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INFN-CHNet meets CCR La Venaria Reale: first results

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***Abstract* – In the field of Heritage Science, mobile instruments for preservation of artworks are more and more in use. INFN-CHNet, the network of INFN devoted to Cultural Heritage, develops instruments and methods to support the research in the field. Among the others, a MA-XRF scanner was built for in-situ analysis. It is fully operative and has been employed in museums, conservation centres and out-door fields. Recently the INFN-CHNet MA-XRF scanner was employed at the CCR "La Venaria Reale", Turin, for the analysis of different artworks undertaking conservation treatments. The versatility of the MA-XRF scanner is highlighted by the diversity of the materials and the techniques of the applications (painting on canvas, panel painting, and wooden cabinet).**

I. INTRODUCTION

Presently the use of non-destructive non-invasive X-Ray based techniques is well established in Heritage Science for the analysis and the conservation of artworks [1-7]. X-Ray fluorescence (XRF) technique plays a fundamental role since it provides information on the elemental composition, and thus contributes to identify the materials present on the superficial layers of an artwork.

Whenever XRF is combined with the capability of scanning an area, providing an elemental distribution on a surface, the technique is indicated as Macro X-Ray Fluorescence (MA-XRF) technique [8].

A number of MA-XRF scanners, commercial [9] as well as built in-house [10], are nowadays available and in use for Cultural Heritage applications. Due to the impossibility, for example for their preciousness or high

weight, to transport most of the artworks inside a laboratory to undertake scientific analyses, an important class of instruments is made up by portable and transportable scanners.

In the present paper we are going to present the Cultural Heritage Network of the National Institute of Nuclear Physics (INFN-CHNet) MA-XRF scanner, developed in-house within the collaboration, through the analyses carried out at the Centro Conservazione e Restauro (CCR) "La Venaria Reale", located nearby Turin. Different examples of artworks are presented, and elemental maps are shown to illustrate the capabilities of the instrument.

Despite the high analytical capabilities of the MA-XRF technique, it is worth to underline the importance of a thorough multi-analytical approach for the comprehensive characterisation of the materials. Other complementary techniques, such as Raman spectroscopy, Fourier-transform infrared spectroscopy (FTIR), X-Ray Diffraction (XRD) and Radiography to cite a few, are invaluable supporting analytical methods.

Nevertheless, data obtained by MA-XRF technique can be a reliable source of important insights for conservators and heritage scientists during their activity.

II. EXPERIMENTAL SET-UP

The INFN-CHNet MA-XRF scanner, shown in Fig. 1 during its installation at the CCR "La Venaria Reale", is a compact (60×50×50 cm^3) and lightweight (around 10 kg) instrument [11]. Maps of elements with atomic numbers higher than Sodium (Z >11) are efficiently provided by the instrument. Its main parts are a measuring head, three motor linear stages and a case containing all the electronics for acquisition and control.

Fig.1 INFN-CHNet MA-XRF scanner positioned in front of a panel on canvas at the CCR La Venaria Reale.

The measuring head is composed by a X-Ray tube (Moxtek©, 40 kV maximum voltage, 0.1 mA maximum anode current, Mo anode) with a collimator (typically 800 μm of diameter), a Silicon Drift Detector (Amptek© XR100 SDD, 50 mm^2 effective active surface) and a telemeter (Keyence IA-100). The motor stage (Physik Instrumente©, travel ranges 30 cm in x, 15 cm in y and 5 cm in z directions) holding the measuring head is screwed on the carbon-fibre case. Typical operating voltage is 30 kV. Signals are collected with a digitizer (model CAEN DT5780) and the whole system is controlled by a laptop.

The control-acquisition-analysis software is developed within the collaboration and allows both an on-line and an off-line analysis. For the MA-XRF analysis the output is a file containing the scanning coordinates and for each position the spectrum acquired. For each map, a single element can be selected and shown in the scanned area, or in a part of it. The relative intensity of each element in a map is shown in greyscale, in which the maximum intensity is in white and the lower in black. Scan is carried out on the x axis, and a step size of typically 1 mm is set on the y axis resulting in a pixel size of 1 mm^2.

A complete review on the instrument can be found in [12].

III. CASE STUDIES

In this paragraph three different applications are presented. Measurements were carried out at the CCR "La Venaria Reale" in the framework of conservation interventions. The elemental maps obtained with the INFN-CHNet MA-XRF analysis have successfully supported the conservation processes.

The first application is a painting on canvas, the second is a painting on panel, and the last is a wooden cabinet. One single problematic for each artwork is reported.

A. Partial loss of the painting layer

"Madonna con Bambino e i Santi Crescentino e Donnino" by Timoteo Viti, early XVI c., is reported as an example of tempera on canvas. This painting was analysed since its condition required to find out the traces of the original painting layers, in order to assess its conservation state. A picture of the painting is presented in Fig.2.

To retrieve the original pigments used in the area of the

Virgin's face, the elemental maps of Fe, Hg, Cu, and Au have been extracted and are reported. The scanned area is 170×110 mm^2, acquisition parameters were 40 μA beam current and 3 mm/s speed.

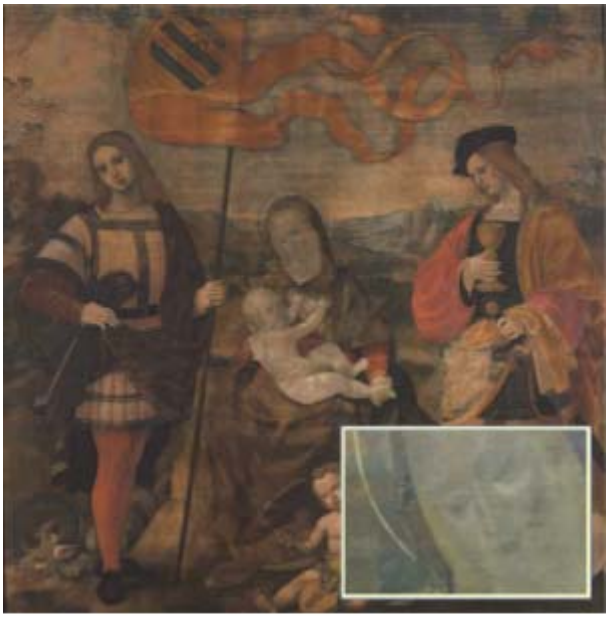

Fig.2 Madonna con Bambino e i Santi Crescentino e Donnino by Timoteo Viti. On the bottom right, a magnification of the Virgin's face.

The MA-XRF analysis led to the hypothesis of the use of earths-ochres in the shading, due to the presence of Fe, and vermilion-cinnabar (Fig. 3, Hg) in the fleshtones as well as the use of azurite (Fig. 3, Cu) in the Virgin's robe, decorated with gold as the halo (Fig. 3, Au) [13].

For this artwork, the MA-XRF analysis has permitted the detection of the traces of the remaining painting layers and the study of the painting technique.

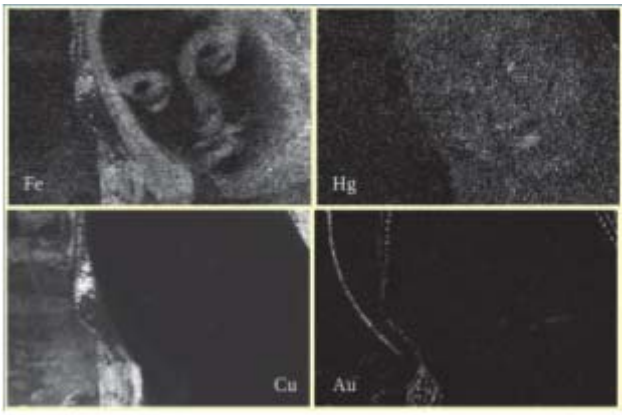

Fig.3 Elemental maps of Fe, Hg, Cu, Au of the area of the Virgin's face.

After the conservation carried out at the CCR "La Venaria Reale", the painting owned by La Pinacoteca di Brera was displayed at the exhibition *Raffaello e gli amici di Urbino*.

B. Characterisation of the blue pigments

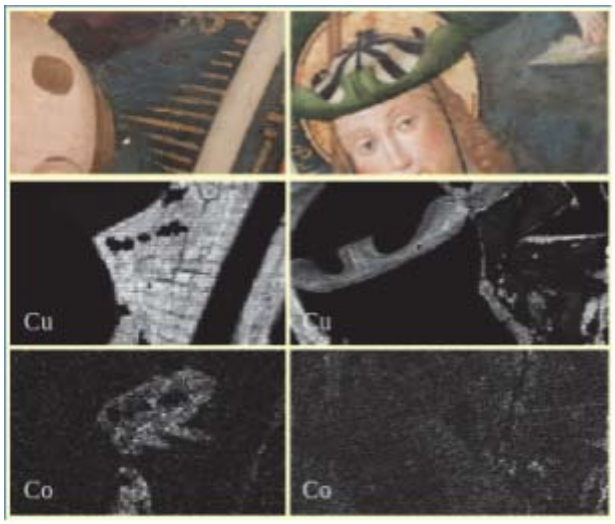

Fig.4 Two areas of the Madonna con Bambino by Francesco Sparapane, oil on panel, XVI c. The corresponding maps of Cu and Co are presented. The scanned areas are, respectively, 12 × 7 cm^2 and 28 × 7 cm^2.

Blue pigments may be realized with different compounds (such as ultramarine, azurite, smalt, indigo). To identify the pigments used in the blue areas of "Madonna con Bambino e S. Antonio e S. Rocco" by Sparapane, partially visible in Fig.1, the MA-XRF analysis was carried out over the two areas presented in Fig.4.

The presence of Cu is likely due to the use of azurite, whereas the presence of Co, with traces of Bi and K, likely attests the presence of smalt [13]. In the first area (left), the elemental maps may indicate the presence of a large area of azurite with the presence of smalt in a smaller area (the maps of Bi and K are not reported), that could be explained with a later retouch or an original glaze. On the contrary, the map of Cu in the second area shows only a well-defined region outlining the face, due to a partial loss of the painting layer. The same conclusion is confirmed from the map of Co.

C. Study of a Chinese wooden cabinet

Together with paintings, the MA-XRF scanner was used on a wooden cabinet from the Castello di Masino, Piedmont, Italy, shown in Fig.5.

For this case study, the query was related to the presence of orpiment (As_2S_3) in the yellow areas. The maps of the area with flowers and stems is reported in Fig.6. The beam current was set to 30 μA and the speed to 3 mm/s.

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Fig.5 Chinese wooden cabinet. On the bottom right, a magnification of the area studied.

Due to the overlap of their energies, the detection of As and S can not be stated directly with one map. By comparing the maps of different X-Ray lines of As, Hg and Pb (not all of which reported), it was possible to attest the likely presence of orpiment in the stems. Further, the map of Au is reported in Fig.6, showing the gilding in the yellow flowers and leafs.

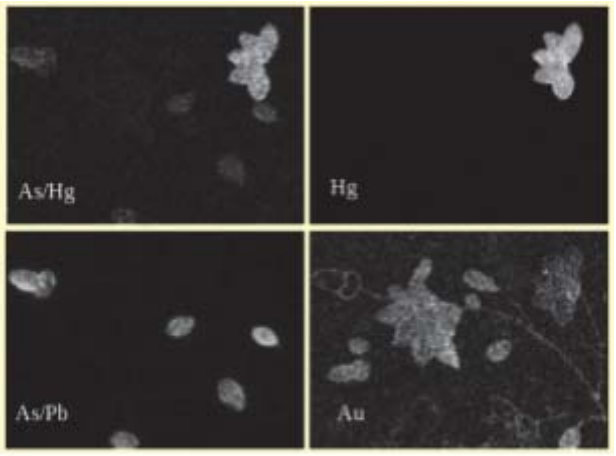

Fig.6 Elemental maps at 11.7 keV (As/Hg), 9.9 keV (Hg), 10.5 keV (As/Pb) 9.6 keV (Au). The scanned area is 14,5 × 10,5 cm^2 .

IV. CONCLUSIONS

The INFN-CHNet MA-XRF scanner was employed at the CCR "La Venaria Reale" to support the conservation activities. Its analytical performances and its versatility have demonstrated the usefulness of the instrument in the Cultural Heritage field.

On the other hand, the elemental maps may not provide all the necessary information for a conservation process, and a number of different techniques are demanded to support or to integrate the results.

Thanks to the expertise within the INFN-CHNet collaboration, an upgrade of the scanner for allowing further applications is continuously on-going. In particular, the feasibility of carrying out different X-Ray based techniques with the same transportable device is under study. For example, the X-Ray radiography (RX) is a well known technique for providing complementary information on painting layers, their structure and their conservation state. Another technique which is planned to be added is the X-Ray Luminescence (XRL) technique, recently employed to study the provenance of lapis lazuli, as reported in [14].

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