

In situ non-invasive analyses of the painting “Cristo in Trono” (Amalfi, SA, Italy)

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Abstract – In the field of cultural heritage, the use of non-invasive techniques is fundamental for assessing the state of conservation of works of art and identifying the correct strategies for their preservation.

The present study regards a preliminary investigation of the painting “Cristo in Trono” (Amalfi, SA, Italy). Non-invasive and portable analytical techniques, such as X-ray fluorescence spectroscopy (XRF), infrared reflectography (IR-R) and ultraviolet fluorescence (UVF) were used.

The XRF measurements revealed the use of some precious pigments such as *lapis lazuli* and *cinnabar*, whereas IR-R allows to evidence many restoration interventions confirming the possibility of strong degradation of the painting.

This multi-analytical approach provides a first screening of the state of conservation of the pictorial layer of this painting to suggest deeper diagnostic investigations, useful for future restorations.

I. INTRODUCTION

Air pollution is considered one of the key issues for the preservation of cultural heritage [1]; therefore, indoor air quality monitoring is very important for works of art located in cities, which are subject to high levels of anthropogenic pollution [2–9]. In fact, several air pollutants can cause damage to cultural heritage [10–17]. However, in some cases the effect of pollutants on cultural heritage may not be discernible to the naked eye, necessitating the use of diagnostic techniques to assess the state of degradation of the works of art themselves.

In this context, the use of non-invasive techniques is fundamental for assessing the state of conservation of works of art and identifying the correct strategies for their preservation, as well as restoration work [18–24].

In fact, the characterization of materials and techniques can contribute to defining the correct restoration applications and preventive conservation planning [25–27]. Moreover, in the field of cultural heritage, it is advisable to use non-destructive analytical techniques to avoid damaging works of art [28–30], especially for those that are already in a precarious state of conservation.

In recent years, precisely because of growing need for their use, scientific research has focused on the development of portable spectroscopic techniques, which allow analyses to be carried out in situ and in a non-invasive manner, without the need to undermine the works of art by taking portions of them, which would be necessary for laboratory analyses [31]. These analytical techniques are particularly useful in the investigation of cultural heritage to characterize raw material and degradation products or identify interesting areas for micro-fragments sampling for laboratory analyses [32].

This study aims to investigate the painting “Cristo in Trono” (Amalfi, Salerno, Italy), using non-invasive diagnostic techniques. The spectroscopic techniques include X-ray fluorescence spectroscopy (XRF), infrared reflectography (IR-R) and ultraviolet fluorescence (UVF). All the analytical techniques considered in this study are portable techniques that will allow analyses to be conducted at several points of the painting and in a short time, without causing any damage to it.

This multi-analytical approach provides a first screening of the state of conservation of the pictorial layer of “Cristo in Trono” painting [33], to suggest deeper diagnostic investigations [34,35], and to give preliminary information for future restorations.

A. Case study. The “Cristo in Trono” Painting

The “Cristo in Trono” painting (Fig.1) is located in Palazzo San Benedetto (Amalfi, Salerno, Italy). From a technical-artistic point of view, it is a tempera painting on canvas. It is dated back to 1885 and attributed to the artists Morelli Domenico and Vetri Paolo, two artists who worked

on the restoration of the Amalfi cathedral. The canvas is directly exposed to the microclimatic conditions of the room, as it is not protected by any covering. According to preliminary information, it underwent a restoration intervention about twenty years ago. Some breaks in correspondence of the base of the support are visible.



Fig. 1. "Cristo in Trono" painting.

II. MATERIALS AND METHODS

Infrared Reflectography (IR-R) analyses were conducted with an IRIS DIGITAL BASIC camera from Bresciani S.r.l., consisting of an objective with interchangeable pass-band filter lenses, capable of recording responses in the infrared spectral range, up to 1100 nm. The lenses are interchangeable and were used in sequence (715 nm; 850 nm; 1000 nm) to detect the presence of any retouches or pre-paintings carried out on the painting. Infrared-reflected images were acquired and elaborated with IC Capture 2.4 software, from the Imaging Source Europe GmbH (Bremen, Germany).

Ultraviolet Fluorescence (UVF) reflectography was performed to highlight the presence of varnishes and protective coatings, faded inscriptions, later retouchings, overpaintings, and to detect restoration interventions. The investigation was conducted by using a UV light (peak 365 nm) and images were acquired by using a Canon 760D reflex camera, equipped by an EFS 10-18 mm objective integrated with image stabilizer.

X-Ray Fluorescence Spectroscopy measurements for elemental pigment analysis on the painting were performed using a Hitachi X-MET 8000 Expert GEO handheld XRF spectrometer, equipped with a Rh anode X-ray tube. The acquisition parameters were set as:

- Light element detection: voltage of 8–15 kV, current of 100–150 μA ;
- Detection of heavy elements: voltage of 15–45 kV, current of 100–33 μA ;
- 30 s acquisition time;
- 3 mm spot size.

III. DISCUSSION

The multi-analytical approach used in this study, based on non-destructive techniques, provides important information on the nature of the pigments (fig. 2) and the state of preservation of the "Cristo in Trono" paintings and may allow conservators and restorers to better understand the characteristics of these works of art [36,37].



Fig. 2. Magnification of the portion of the painting depicting Christ: observe the colours of the robes. Red circles indicate the three measuring points of XRF analysis.

X-ray fluorescence spectroscopy made it possible to identify the nature and state of preservation of the pigments used by the artists to make comparisons with other paintings and/or contemporary artists.

XRF analyses on the three main pigments - blue, green and red (figure 2) - of the "Cristo in Trono" painting were performed with the aim of identifying their elemental composition and confirming their attribution to specific pictorial materials.

The absence of cobalt (Co), copper (Cu), and iron (Fe) in significant amounts, together with the presence of sulfur (S), silicon (Si), aluminum (Al), and calcium (Ca), with minor impurities of potassium (K) and iron (Fe), supports the attribution of the blue pigment to *lapis lazuli*. Sulfur (S) and calcium (Ca) could also indicate the contribution of the gypsum-based preparatory layer. Lead is present at a relevant concentration and may be related to the use of lead white (*biacca*), possibly applied in mixture with the pigment to adjust tonality and opacity, though a contribution from later retouching cannot be excluded. Chromium and antimony were also detected; these elements may indicate the presence of chrome yellow and Naples yellow, as used to modulate the tone, although their historical introduction suggests that they could be associated with subsequent restoration materials rather than the original palette.

The XRF measurement (fig. 3) performed on the green pigment of the tunic have detected sulfur (S) and calcium (Ca) as the main components of the preparatory layer, which was likely based on gypsum, although the presence of these elements could also be compatible with other calcium-containing substrates. Silicon (Si), aluminum (Al), potassium (K), and iron (Fe) are the primary constituents of the green pigment, consistent with *green earth*. Lead (Pb) is also present and may be related to the addition of *biacca* mixed with the pigment to adjust tonality or opacity, together with traces of chromium (Cr), suggesting the

addition of a small amount of a chromium-based pigment to enhance the chromatic effect.

Finally, the spectrum collected from the red sleeve displayed the typical mercury peaks, unequivocally confirming the use of *cinnabar* (HgS) as the main red pigment. Lead (Pb) is also present, as result from the use of *biacca*, mixed with the pigment to achieve a lighter tone. Silicon (Si), Potassium (K), and Iron (Fe) are typical elements of earth pigments and ochres, likely originating from the underlying red underlayer (red ochre) beneath the analyzed point. Calcium (Ca) could be associated with the preparatory layer, likely composed of lime and/or gypsum.

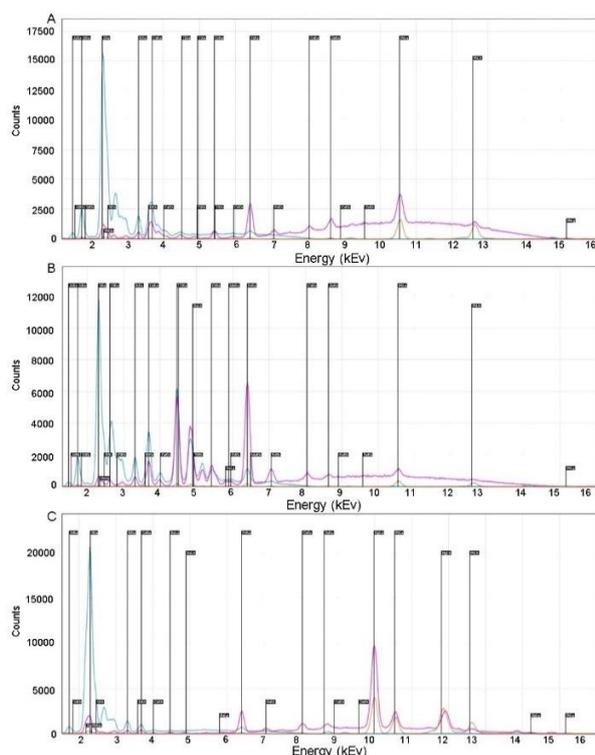


Fig. 3. XRF spectra collected on three areas of the “Cristo in Trono” painting: (a) blue mantle (*lapis lazuli*); (b) green tunic (*green earth*); (c) red sleeve (*cinnabar*).

XRF analyses also detected the presence of chlorine in certain areas, presumably related to past cleaning treatments by using chloride-based biocides, which may have played a role in the degradation of the lower part of the canvas, possibly due to contact with the floor and moisture absorption.

IR-R investigation was performed to detect the presence of any hidden details, such as retouches, underdrawings and pentimenti, beneath the surface of the “Cristo in Trono” painting. The images collected with different filters (Fig. 4) show the presence of many underdrawings, already visible with the 715 nm filter and still present at 1000 nm, in several areas of the painting. It is worth noting that IR-R also allows to evidence many restoration interventions, mainly located in the lower part of the painting, confirming the possibility of strong degradation of the painting, due to contact with the floor and moisture absorption.

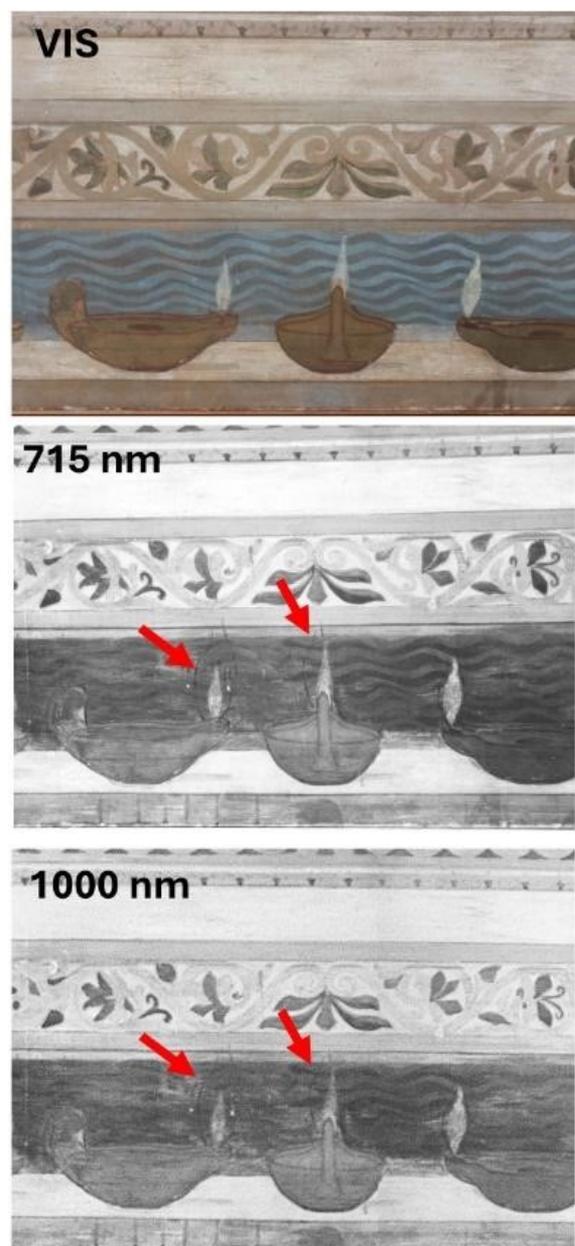


Fig. 4. Infrared reflectography of the “Cristo in Trono” painting. Visible light images (VIS) compared with IR-R images acquired at 715 nm and 1000 nm. Red arrows indicate underdrawings and pentimenti.

IV. CONCLUSIONS

In this study a preliminary spectroscopic investigation of the painting “Cristo in Trono” (Amalfi, SA, Italy) was presented using non-invasive and portable analytical techniques, such as XRF, IR-R and UVF.

XRF highlighted the use of precious pigments such as lapis lazuli and cinnabar, whereas IR-R showed some restoration interventions thus confirming the degradation of the painting layer.

This multi-analytical approach provided useful information on the nature and state of degradation of pictorial materials to plan the best conservation strategy and any targeted interventions.

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