

Multi-band infrared imaging for the characterization of underlying elements in the *Santa Maria in Cosmedin* altarpiece

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Abstract – This paper presents the integrated application of near and mid-infrared imaging techniques for the characterization of the wooden altarpiece preserved inside *Santa Maria in Cosmedin Basilica* (Rome, Italy). The visible part of this polychrome artefact is the result also of several changes applied during the centuries. The stratigraphic analysis of the artwork has been carried out by the use of pulsed thermography and reflectographic techniques in order to detect structural elements, such as defects on the support, and to disclose underlying graphical/pictorial features, such as underdrawings and *pentimenti*. The results allowed the description of the conservative state of the altarpiece and a better comprehension of its manufacturing process.

I. INTRODUCTION

The painted altarpiece preserved inside the *Santa Maria in Cosmedin Basilica* is an important holy artefact of the Greek orthodox community living in Rome [1]. The historic and artistic provenance of this precious artefact is not clear, but several retouching and restorations have been documented during the centuries performed for stylistic adjustments and conservative issues on the multi-layered pictorial structure. Therefore, an exact reconstruction of its artistic process is complicated as well as interesting and it has been the topic of several historiographic studies carried out in the last century, resulting in different hypothesis about dating and author.

On the occasion of a recent restoration, non-destructive stratigraphic investigations been performed on the altarpiece with the aim of better determining its historical and artistic framework.

For this kind of purpose, infrared (IR) imaging techniques are commonly employed in Cultural Heritage (CH)

examinations, exploiting the different optical behaviour of the infrared radiation through the pictorial layers for the detection of subsurface features, such as structural defects and underlying graphical/pictorial elements [2].

In this work, integrated reflectographic and thermographic measurements have been performed in the near and mid-infrared (MWIR) regions. In particular, near-infrared (NIR) reflectography (0.7–1.0 μm), pulsed thermography and MWIR reflectography, both operating 3–5 μm regions, were employed.

Specifically, near-infrared reflectography (NIRR) is the most commonly used technique for the identification of underlying features in painted artefacts, where a a CCD camera and a suitable illumination source, typically a halogen lamp [3] are employed.

In the last decades, pulsed thermography (PT) and mid-infrared reflectography (MIRR) have undergone a similar applicative growth, being successfully employed for the investigation on Cultural Heritage (CH), such as bronzes [4]–[6] and several type of painted artefacts, i.e. wooden and canvas paintings [7], frescoes [8] and illuminations on parchment/paper [9]–[11].

In particular, PT is employed for the detection of subsurface inhomogeneities, such as damage on the substrate and/or pictorial elements, by evaluating the temperature evolution recorded by a themocamera at the sample surface generated by an external pulsed stimulus[6].

The MIRR technique is similarly applied in multi-layered artefact investigations by recording by an infrared camera the reflected radiation in the MWIR region following the sample illumination with a halogen lamp[12], [13].

The different penetrative power in NIR and MWIR bands within the artefact allows the achievement of complementary results fundamental for establishing its

state of conservation and, at the same time, for visualizing graphical and pictorial elements located beneath the several overlapping layers, such as in the present case study.

II. THE COSMEDIN ALTARPIECE

The object studied in this work is an altarpiece representing the Virgin *Theotókos* of the *Hodigitria* typology preserved inside the Winter Choir of the *Santa Maria in Cosmedin Basilica*, the Greek Melkite Catholic Church located in Rome. The painting displays the Virgin Mary holding the Child in the typical Greek blessing pose, both wearing colourful garments, represented on a golden background decorated with a damask pattern made by punching (Fig.1). The altarpiece is also called *Madonna Theotókos* for the Greek inscription (ΘΕΟΤΟΚΩΙ ΑΕΙΠΑΡΘΕΝΩΙ) in the title block that means “Mother of God always Virgin”. The painting is an oil on wood plank composed of four vertically jointed panels and a thinner horizontal one in the upper side, probably added in modern age, for a total dimension of 168 cm×128 cm×5 cm.



Fig.1 - Photograph of the “*Madonna Theotókos*” altarpiece, *Santa Maria in Cosmedin Basilica*, Rome.

The artistic procedure and the history of this artefact are still under investigation, mainly because of the poor literary sources available, giving rise to a debate among art historians. Nevertheless, several hypothesis have been formulated during the last century concerning the altarpiece dating: the few literary sources propose an ancient provenance from the Greek tradition reaching Rome during the iconoclastic persecutions [14], while during the 1900s it was suggested that it could be a medieval icon completely covered by a Renaissance repainting [15]–[17]. Recent studies hypothesize a late 15th century dating in connection with the renewed devotional

and artistic interest for the medieval iconography typical of that period [18].

Despite the knowledge of the exact provenance of the altarpiece, repainting has been documented among the 1618 and the 1719, while two restoration works have been performed in 1934 and 1955, mainly for structural reinforcements and yellowed varnish removal. These actions have added further elements to the original appearance thus increasing the complexity of its structure. Moreover, the critic microclimatic conditions of the Chapel, where the altarpiece has been preserved for centuries, have led to the deterioration of the wooden support and, consequentially, also of the painted layers. This led to the necessity of conservative procedures carried out in autumn 2018.

During this last restoration, a new element has been revealed in the title block: the inscription “IO PIACERE”, probable signature of an Italian artist working in central Italy during the 15th century. This element supports the hypothesis of the latest studies, making plausible a chronological provenance of the *Cosmedin* altarpiece around the end of the 15th century.

III. INFRARED IMAGING TECHNIQUES

Since its introduction in CH conservation science, the NIRR technique has shown great potentialities for the non-destructive stratigraphic analyses for the visualization of subsurface graphical/pictorial features [3,13]. In fact, the NIRR technique exploits the lower degree of scattering capability by the paint because of the larger wavelength in the NIR with respect to the visible. Thanks to the consequent larger probed depth it is possible to detect features beneath the surface layer, such as underdrawings and *pentimenti*.

NIRR survey consists in illuminating the sample with a halogen lamp and recording the reflected radiation in the near IR spectral range by a CCD camera. For the present work, the CCD sensor (Kodak KAF8300) consisted of a matrix of 3348x2574 pixels of silicon, each pixel having an area of 5.4 μm^2 . The camera was equipped with a Leica lens and two bandpass filters (one at 900 nm and one at 1000 nm). The images have been processed using the “MaxImLE” acquisition software in order to subtract the CCD sensor dark noise and enhance any interesting details. Pulsed thermography has been applied to CH field more recently. It is one of the so called photothermal techniques widely applied to determine the thermal transport properties of materials [20], [21]. It has proved to be a useful method for the analysis of structural inhomogeneities and subsurface features in the investigated sample by the detection of the temperature evolution at the sample surface induced by a visible light induced thermal perturbation [9, 14-15]. To this aim, a MWIR infrared camera is used to provide maps of the locally emitted radiation (thermograms) which can reveal

the presence of subsurface inhomogeneities since they affect the local in depth heat propagation. This results in a non-uniform surface temperature distribution displayed by the thermograms. In this work, a short-time perturbation of 2ms has been induced on the altarpiece by means of two flash lamps positioned at a distance of 0.5 m and at 45° with respect to the artwork surface and then detecting the time evolution of the IR emission by a CEDIP Jade III MWIR camera, (320x240 pixel, InSb focal plane array, 30 μm pitch, 3.6-5.1 μm wavelength range). The thermographic images, the so called thermograms, are recorded in a depth-resolved sequences and processed by the Altair 5.50 software.

The same MWIR range is employed for the mid-infrared reflectography also capable of detecting sub-surface graphical features in multi-layers artworks, exploiting the lower scattering across the pictorial layers of middle-infrared wavelengths with respect to the NIR [6, 11]. In this approach, the sample has been illuminated by MWIR radiation keeping the illumination time at minimum to limit the heating of the artwork's surface. The signals have been recorded by the same IR camera and software used for PT.

IV. RESULTS AND DISCUSSION

In the following section, the results obtained by the three above mentioned techniques have been compared and discussed.

A. The Virgin Mary

In the analysis of Virgin's face (Fig.2a), the thermograms detect several defects on the wooden support, also observed in the NIR and MWIR reflectograms. In particular, as shown in Fig.2b, Fig.2c and Fig.2d, two defects vertically-extended are detected in correspondence of Virgin's eyes, probably caused by the panels joint and the consequent mechanical stress. Under the left eye, a small defect is revealed, not visible at the naked eye and probably related to a restored *lacuna*. Furthermore, an important cracking area in the right side of the face has been partially detected by PT and better appreciable through NIRR analysis, providing the damage mapping disclosed also at greater depth by the MWIR reflectogram (see rectangle in Fig.2b, Fig.2c and Fig.2d). In addition, MWIR reflectograms reveals underlying features in correspondence of the nose and the eyebrows, indicating a further pictorial layer under the visible one.

In Fig.3b, Fig.3c and Fig.3d three frames of the thermographic sequence are reported in order to identify and to depth-resolve the subsurface inhomogeneities. In the first thermogram collected just after the light perturbation (Fig. 3b), the damage of panels links is evident and a superficial different material is detected in correspondence of the *globus cruciger* held by the Child, probably related to the recent restoration. Similar element is revealed in both the two thermograms recorded at

increasing delays (Fig.3c-d), which describe the extension in depth of the defect: in this case, the detachment is revealed up to the end of the thermographic sequence indicating that the damage is more extended within the stratigraphic structure. On the contrary, the detachment shown just in Fig.3b is probably a more superficial damage. Furthermore, the thermogram at higher delay (Fig.3d) highlights sub-surface *craquelures*.

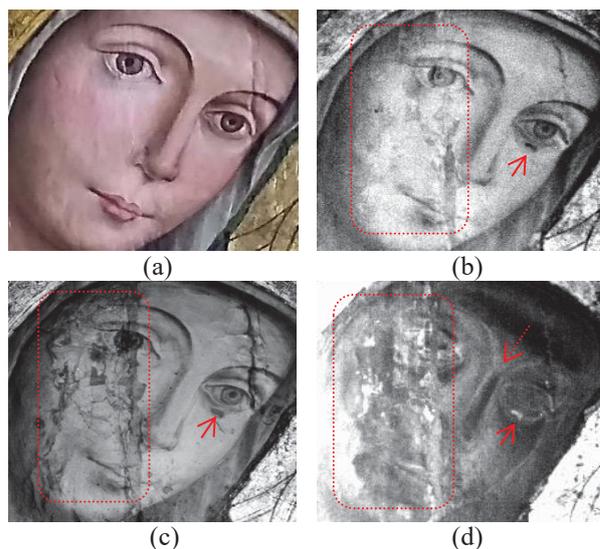


Fig.2 - "Madonna Theotokos" altarpiece, Santa Maria in Cosmedin Basilica, Rome: a) picture; the rectangles and the arrows indicate a structural damage and a restored lacuna in the thermogram (b), in NIR (c) and MWIR reflectograms (d). The dashed arrow in the MWIR reflectogram indicate underlying pictorial elements.

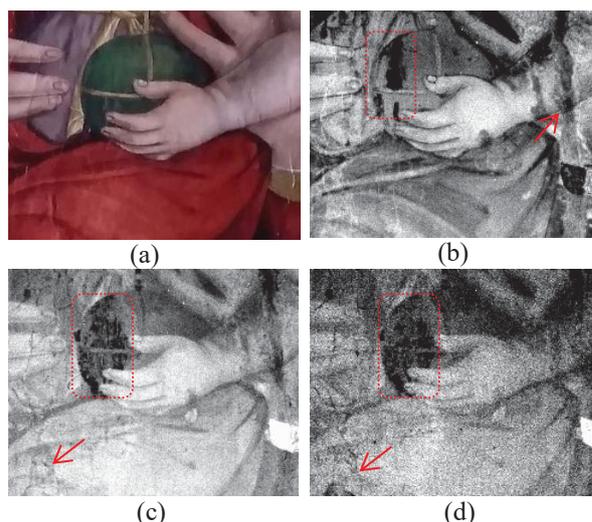


Fig. 3 - "Madonna Theotokos" altarpiece, Santa Maria in Cosmedin Basilica, Rome: a) picture; b) thermogram recorded just after the light perturbation where the arrow and the rectangle indicate structural defects and a restoration; c-d) thermograms recorded at increasing delay from the light perturbation where the rectangle

indicates a sub-superficial detachment while the arrows point out deeper craquelures.

B. The blessing Child

An important detachment has been detected in correspondence of the right thumb of the Child, revealed both in the thermogram (Fig.4b) and in the NIR and MWIR reflectograms (Fig.4c and Fig.4d, respectively). Here, the results show the absence of the thumb detected at different depths, indicating a detachment. Moreover, NIR and MWIR reflectograms disclose more clearly the underdrawings of some of the fingers.

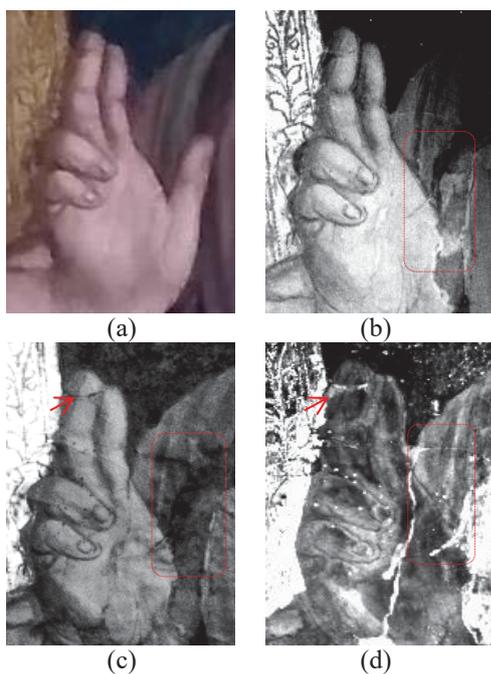


Fig.4 - “Madonna Theotókos” altarpiece, Santa Maria in Cosmedin Basilica, Rome: a)picture; b)thermogram, where the absence of the right thumb is revealed, also detected by NIR and MWIR reflectograms (c), (d) (rectangles). Here, the arrows indicate the underdrawings of some of the fingers.

In addition, damage in correspondence of the panels’ junctions have been revealed also in the Child’s feet area, as shown in the thermogram, and in the NIR and MWIR reflectograms (Fig.5b, Fig.5c and Fig.5d, respectively). Here, a further important feature has been disclosed, such as the *pentimento* on the left foot disposition, detected by the three techniques.

The latter information and the presence of underdrawings are fundamental aspects for the comprehension of the altarpiece realization process because, in general, they are characteristic of original artworks, while in copies and reproductions changes of mind would not be present.

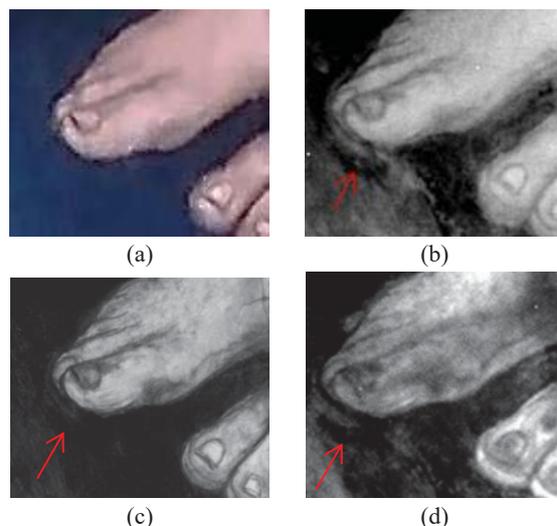


Fig.5 - “Madonna Theotókos” altarpiece, Santa Maria in Cosmedin Basilica, Rome: a)picture; a *pentimento* relative to the foot position and shape is revealed in the thermogram(b) and also in the NIR and MWIR reflectograms (c),(d).

V. CONCLUSIONS

In this paper, the integration of three infrared imaging techniques is presented for the stratigraphic characterization of the wooden altarpiece preserved inside Santa Maria in Cosmedin Basilica in Rome. In particular, near-infrared and mid-infrared spectral ranges have been investigated using pulsed thermographic and reflectographic techniques. The goal of this study was twofold: on the one hand, mapping the structural conservative status of the wooden support, and on the other hand recovering graphical and pictorial details beneath the surface useful for the reconstruction of the altarpiece realisation process.

The results have highlighted a complex stratigraphy regarding the iconographic apparatus and the damage to the support and to the pictorial layers. The wooden structure proved to be in good conservative conditions even though some critical areas have been detected in correspondence of the panels junctions. Retouched areas have also been detected. Several differences with respect to the visible layer have been revealed, especially in correspondence of the faces and hands of the two figures, confirming a complex layering. The investigations have highlighted some underdrawings and different *pentimenti*, distinctive elements of original artworks.

In conclusion, considering the overlapping of ancient and modern features in the revealed pictorial stratigraphy and the recent discover of the inscription “IO PIACERE”, the 15th century-dating and the attribution to the artist Giovanni Piacere suggested by the latest studies cannot be excluded.

ACKNOWLEDGMENTS

The authors are gratefully to Padre Chihade Abboud, Rector of the Church Santa Maria in Cosmedin, for providing the possibility to carry out the investigations on the altarpiece.

This work has been performed within the framework of the project ADAMO, part of the activities of the Centre of Excellence for the District of Technologies for Culture (DTC) of Lazio Region.

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