

## IN SITU DIAGNOSTIC ANALYSIS OF THE SECOND HALF OF XVIII CENTURY “MORTE DI SANT’ORSOLA” PANEL PAINTING COMING FROM CHIESA DEI SANTI LEONARDO E ERASMO ROCCAGORGA (LT, ITALY)

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### Abstract

By means of combined use of non-destructive and non-invasive *in situ* analysis, diagnostic research has been carried out on pigments and underlayers used to fabricate an oil painting representing the “Morte di Santa Orsola”, corresponding to the second half of XVIII century, from the church of Saints Leonardo and Erasmo (Roccagorga - Latina, Italy). The aim of the work has been the evaluation of the materials employed and the state of conservation of the artwork. The structural and morphological properties of the painting were defined in detail using different and complementary analysis such as UV-Vis-P, IR-R, ED-XRF, Raman, DRS and FT-IR. The results showed that the palette was composed mainly of ochre and earth pigments except for the blue, red and white hatchings, constituted respectively as Prussian blue, cinnabar and white lead. At the time, the preparatory underlayer essentially had a gypsum, animal glue and white lead composition. Moreover, using infrared reflectography it was possible to discover a pentimento of the artist during the creative process. Such valuable information allowed the conservators to better understand the features of painting from a conservation point of view in order to define the best restoration strategy.

**Keywords:** *In situ* diagnostic analysis; Morte di Santa Orsola; Roccagorga, pigment identification; XRF; Raman; FTIR; DRS.

### Introduction

Diagnosis is the most important step in the process of conservation and protection of cultural heritage [1-3]. In the field of cultural heritage non-destructive and non-invasive *in situ* analyses are strongly recommended and sometimes even required [4-6]. In some cases, on the basis of the importance of artistic artefacts or archaeological finds it is impossible to take sample. Moreover, frequently such artworks cannot be moved from their collocation, due to their dimensions, fragility, or insurance problems.

The “Morte di Santa Orsola” panel is an oil painting on canvas (Fig. 1), about 300x180cm, made in the second half of XVIII century, located in the Saints Leonardo and

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Erasmus church, (Roccagorga - Latina, Italy). The painting does not bear the date nor the signature of the artist. The canvas depicts the legend of Saint Orsola transfixed by an arrow by the king of the Huns because she refused to marry him.



**Fig. 1.** Definition of the points analysed from the “Morte di Santa Orsola” panel by means XRF, Raman and/or Reflectance spectroscopy

The figure of Saint Orsola is placed at the centre of the canvas and is dying after being hit by an arrow. On her right, a handmaid is depicted wearing a green dress and to her left, there is an angel with an arm raised. On the top of the main scene two cherubs emerge holding some floral ornaments. A dead figure is located in the lower left edge. Unfortunately, the painting suffered extensive damage due to humidity.

The recent conservative intervention has been urgently put in action due to the perimeter collapse of the textile support from the frame leading to the definitive fall of the painting on the underlying altar. The traumatic event has produced the loss of conspicuous portions of the pictorial layers, as well as the fragmentation and the detachment in different parts. The presence of biodeteriogenic organisms, detected by an autoptic examination, both along the edge of the support and in correspondence of the wooden frame, caused the laceration of the fabric perimeter [7]. The painting already showed precarious conditions of preservation before the collapse, as it was possible to be observed by photographic documentation. In addition, the artwork was subject to previous conservation procedures. At the same time to an accumulation of substances, probably of organic nature, on the back and the development of microorganisms in the form of stains, there was a sheathing related to a previous intervention, as well as accentuated deformations and lacerations. The painted surface moreover showed widespread

deposits of undefined material that resembled "sketches", extended repainting and chromatically altered protective varnish.

The diagnostic campaign took place immediately after the first conservation work consisting only of a preliminary photography study related to the state of conservation.

The first approach was focused on the analysis using portable equipment, precisely infrared reflectography (IR-R) integrated with visible and ultraviolet photography (UV-P). These represent some of the most widespread and non-invasive methodologies employed to characterize a painting. This approach allows, thanks to the transparency of the painting layer into the near-IR wavelength, the definition of details on the inner layers such as preparatory drawing, pentimento, gap or a later retouch of the artist. This is because infrared radiation reflects on the preparatory drawing. The optic contrast lines remain unaltered in the infrared on the surface beyond the visible spectrum area. As regards pigments, the light absorption value is based on wavelength [8-10].

The second step was aimed to determine the pigments typologies and materials of the painting. For this purpose, we used combined different portable non-destructive techniques. X-ray fluorescence (XRF), Raman spectroscopy and infrared spectroscopy (FTIR) has been selected [1, 2, 5, 6, 8-11].

## Materials and Methods

Visible (VIS), ultraviolet (UV) and infrared (IR) photography was carried out by means of Madatec multispectral system equipped with a Samsung NX500 28.2 MP BSI CMOS camera and different Madatec spotlights respectively at wavelength of 365nm (UV), 440nm (blue) and 532nm (green). The induced fluorescence was obtained by means of the following filters: HOYA UV-IR filter cut 52 and Yellow 495 52mm F-PRO MRC 022.

Three different visible blocking filters were used for IR reflectography 760, 850 and 950nm.

The images were taken after the camera calibration with a gypsum white standard reference to obtain a correct chromatic image.

XRF measurements were performed using a portable ED-XRF (Energy Dispersive X-Ray Fluorescence), characterized by a x-ray tube excitation source with tungsten (W) anode which operated at 38kV and 350 $\mu$ A and a cooled silicon drift Peltier detector with its booster-power supply and multichannel (Amptek MCA 8000 A). The detector resolution is from 140eV to 5.9KeV (Mn K $\alpha$ ); the instrument permits to detect respectively the K and L lines of the elements with  $12 < Z < 52$  and  $Z > 35$ . Calibration was acquired using alloy certified reference materials. For all the investigated samples, the lines detected at 8.4, 9.8, 10.2, 11.5 KeV are attributed to the L $\alpha$  and L $\beta$  transitions of tungsten anode. XRF spectra were manipulated with PyMca software and then pigments were associated to data obtained consulting Colour Lex [10] website and scientific bibliography.

Raman measurements were performed using a portable Oceanhood Raman Spectrometer RK785-I. Measurements were performed using an excitation wavelength of 785nm, 0-150mW laser power, coupled to a digital portable optical microscope Dino-lite for the analysis of the point of incidence of the beam (spot 500 $\mu$ m) and a charge-coupled device (CCD) detector (thermoelectric cooled, TE). For all measurements, maximum power employed was 50mW. Spectra have been registered in the 60–3150 $\text{cm}^{-1}$  wavenumber range, by using an acquisition time of 3 s. The resolution of the spectrometer is about 4  $\text{cm}^{-1}$ . Spectra were interpreted through online database such as ruff [13] and scientific literature.

Diffused reflectance spectroscopy was performed using QualitySpec® Trekspectrometer (Malvern Instruments), with a tungsten halogen lamp with quartz glass and certified spectralon calibration standard. The resolution of the instrument is about 3nm till 700nm, 9.8nm from 700

to 1400nm and 8.1nm between 1400 and 2500. The spectra collected were interpreted through USGS database (United States Geological Survey) [14] and literature.

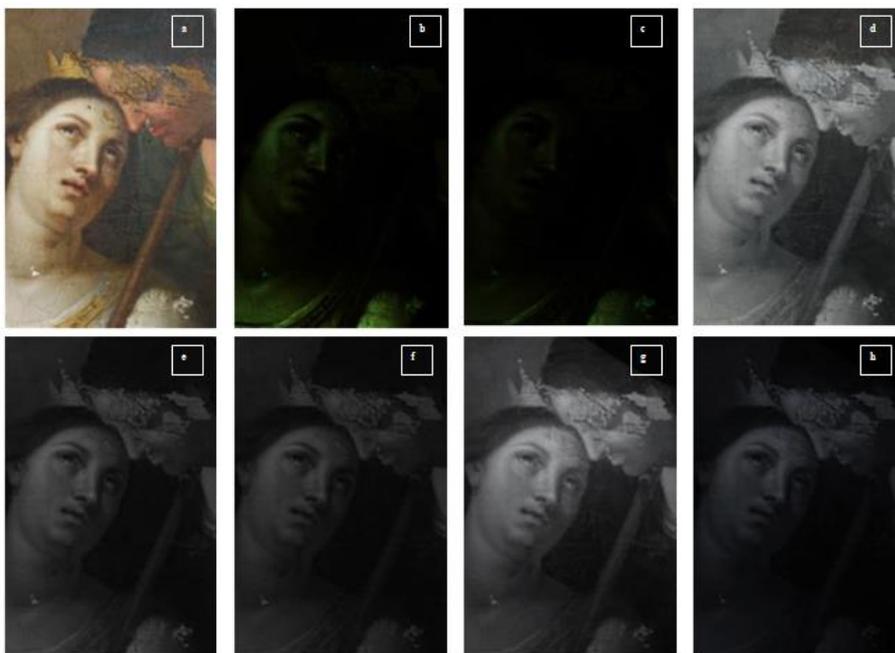
Fourier-transform IR spectroscopy (FTIR) was performed using a Perkin Elmer Spotlight Spectrum 400 FTIR spectrometer in attenuated total reflectance. Spectra were analysed using [15, 16] and through the instrument library.

## Results and Discussions

### *Multispectral analysis*

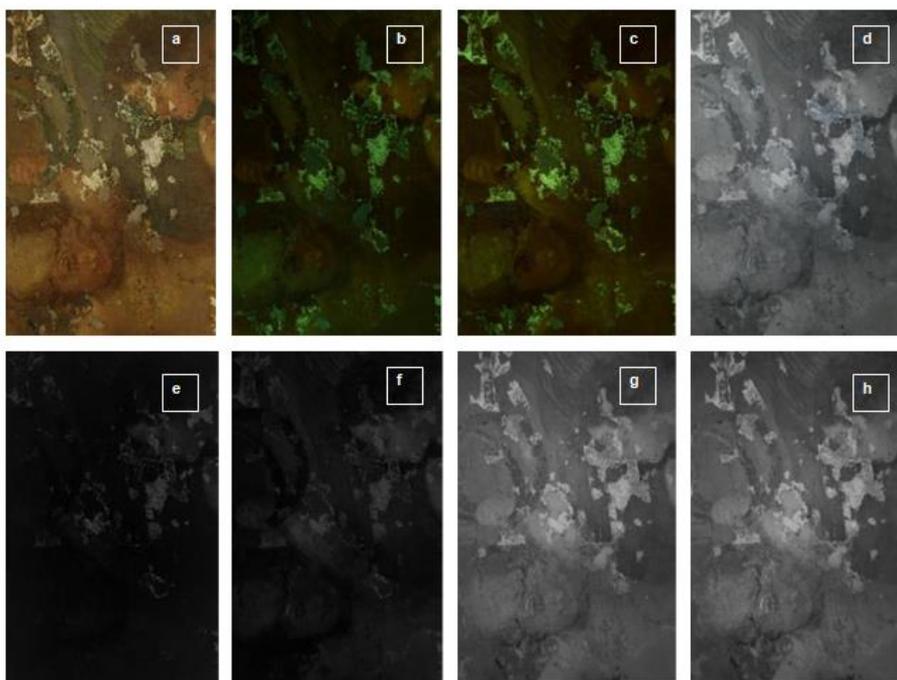
From the macroscopic evaluation it was possible to determine the high level of degradation of the iconographic fabric characterized by cracking's and gaps. In such degradation, it was possible to distinguish the white preparatory layer and the support underneath, a dark brown canvas. Some areas of the painting were brighter due to the presence of the final varnish, employed as a protective layer or for reviving the pictorial surface [26]. In figure 2a, for instance, it is possible to discriminate a brighter rectangular area around the face of Saint Orsola where the varnish was not completely removed.

The multispectral analysis was carried out on four areas of the artwork. For each parts 8 shoot were taken with different filters and lights: visible, ultraviolet (UV), VIVL (blue), IR (760nm), VIL (green), VIL (blue), IR (850nm), IR (950nm) photos (Figs. 2, 3, 4 and 5).

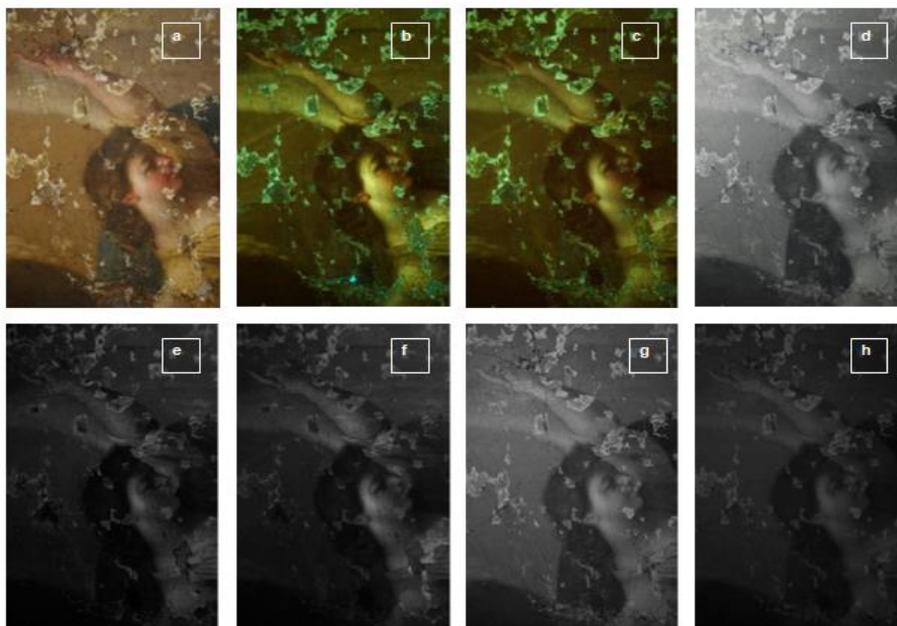


**Fig. 2.** The Saint Orsola's face: (a), (b), (c), (d), (e), (f), (g) and (h) photographs are respectively taken in Visible, UV, VIVL (blue), IR (760nm), VIL (green), VIL (blue), IR (850 nm), IR (950nm).

Through fluorescence contrast between the preparation layer, the pictorial drafting and the colours used as chromatic compensation, it was possible to distinguish gaps of the iconographic fabric under UV lights. A greenish fluorescence, typical of preparation layer characterized by gypsum and glue, was observed on those gaps (Fig. 4b). Whereas a darker green fluorescence was observed in the brighter areas where the varnish was still present (Fig. 3b), in contrast with a particular remarkable bluish fluorescence in the parts without varnish (Fig. 2b) [27, 29, 32, 35].



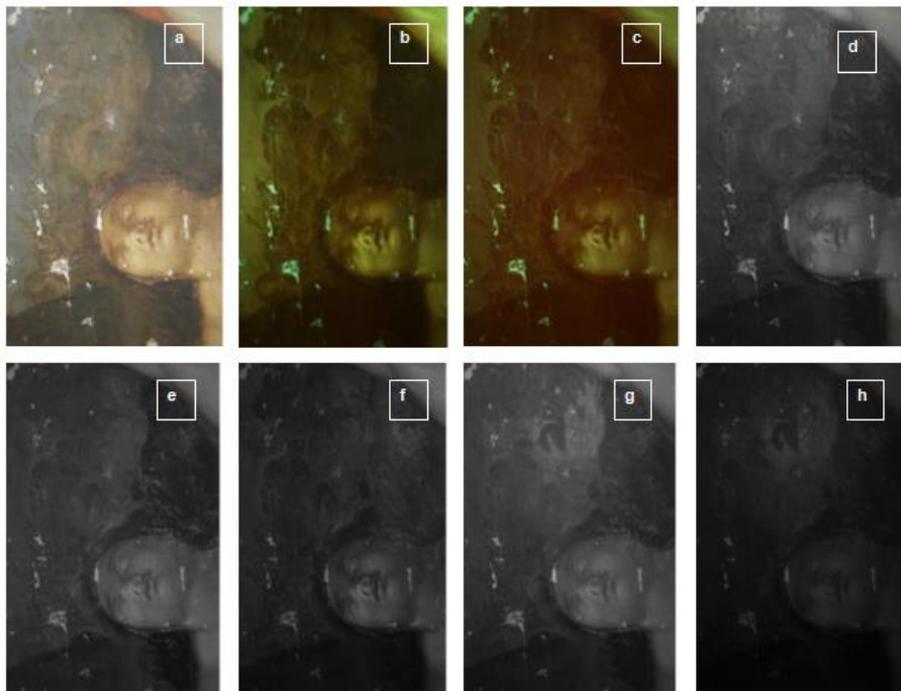
**Fig. 3.** The two cherubs face: (a), (b), (c), (d), (e), (f), (g) and (h) photographs are taken respectively in Visible, UV, VIVL (blue), IR (760nm), VIL (green), VIL (blue), IR (850 nm), IR (950nm).



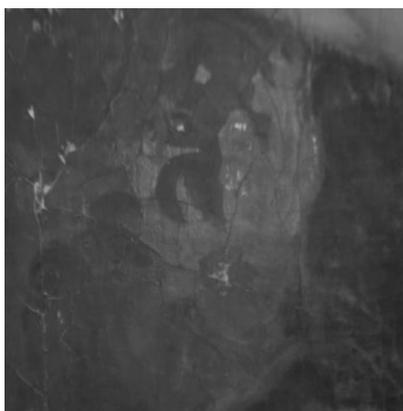
**Fig. 4.** The face of an angel: (a), (b),(c), (d), (e), (f), (g) and (h) photographs are taken respectively in Visible, UV, VIVL (blue), IR (760nm), VIL (green), VIL (blue), IR (850nm), IR (950nm).

IR reflectography allowed to better distinguish the edges of the iconographic images, to highlight the retouched or integrated areas, which appeared darker and in relief (Fig. 2g). This was confirmed by the absence of fluorescence in UV photography. In IR it was also possible to

discover, of particular interest, a pentimento of the artist during the drafting process of the painting in the area representing the dead figure (Fig. 5g and h). Using the VIL technique, with a blue light source, it was possible to detect a clear luminescence, on the angel's robe, corresponding to some white hatchings apparently retouched, probably caused by the application of a modern pigment (Fig. 4f) [28].



**Fig. 5.** The face of a dead figure: (a), (b), (c), (d), (e), (f), (g) and (h) photographs are respectively taken in Visible, UV, VIVL (blue), IR (760nm), VIL (green), VIL (blue), IR (850nm), IR (950nm).



**Fig. 6.** The face of a dead figure: Detail of fig.5g in IR (850nm) showing a pentimento of the artist.

#### ***ED-XRF, Raman, Reflectance and FTIR spectroscopy***

On the base of restorer's suggestions, eighteen spots (Fig. 1) were selected and analysed by means of XRF spectroscopy, to collect all the different chromatic hatchings (blue, red, pink, green, brown, yellow and white). Elements such as sulphur (S), iron (Fe), lead (Pb) and calcium (Ca), were detected in every spectrum (Table 2), all attributable to the preparation layer of the

painting made of gypsum ( $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ), white lead and glue. The presence of copper (Cu) and argon (Ar) are related to the instrument modalities to collect spectra [31]. The palette used by the artist, from spectra interpretation, was mainly composed by earth pigments such as red and yellow ochre, associated to a high iron content. Blue areas were characterized by a Fe-based blue, probably mixed with a white Pb-based pigment to obtain different shades. This hypothesis is supported by the high intensity exhibited by the signals associated to lead  $L\alpha$  and  $L\beta$  (10.50 and 12.62keV) and iron  $K\alpha$  and  $K\beta$  (6.40 and 7.06keV) transitions. Lead is the major chromophore responsible for the white pigment, such as white lead ( $2\text{PbCO}_3 \cdot \text{Pb}(\text{OH})_2$ ). It is also used combined with other pigments to lighten some parts. High energy of signals at 9.95 and 11.87keV indicated the presence of mercury in the red points examined, leading to the hypothesis that the artist used cinnabar ( $\text{HgS}$ ), as main component mixed, from the observation of iron signals, with a red ochre, Fe-based pigment [4]. The pink area of the angel's cheek was obtained by mixing cinnabar in a different ratio with white lead [31]. As shown in figure 7, yellow parts presented intense signals of lead (Pb) and iron (Fe) followed by antimony (Sb) at around 3.60 and 3.97keV and zinc (Zn) at 8.63 and 9.61keV, suggesting the application of a yellow ochre as major pigment mixed with Naples yellow, a lead antimonate  $\text{Pb}_3(\text{SbO}_4)_2$ , known since antiquity but in use since the second half of the 18<sup>th</sup> century [17]). The small signal at 4.50 KeV could be associated to the presence in trace of barium (Ba) or titanium (Ti), as the Ba L-lines and the Ti K-lines overlap. The first one might be related to an impurity, an additive charge or to lithopone, while more likely the second one is connected to a more modern white pigment mixed together with zinc (titanium oxide,  $\text{TiO}_2$  and zinc oxide,  $\text{ZnO}$ ) [18]. The chromophore responsible for the green areas is mainly iron, as green earth (aluminosilicate of magnesium, iron and potassium) mixed with Naples yellow to obtain different shades. As for brown colour the artist used a Fe-base pigment, probably Siena earth or burnt umber.

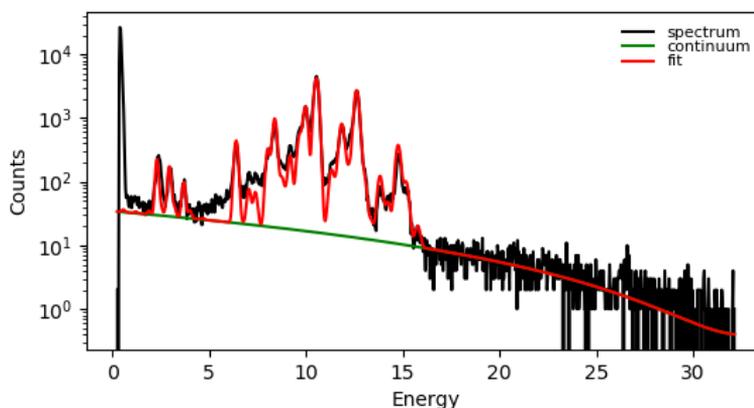


Fig. 7. XRF spectrum of a yellow area recorded on a detail of the angel's mantle (point of analysis mis. 14 reported in table 2).

Raman spectroscopy was carried out on 12 chromatic backgrounds, as reported in table 2. Raman spectra confirmed the results obtained by XRF analysis. The main composition of the artist *palette* was composed by ochre. The use of cinnabar as red colour is validated by the presence, in the spectrum recorded, of bands at 253, 282 and 343  $\text{cm}^{-1}$  mixed with red ochre, showing bands at 224 and 404  $\text{cm}^{-1}$  (Fig. 8). Spectra collected in the yellow backgrounds showed bands at 217, 402 and 560  $\text{cm}^{-1}$  typical of yellow ochre. Raman spectrum of the brown area revealed the application of Sienna earth and burnt umber, identified by peaks at around 399 and 644  $\text{cm}^{-1}$  [13, 19]. Green earth was detected by the presence of celadonite (285 and 351  $\text{cm}^{-1}$ ) and glauconite peaks (705  $\text{cm}^{-1}$ ) [20]. Different Raman spectra (1, 6\_1, 8, 9 and 10) showed a strong fluorescence background, due to scattering phenomena and the presence of

residual varnish, making impossible the interpretation and the identification of white and blue pigments.

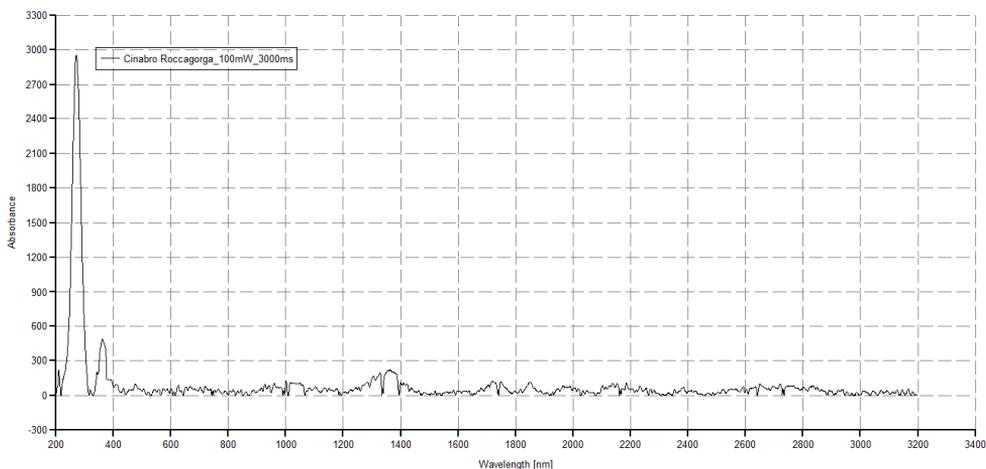


Fig. 8. Raman spectrum acquired on a red area of the angel’s cheek ( point of analysis mis. 5 reported in table 2).

Reflectance spectroscopy was carried out on 11 areas as reported in Table 1. The results obtained confirmed the identification of the pigments previously done through the other techniques [36, 37].

Table 1. Summary of the absorption bands and the characteristic peaks collected using Reflectance spectroscopy, on the different backgrounds, the identified colours and the reference peaks

Hatching	Absorption bands (nm)	Reflectance peaks (nm)	Pigment	Reference	Absorption bands rif.(nm)	Reflectance peaks rif. (nm)
1	650-850, 1448, 1725, 1760, 1945, 2307, 2300-2500	605	-	-	-	-
2	370-570, 1211, 1445, 1729, 1758, 1945, 2302-2500	-	Cinnabar and white lead	HS133.3B; GDS796 (USGS)	350-576, 840, 865, 886, 915, 1413, 1932, 2227, 2309, 2353, 2459 (cinnabar); 985, 1443, 1677, 1730, 1765, 1947, 2005, 2149, 2268, 2322, 2454 (white lead)	-
3	373-903, 1209, 1452, 1729, 1758, 1947, 2309, 2352-2470	-	Cinnabar and white lead	HS133.3B; GDS796 (USGS)	350-576, 840, 865, 886, 915, 1413, 1932, 2227, 2309, 2353, 2459 (cinnabar); 985, 1443, 1677, 1730, 1765, 1947, 2005, 2149, 2268, 2322, 2454 (white lead)	-
4	350-539, 1443, 1729, 1751, 1945, 2205, 2300, 2345-2484	598	White lead and green earth or malachite	11000 (CHSOS) GDS796, HS254.2B (USGS)	600-800, 900, 950 (green earth); 600-900, 1205, 1849, 1927, 2029, 2219, 2270, 2357, 2407 (malachite); 985, 1443, 1677, 1730,	560, 810 (green earth); 550 (malachite)

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					1765, 1947, 2005, 2149, 2268, 2322, 2454 (white lead)	
5	378-566, 1211, 1448, 1727, 1760, 1819, 1945, 2307, 2352-, 2480	-	Cinnabar and white lead	HS133.3B; GDSS796 (USGS)	350-576, 840, 865, 886, 915, 1413, 1932, 2227, 2309, 2353, 2459 (cinnabar); 985, 1443, 1677, 1730, 1765, 1947, 2005, 2149, 2268, 2322, 2454 (white lead)	-
6_1	1211, 1448, 1729, 1760, 1952, 1997, 2305, 2352- 2475	-	white lead	GDS796 (USGS)	985, 1443, 1677, 1730, 1765, 1947, 2005, 2149, 2268, 2322, 2454	-
7	680-970, 1441, 1730, 1753, 1942, 2200, 2305, 2349, 2385-2485	607	Yellow ochre, Naples yellow and white lead	GDS794. GDS787 GDS796 (USGS)	690-847, 1155-1395 (Naples yellow); 371, 650-1030, 920, 1415, 1912, 2208, 2330- 2500 (yellow ochre); 985, 1443, 1677, 1730, 1765, 1947, 2005, 2149, 2268, 2322, 2454 (white lead)	597, 773 (yellow ochre); 597, 968 (Naples yellow)
8	643-896, 1424, 1728, 1755, 1942, 2215, 2305, 2350-2485	570	White lead, green earth or malachite	11000 (CHSOS) GDS796 (USGS)	600-800, 900, 950 (green earth); 600- 900, 1205, 1849, 1927, 2029, 2219, 2270, 2357, 2407 (malachite); 985, 1443, 1677, 1730, 1765, 1947, 2005, 2149, 2268, 2322, 2454 (white lead)	560, 810 (green earth); 550 (malachite)
9	368, 418, 1441, 1727, 1763, 1942, 2307, 2347, 2387-2487	622	-	-	-	-
10	622-811, 1448, 1729, 1760, 1945, 2305, 2352-2480	515	-	-	-	-
11	350-685, 418, 1448, 1722, 1755, 1945, 2305, 2349-2482	-	Burnt umber and white lead	GDS796 (USGS)	1932 (burnt umber) 985, 1443, 1677, 1730, 1765, 1947, 2005, 2149, 2268, 2322, 2454 (white lead)	-

FTIR spectroscopy allowed to characterize the green and blue areas. The spectrum collected in the green background confirmed the use of green earth. Indeed, bands correspondents to the silicates (glauconite and celadonite), constituting such pigment, have been detected [33]. Blue colour was obtained by applying a Fe-based pigment, most likely Prussian blue (ferric ferrocyanide). The pigment was, as a matter of fact, synthesized for the first time in 1704 and in use since the half of the 18<sup>th</sup> century.

**Table 2.** Summary of the elemental and molecular identification obtained respectively by XRF, Raman and Reflectance spectroscopy. The relative quantity of the elements present in each XRF spectrum is represented by the symbol + (= small amount, ++ = medium amount, +++ = large amount)

Colour	Points of analysis	Elemental composition by XRF	Molecular identification by Raman spectroscopy	Identification by Reflectance spectroscopy
Blue, sky	Mis. 1	Pb (+++), W (++) , Fe (++) , Cu (+), S, Ca, Ar	Fluorescence	-
Red, mantle of Saint Orsola	Mis. 2	Pb (+++), Hg (+++), W (++) , Fe (+), Cu (+), Ar, S, Ca/ Sb	Cinnabar and red earth	Cinnabar and white lead
Pink, cheek of the cherub	Mis. 3	-	cinnabar	Cinnabar and white lead
Green, palm leaf	Mis. 4	Pb (+++), Fe (++) , W (+), Cu, Sb, S, Ar, Ba/Ti	Green earth	White lead, green earth or malachite
Pink, cheek of the angel	Mis. 5	Pb (+++), Hg (++) , W (++) , Fe(+), Cu (+), S, Ca, Ar	cinnabar	Cinnabar and white lead
White, mantle of Saint Orsola	Mis. 6_1	Pb (+++), W (++) , Cu (+), Fe (+), S (+), Ca, Ar	fluorescence	White lead
White, mantle retouch of Saint Orsola	Mis. 6_2	Pb (+++), W (++) , Cu (+), S (+), Ar, Ca, Fe	-	-
Yellow, mantle detail	Mis. 7	Pb (+++), Fe (++) , W (++) , Zn (+), Sb (+), Cu (+), Ba/Ti, S, Ar	Yellow ochre	White lead, yellow ochre or Naples yellow
Green, mantle of handmaid	Mis. 8	Pb (+++), Fe (+++), W (++) , Cu, Sb, Ar, S, Ba/Ti	fluorescence	White lead, green earth or malachite
Blue, handmaid's ribbon	Mis. 9	Pb (+++), Fe (++) , W (++) , Cu (+), Ca (+), S, Ar	fluorescence	-
Blue, mantle of angel	Mis. 10_1	Pb (+++), Fe (++) , W (++) , Cu (+), Ca (+), Ar, S	fluorescence	-
Light blue, mantle of angel	Mis. 10_2	Pb (+++), Fe (++) , W (++) , Cu (+), Ca (+), Ar, S	-	-
Light blue, mantle of angel	Mis. 10_3	Pb (+++), Fe (++) , W (++) , Cu, Ca, S, Ar	-	-
Dark blue, mantle retouch of angel	Mis. 10_4	Pb (+++), Fe (++) , W (++) , Cu, Ca, S, Ar	-	-
Brown, rod	Mis. 11	Pb (+++), Fe (++) , W (++) , Cu (+), Ca (+), S, Ar	Sienna earth and burnt umber	White lead, burnt umber
Pink, incarnate of Saint Orsola	Mis. 12	Pb (+++), W (++) , Cu (+), S (+), Hg, Ar, Ca, Fe	-	-
Pink, cherubim's cheek	Mis. 13	Pb (+++), Hg (+++), Fe (++) , Cu (+), Sb/Ca (+), S, Ar	-	-
Yellow, mantle detail of angel	Mis. 14	Pb (+++), W (++) , Fe (++) , Cu (+), Sb (+), Zn (+), S, Ar, Ba/Ti	-	-
Yellow, crown of Saint Orsola	Mis. 15	Pb (+++), Fe (+++), W (++) , Sb (+), Cu (+), Ba/Ti, Ar, S	Yellow ochre	-

Typical bands at  $2157$  and  $680\text{cm}^{-1}$  were observed, related to respectively by  $\text{C}\equiv\text{N}$  bond of the cyanide ion to  $\text{Fe}^{2+}\text{-CN-Fe}^{3+}$  bond [21]. The other bands detected were generated by the binder used, linseed oil. In particular, characteristic bands due to the  $\text{CH}_2$  vibration bonds ( $2917$  and  $2848\text{cm}^{-1}$ ), to the  $\text{C}=\text{O}$  double bond ( $1720\text{cm}^{-1}$ ) and to the aromatic content ( $707\text{cm}^{-1}$ ) [22, 23] were observed. Such results are in agreement with the spectra present in [25].

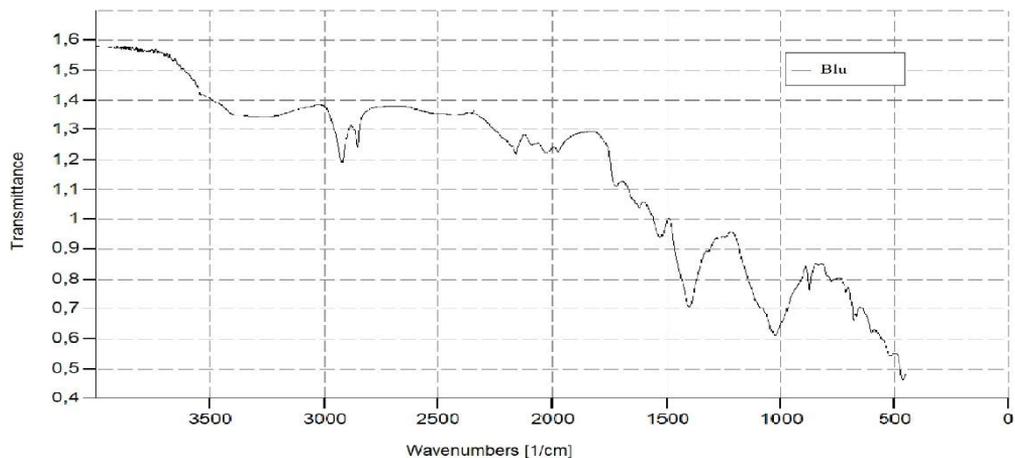


Fig. 9. FTIR spectrum collected in a blue background of the panel.

By using this technique, it was also possible to recognize the nature of the varnish and of the “sketches”. The sketches were characterized by bands connected to the  $\text{C}=\text{O}$ ,  $\text{CN}$  and  $\text{NH}$  ( $1623$  and  $1524\text{cm}^{-1}$ ) vibrational bonds,  $\text{CH}_2$  and  $\text{CH}_3$  ( $1399$  and  $1016\text{cm}^{-1}$ ) and methylene group ( $2910$  and  $2844\text{cm}^{-1}$ ) typical of an animal glue, [24, 25, 30].

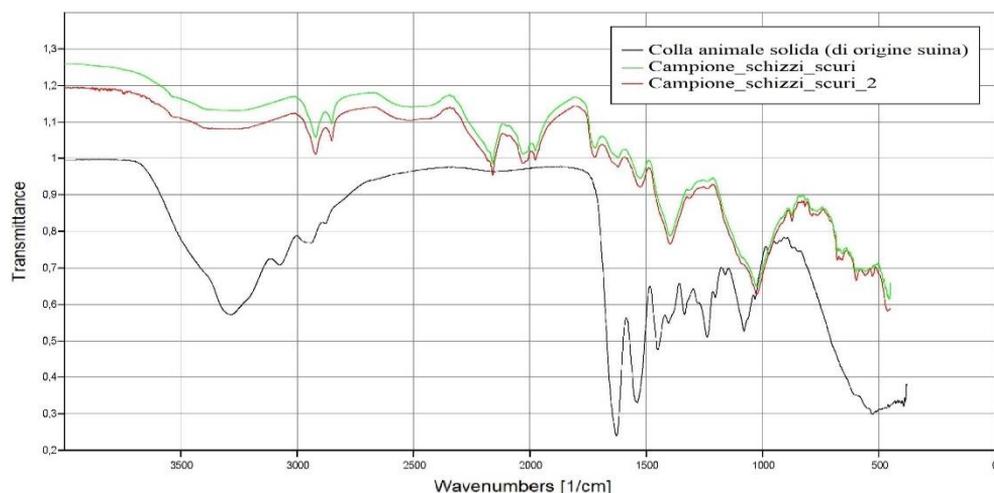


Fig. 10. FTIR spectra collected on two dark spots of the painting respectively in green and red. In black the animal glue spectrum of the instrument database.

A spectrum of the varnish was collected to help the cleaning process, identifying bands representative of a natural varnish, composed of terpene resins. The bands detected were generated by the vibrations of the terpene's bonds such as  $\text{O-H}$  ( $3460$  and  $3230\text{cm}^{-1}$ ),  $\text{CH}_3$  ( $2921$ ,  $1398$  and  $1381\text{cm}^{-1}$ ),  $\text{CH}_2$  ( $2858$  and  $1450\text{cm}^{-1}$ ),  $\text{C}=\text{C}$  ( $1608\text{cm}^{-1}$ ), aromatic ring ( $1495\text{cm}^{-1}$ ),  $\text{C-H}$  and  $\text{C-O}$  ( $1052\text{cm}^{-1}$ ) bonds [23, 34].

## Conclusions

The combined use of UV-Vis-P, IR-R, ED-XRF, Raman, DRS and FT-IR diagnostic techniques has provided deep insight of the panel representing the “Morte di Sant’Orsola”, approximately dated around the second half of the 18<sup>th</sup> century, coming from Church of Saints Leonardo and Erasmo (Roccaporga - Latina, Italy). The single use of an instrument didn’t allow us to have reliable information and to give a complete characterization of the panel and a correct interpretation of data in order to understand the pigments and materials used. For instance, to determine the blue hatchings, the XRF analysis alone, was not exhaustive. The first information achieved by using the multispectral system allowed us to observe the conservation state of the painting, details of the execution, the presence of retouches and moreover to identify a pentimento of the artist during the creativity process of the work. Raman, XRF and reflectance spectroscopy were then employed in combination with FTIR spectroscopy for the characterization of the materials used and in particular for the identification of the pigments, at elemental and molecular level. From the interpretation of the collected data, it was possible to discover the composition of the preparation layer of the canvas, constituted by white lead, animal glue and gypsum. The palette used by the artist was predominantly composed by ochre (yellow and red ochre) and earth pigments (sienna, green earth and burnt umber). Furthermore, in the yellow and red areas along with the ochre, Naples yellow and Cinnabar respectively were detected. For the white colour the artist employed white lead while for the blue backgrounds Prussian blue was used.

FTIR spectroscopy analysis allowed to determine the varnish applied, a natural one, mainly composed by terpene resins and moreover the presence of a staining oil, linseed oil [35]. Therefore, the integration of those different methods allowed to have more accurate information about the materials used, the state and the execution technique of the artwork. The knowledge achieved can be employed by the conservators as guideline to better understand the oil painting panel to proceed to a correct conservation and restoration intervention.

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