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INFN-CHNet at work: X-ray fluorescence analyses on works of art at the CCR "La Venaria Reale"

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Summary. — INFN-CHNet, the network of the Italian National Institute for Nuclear Physics (INFN) devoted to Cultural Heritage, has the mission to develop instruments and methods for heritage science. Within this network, a Macro X-Ray Fluorescence (MA-XRF) scanner was realised for both elemental imaging and spectroscopy. It has been used for a number of applications, such as paintings, ceramics, mosaics and manuscripts. As an example, some measurements conducted at the Centro di Conservazione e Restauro "La Venaria Reale" will be presented. Furthermore, general aspects of the analysis with the INFN-CHNet MA-XRF scanner will be discussed.

1. – The INFN-CHNet Collaboration

The National Institute for Nuclear Physics (INFN) is the Italian research agency dedicated to the study of the fundamental constituents of matter and the laws that govern them. The main fields of research are nuclear, particle, theoretical and astroparticle physics. However, it conducts technological research and promotes the use of fundamental physics instruments, methods and technologies in other sectors. One of the fields of application of nuclear techniques is heritage science and, in 2017, the network of the INFN for cultural heritage, INFN-CHNet [1,2], was founded, with the mission to harmonise and to enhance the expertise of the Institute in the field towards its structures spread over the Italian territory. Several results have already been achieved by developing facilities for heritage science applications as reported in [3, 4].

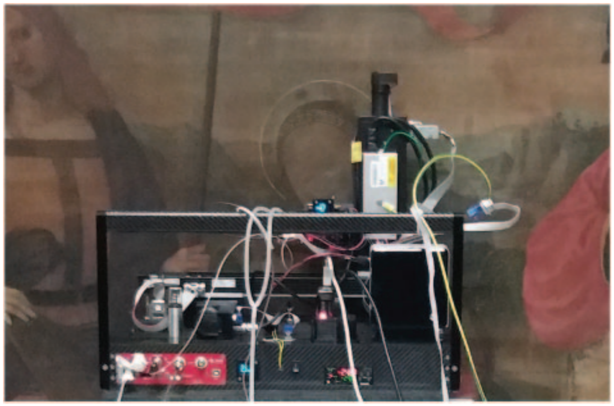

Fig. 1. – INFN-CHNet MA-XRF scanner placed in front of a painting at the CCR "La Venaria Reale".

2. – The INFN-CHNet MA-XRF scanner

The INFN-CHNet MA-XRF scanner (fig. 1) is a compact ($60 \times 50 \times 50\,\text{cm}^3$) and lightweight (around 10 kg) instrument developed within the collaboration. Its main parts are the measuring head, three motor linear stages and a case containing all the electronics for acquisition and control.

The measuring head is composed of an X-Ray tube (Moxtek, 40 kV maximum voltage, 0.1 mA maximum anode current, Mo anode) with a removable collimator, a Silicon Drift Detector (Amptek XR100 SDD, $50\,\text{mm}^2$ effective active area) and a telemeter (Keyence IA-100). The motor stages (Physik Instrumente, travel ranges 30 cm in x, 15 cm in y and 5 cm in z directions) holding the measuring head are screwed to the carbon-fibre case. Signals are collected with a multi-channel analyser (model CAEN DT5780) and the whole system is controlled by a laptop. The control-acquisition-analysis software is developed within the network and allows both on-line and off-line analysis.

The output of the acquisition process is a file containing the scanning coordinates and, for each position, the spectrum acquired. For each map, or in a part of it, a single element can be selected and represented. The relative intensity of each element is shown with a grey scale, in which the maximum intensity is in white and the lowest is in black. Scanning 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 $1\,\text{mm}^2$. A complete review on the instrument can be found in [5]. The instrument has already been successfully used for a number of different applications, *e.g.*, paintings [6, 7], manuscripts [8], ceramics [9], and furniture [10].

3. – Applications at the CCR "La Venaria Reale"

The work of art presented, the *Madonna con Bambino ed i Santi Crescentino e Donnino* by Timoteo Viti, is a painting on canvas ($168 \times 165\,\text{cm}^2$, Milano, Pinacoteca di Brera, inv. 576), dated between 1500 and 1510 [11]. The painting presented bad conservation conditions on the areas around the faces of the Virgin and the Child. The match of the elemental maps with the painted areas allowed the identification of pigments in a non-invasive and non-destructive way. Here the area of the Virgin's face is presented

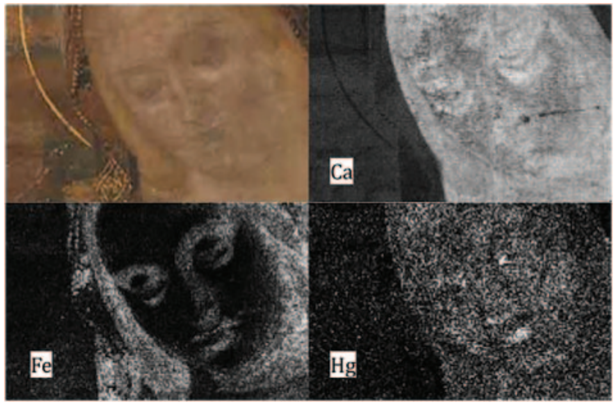

Fig. 2. – Image of the scanned area (top left) and XRF maps of Ca, Fe, Hg.

and discussed. The scanned area is $170 \times 110\,\mathrm{mm}^2$, the parameters of the source were $28\,\mathrm{kV}$, $40\,\mu\mathrm{A}$, and a $800\,\mu\mathrm{m}$ collimator was used.

As can be seen from fig. 2, the visage area is characterised by calcium, which can be explained with a calcium-based compound such as gypsum for the preparatory layer [11], and low intensity lead peaks, which suggest the use of a proper white pigment (*biacca*). This result is confirmed by infrared spectroscopy in the painted area [12]. Moreover, from the lead distribution map (fig. 3, Pb), it is possible to notice that the counts related to this element increase in the background. In addition, the match of the spatial distributions of tin with lead may indicate the use of lead-tin yellow for the *aura* of the Virgin.

The blue mantle was painted with a copper-based pigment, most likely azurite, and iron-based compounds, such as earths and ochres, were employed for shading. The embroidery as well as the outline of the halo were realised with the use of gold. Mercury was detected in the fleshtone, highlighting the presence of vermillion. Mercury and iron-based pigments were also employed to paint the hair of the Virgin.

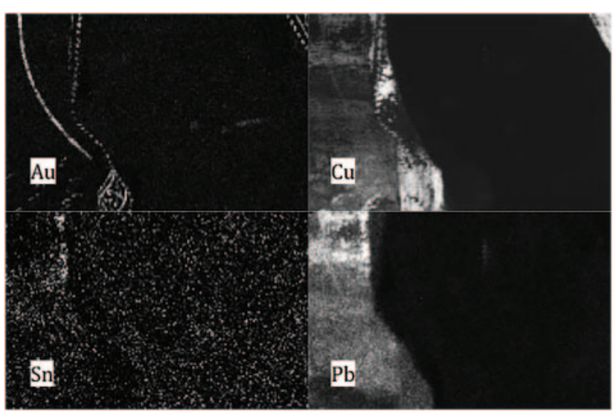

Fig. 3. – XRF maps of Au, Cu, Sn, Pb of the same area presented in fig. 2.

4. – Conclusion

The INFN-CHNet MA-XRF scanner was successfully employed during the conservation process at the CCR "La Venaria Reale". Most of the painting palette was identified, even though the impossibility to detect elements lighter than sodium limits its knowledge. Thanks to the versatility of the device and the expertise within the INFN-CHNet group, further improvements of the scanner are planned in the near future.

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