly suitable for analysing this type of work as it is totally non-invasive and non-destructive [11,12].

In the ultraviolet-induced, visible luminescence (UVL) mode, the work revealed the presence of materials that react differently to the UV radiation used as a source to stimulate the artwork (365 nm) (Fig.5). The presence of a single, homogenous surface varnish is difficult to interpret, as no brush strokes can be recognised. It is probable that the inhomogeneous fluorescence is generated by the overlapping of several materials of different natures [13]; in fact, there are areas affected by blue/green fluorescence, sometimes associated with protein-based paints, and others more yellow associated with oil-resin materials [14]. What is easily detectable is the presence of numerous retouches and subsequent interventions, which appear darker, such as the lower band where the signature is present (gilding never fluoresces unless shellac varnishes are present). It is therefore possible that the artwork has been restored several times over the years and that this fluorescence is also the result of the layering of different materials.

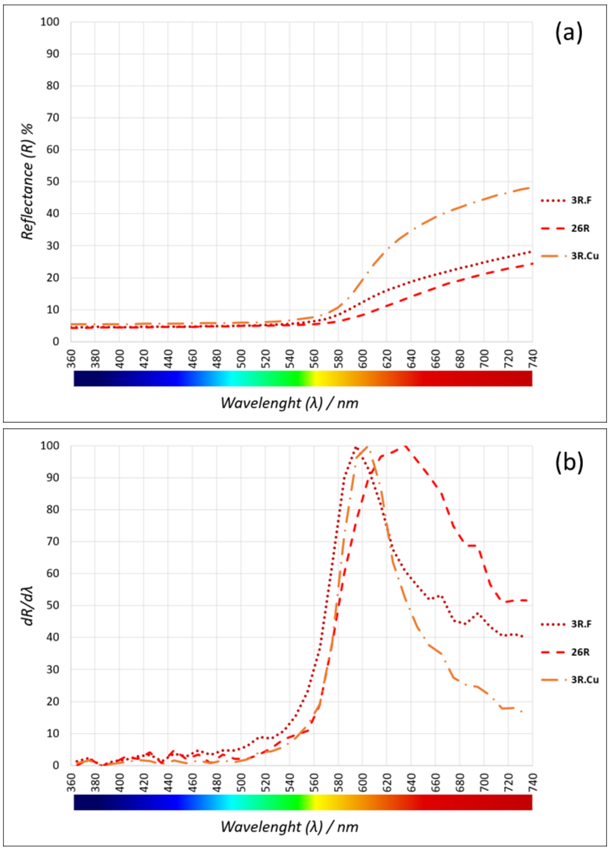

Fig. 4. Spectra in reflectance (a) and relative first derivatives (b) of selected red point after the restauration.

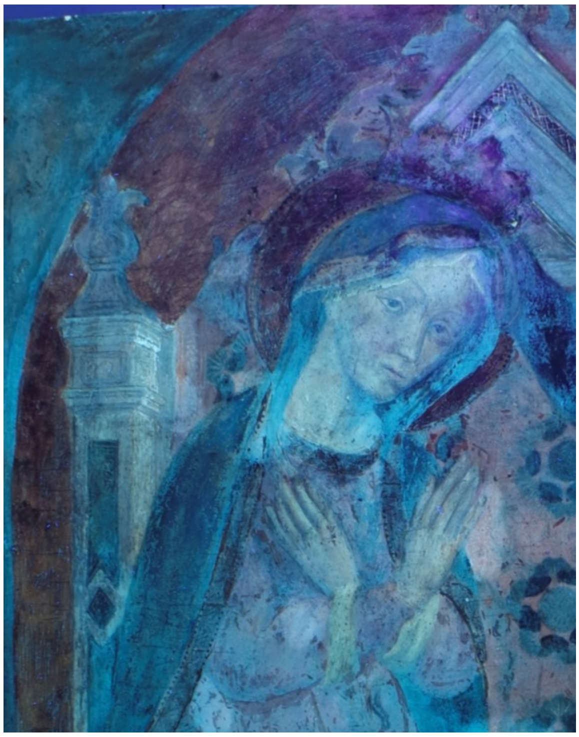

Fig. 5. UV-induced luminescence in the visible image of a detail of the altarpiece before restauration.

Furthermore, infrared reflectography (IRR) (950nm high-pass IR filter) (Fig.6) has revealed the presence of a light preparation on which the preparatory drawing was made, outlining the figures, and rendering their details in a particular way, as can be seen in the minuteness of the rendering of the faces and the folds of the Virgin's dress. This technique also made it possible to reveal the presence of a double signature at the bottom, below the one currently visible [12, 15]. This technique has made it possible to advance certain hypotheses on the use of certain pigments, such as azurite for the Virgin's mantle. In fact, this pigment absorbs infrared radiation and is opaque in reflectography [16]. It is also interesting to note that the mantle in the visible range appears homogenous but not in infrared reflectography; in fact, it is interrupted by some light areas, especially on the head, indicating the possible presence of another blue pigment. A second hypothesis is formulated on the Virgin's red dress, which appears transparent in IR. This behaviour is typically associated and compatible with the cinnabar pigment [12, 16].

Finally, by means of infrared-reflected false-colour (IRRFC), it was also possible to obtain interesting information on the pigments and repainting performed on the panel.

IRRFC are produced by splitting the visible image into its red, green and blue (RGB) components and shifting the red and green components into the green and blue channels respectively [11].

Looking at Figure 7, for example, on the head of the Virgin, the presence of repainting that appears dark red, probably belonging to an organic blue, is clearly visible. The robe and background, on the other hand, which appear red in the visible and transparent in the IRR, here appear orange/yellow: typical behaviour of cinnabar pigment [16].

Fig. 6. Infrared reflectography (950nm high-pass IR filter) of a detail of the altarpiece before restoration.

Fig. 7. Infrared-reflected false-colour image of a detail of the altarpiece before restoration.

IV. CONCLUSIONS

This study is a preliminary work, and it has to be implemented by other techniques, now in progress.

By means of the following research, it was possible to study, at least in a preliminary way, the surface of the panel and to partially understand its composition. Using totally non-invasive and non-destructive techniques, it was in fact possible to compare the colourimetric components before and after restoration, and thus to understand which points have a colourimetric variation that is visible even to the naked eye and which are not possible to perceive without a colorimetric analysis. The study of all analysed points is in progress and from the analysis of the red points selected for this work it is already possible to understand and confirm an appreciable variation in luminosity.

By means of multispectral imaging techniques, on the other hand, it was possible to observe the inhomogeneous surface composition of the panel and the position of previous retouches by means of UV luminescence, while in IR and IRFC reflectography it was possible to observe hidden areas that cannot be observed in the visible light, i.e. what lies beneath the pictorial film, such as the double signature at the bottom.

The preliminary analyses performed will require additional studies for a full understanding of the artwork.

In fact, further analyses using hyperspectral imaging techniques and portable XRF are in progress. This will provide the possibility of performing imaging techniques with spectra immediately connected to the pixels under consideration and performing elemental analyses with XRF, a particularly useful technique for obtaining immediate information on the elemental composition of the pigments.

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