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X-ray fluorescence analysis of bronze sculptures by Giuseppe Renda

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***Abstract* – In this study the elemental composition analysis of three bronze sculptures by Giuseppe Renda (one of the most famous interpreters of the Neapolitan Verism in the 19th and 20th centuries), respectively named *"La Fortuna"*, *"Scugnizzo"* and *"Non mi toccare"*, was performed, for the first time, by means of portable X-ray fluorescence (XRF) spectroscopy.**

The analysis of the investigated artefacts, closely related to the sample preparation and preservation, was carried out with the aim of improving the knowledge of the Southern Italy bronze art of the second half of the 20th century and in order to suggest to restorers the best interventions to minimize the conservation problems that could affect the durability of the precious artefacts.

Noteworthy, the achieved results represent useful and essential tools to obtain information on the execution technique, in a completely non-invasive way, and to address management issues of the investigated artworks.

I. INTRODUCTION

Among the most important artworks by Giuseppe Renda (Polistena (RC) 1859 - Naples 1936), a Calabrian artist considered among the greatest interpreters of Neapolitan *"verismo"* in the 19th and 20th centuries, there are certainly three bronze sculptures named *"La Fortuna"*, *"Scugnizzo"* and *"Non mi toccare"*, respectively [1-2]. These artworks, part of the collection of the Marchese srl company of Polistena (RC), are re-propositions of famous plaster casts made by the artist at the beginning of the 20th century and melted in metal in the second half of the same century.

In particular, *"La Fortuna"* was presented by the artist in Milan in 1906, in the exhibition organized on the opening of the Simplon Pass. The plaster *"La Fortuna"* was later donated by the heirs of sculptor Giuseppe Renda to the Banca Popolare of Polistena, which oversaw its bronze casting at the Chiurazzi Foundry in Naples, as would also be confirmed by the different stamps at the base of the monument now displayed in the atrium of Palazzo Avati in the Calabrian municipality. Going on, from the plaster model of *"Scugnizzo"* (Cosenza, Renda heirs collection), also made in the first decade of the 20th century, two bronze versions are instead known: the first one, kept at the Lanza Institute in Reggio Calabria, and the second one, preserved at the Marchese srl company in Polistena, of which, however, neither the year of casting nor the foundry executing the model are known.

Finally, in the Renda heirs collection in Cosenza is kept the plaster *"Non mi toccare"*, from which the bronze artwork was made. As in the case of the *"Scugnizzo"*, the bronze *"Non mi toccare"* also lacks information about the commissioner, place and period of execution.

In this study, the elemental compositional analysis of the three aforementioned bronze sculptures was performed, for the first time, on representative fragments taken during restoration operations, by means of portable X-ray fluorescence (XRF) spectroscopy [3-13], with the aim: (i) of knowing the constituent elements of the bronze alloy of the three works now preserved in Polistena, in order to verify the hypothesis that the bronzes came from a single foundry, probably the same one that made "La Fortuna" in the second half of the 20th century; (ii) of identifying the most appropriate methodologies to carry out the cleaning during the restoration of the three artifacts, particularly of the bronze sculpture of *"La Fortuna"*, which is composed of several metal elements welded together [14-19]. Indeed, evident are the chromatic and material differences in the bronze that constitutes the allegory of *"La Fortuna"*, represented as a naked woman, compared to the wheel that provides its base, executed by making use of an alloy with

a decidedly darker tone.

II. MATERIALS AND METHODS

Photos of the investigated artworks, *"La Fortuna"* (front side (a) and back side (b)), *"Scugnizzo"* (c) and *"Non mi toccare"* (d) are reported in Figure 1.

In particular, with reference to the artwork *"La Fortuna"*, four representative samples were analyzed: ID1, ID2 and ID4, all taken from the back side, and ID3, sampled from the front side. Furthermore, for *"Scugnizzo"* and *"Non mi toccare"*, one sample for each of them, i.e. ID5 and ID6, respectively, was investigated.

Figure 1. Photos of the investigated artworks, "La Fortuna" (a, b), "Scugnizzo" (c) and "Non mi toccare" (d).

For the analysis, a portable XRF Alpha 4000 analyzer (Innov-X systems, Inc., Woburn, MA, USA), which allows the detection of chemical elements with an atomic number (Z) between phosphorus and lead was employed [20-24]. It is equipped with a Ta anode X-ray tube as source and a Si PIN diode (active area of 170 mm^2) as detector. For each point, two sequential tests were performed, the first with operating conditions of 40 kV and 7 μA and the second with 15 kV and 5 μA, for a total spectrum collection time of 120 s. The instrument was controlled by a Hewlett-Packard iPAQ Pocket PC, which was also used for the data storage.

The calibration was performed using a soil light element analysis program (LEAP) II and was verified using alloy certified reference materials produced by Analytical Reference Materials International [25-30].

III. RESULTS AND DISCUSSION

Figure 2 shows the XRF spectra concerning the analyzed samples, while Table 1 reports their elemental composition. The different composition of the alloys used for the creation of the artwork *"La Fortuna"* indicates the artist's desire to obtain different material effects in correspondence to the three main parts that constitute the artwork (base, wheel, and female figure), cast by the Chiurazzi foundry in Naples in the last quarter of the last century.

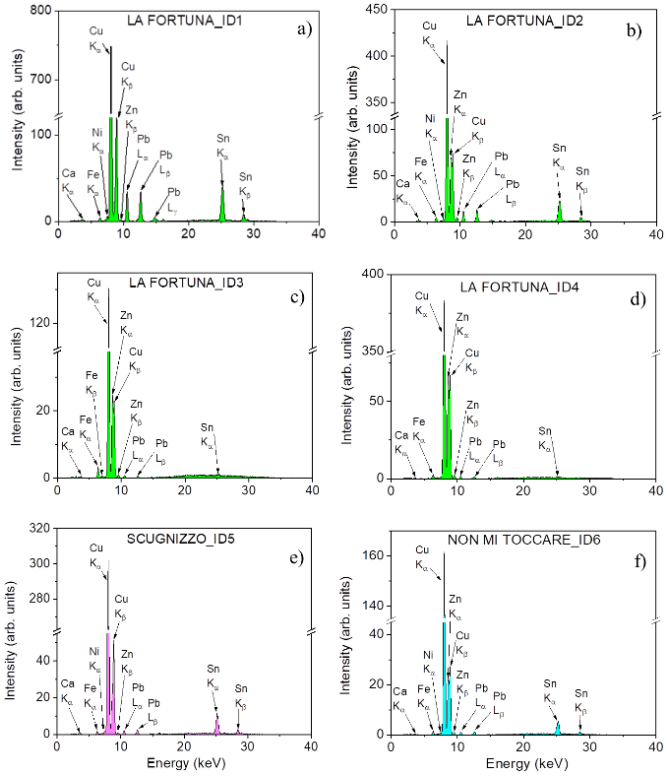

Figure 2. The XRF spectra referred to the analyzed samples.

Table 1. X-ray fluorescence (XRF) elemental composition. Minor or trace elements reported in brackets.

Sample ID	Qualitative elemental composition
1 (*"La Fortuna"*)	Cu, Sn, Pb (Fe, Zn, Ni, Ca)
2 (*"La Fortuna"*)	Cu, Sn, Zn (Pb, Fe, Ni, Ca)
3 (*"La Fortuna"*)	Cu, Zn (Pb, Fe, Sn, Ca)
4 (*"La Fortuna"*)	Cu, Zn (Pb, Fe, Sn, Ca)
5 (*"Scugnizzo"*)	Cu, Sn, Zn (Pb, Fe, Ni, Ca)
6 (*"Non mi Toccare"*)	Cu, Sn, Zn (Pb, Fe, Ni, Ca)

In particular, the presence of Sn in the alloy of sample ID2, taken from the base, can be attributed to the desire to have a bronze as rigid as possible in order to enhance the artwork's supporting role. In addition, the detection of Pb on the female figure (ID3) is determined by the need to obtain a surface as homogeneous as possible. On the other hand, the traces of Ca, present in all the investigated fragments, can be attributed to the casting earth [31-34].
Finally, the results of the analysis of the samples taken from the sculptures *"Scugnizzo"* (ID5) and *"Non mi toccare"* (ID6), put in evidence that the two artworks were probably cast by the same foundry. In any case, the alloys used are entirely compatible to the materials used in Neapolitan foundries in the 20th century, so it cannot be ruled out that these two artworks were also made in the second half of the 20th century by the Chiurazzi Foundry in Naples.

IV. CONCLUSIONS

Three bronze sculptures, respectively named *"La Fortuna", "Scugnizzo"* and *"Non mi toccare"*, made by Giuseppe Renda, a Calabrian artist considered among the greatest interpreters of Neapolitan *"verismo"* in the 19th and 20th centuries, were investigated.
In particular, the compositional analysis of the three aforementioned artworks was performed, for the first time, on representative fragments taken during restoration operations, by means of portable X-ray fluorescence (XRF) spectroscopy. From obtained results, we can conclude that the different composition of the alloys used for the achievement of the artwork *"La Fortuna"* indicates the artist's desire to obtain different material effects in correspondence to the three main elements that constitute this artwork (base, wheel, and female figure). Moreover, the traces of calcium, present in all the investigated fragments, can be attributed to the casting earth. Going on, the alloys composition of the samples taken from the sculptures *"Scugnizzo"* and *"Non mi toccare"* put in evidence that these two artworks were probably cast by the same foundry, probably the Chiurazzi Foundry in Naples, being fully compatible to the materials used in Neapolitan foundries in the 20th century. Finally, as far as the restoration operations of these bronze sculptures are concerned, the presence of calcium will determine the use of bisodium EDTA (Ethylene-Diamino-Tetra-Acetic Acid), while the presence of different alloys will determine the use of this tetracarboxylic acid at different concentrations, mixed with ammonium carbonate and bicarbonate, always applied to pulp compresses.

REFERENCES

[1] F. Negri Arnoldi, "La fortuna di Giuseppe Renda", in Giuseppe Renda (1859-1939) a cura di F. Negri Arnoldi, Napoli, Electa, 1995, pp.11-14.

[2] D. Esposito, "Giuseppe Renda. Un polistenese nel vivo della Belle Époque internazionale", Fioranna, Napoli 2020.

[3] F. Caridi, G. Acri, G. Paladini, V. Venuti, V. Crupi, P. Faenza, D. Majolino, "Spectroscopic investigation on a XVII-XVIII century terracotta slab from Calabria, Southern Italy", Jour. of Phys.: Conference Series, vol.2204 2022 012022. IEEE International Conference on Metrology for Archaeology and Cultural Heritage, MetroArchaeo 2021, Milan 20-22 October 2021.

[4] Miliani, F. Rosi, B.G. Brunetti, A. Sgamellotti, "In Situ Noninvasive Study Of Artworks: The Molab Multitechnique Approach", Acc. Chem. Res. vol.43 2010 pp. 728-738.

[5] D.A. Scott, "Copper and Bronze in Art: Corrosion, Colorants, Conservation", Getty Trust Publications: Los Angeles, U.S.A., 2002.

[6] L. Torrisi, G. Mondio, A.M. Mezzasalma, D. Margarone, F. Caridi, T. Serafino, A. Torrisi, "Laser and electron beams physical analyses applied to the comparison between two silver tetradrachm greek coins", Eur. Phys. Journal D vol. 54 2009 pp.225 – 232.

[7] S.E. Spoto, R. Somma, G. Paladini, F. Caridi, M. Interdonato, D. Majolino, V. Venuti, "From lapis lazuli to synthetic ultramarines: a μ-Raman spectroscopy investigation on the history and development of "the Most Perfect" Color", 2022 IMEKO TC-4 International Conference on Metrology for Archaeology and Cultural Heritage, University of Calabria, Italy, October 19-21, 2022.

[8] G. Acri, B. Testagrossa, P. Faenza, F. Caridi, "Spectroscopic analyses of ancient gilts of the Antonello Gagini Annunciation's sculptural group, church of St. Theodore martyr in Bagaladi, Reggio Calabria, Italy", Mediterranean Archaeology and Archaeometry, vol.20 2020 pp.1-5.

[9] V. Crupi, S. D'Amico, L. Denaro, P. Donato, D. Majolino, G. Paladini, R. Persico, M. Saccone, C. Sansotta, G.V. Spagnolo, V. Venuti, "Mobile Spectroscopy in Archaeometry: Some Case Study", J. Spectrosc., vol.8295291 2018.

[10] T. Ganetsos, A. Regkli, N. Laskaris, I. Liritzis, "Spectroscopic study of colour traces in marble sculptures and architectural parts of monuments of archaic period in Delphi, Greece", Mediterr. Archaeol. Archaeom., vol.19 2019 pp.51–61.

[11] P. General-Toro, R. Bordalo, P.R. Moreira, E. Vieira, A. Brunetti, R. Iannaccone, C. Bottaini, "Art Casting in Portuguese 19th Century Industrial Foundries: A Multi-Analytical Study of an Emblematic Copper-Based Alloy Monument", Heritage vol. 4 2021 pp.3050-3064.

[12] M. Ricca, G. Paladini, N. Rovella, S.A. Ruffolo, L. Randazzo, V. Crupi, B. Fazio, D. Majolino, V. Venuti, G. Galli, M.F. La Russa, "Archaeometric Characterisation of Decorated Pottery from the

Archaeological Site of Villa dei Quintili (Rome, Italy): Preliminary Study" Geosci. Vol.9 2019

[13] F. Caridi, M. Ricca, G. Paladini, V. Crupi, D. Majolino, A. Donato, S. Guido, G. Mantella, L. Randazzo, M.F. La Russa, V. Venuti, "Multi-Technique Diagnostic Investigation in View of the Restoration of *The Glory of St. Barbara* Painting by Mattia Preti", Appl. Sci., vol.12 2022 1385.

[14] S.E. Spoto, G. Paladini, F. Caridi, V. Crupi, S. D'Amico, D. Majolino, V. Venuti, "Multi-Technique Diagnostic Analysis of Plasters and Mortars from the Church of the Annunciation (Tortorici, Sicily)" Materials, vol.15 2022 958.

[15] F. Caridi, B. Testagrossa, P. Faenza, G. Acri, "Spectroscopic Investigations of Pigments on a Late Roman Milestone from Calabria, Southern Italy", SCIRES-IT, vol.10 2020 pp.81-88

[16] L. Torrisi, F. Caridi, L. Giuffrida, A. Torrisi, G. Mondio, T. Serafino, M. Caltabiano, E.D. Castrizio, E. Paniz, A. Salici, "LAMQS analysis applied to ancient Egyptian bronze coins", Nucl. Instr. and Meth. in Physics Research, Section B: Beam Interactions with Materials and AtomsVolume vol. 268 2010 pp.1657 – 166415.

[17] V. Venuti, F. Caridi, E. Colica, V. Crupi, S. D'Amico, S. Guido, D. Majolino, G. Paladini, G. Mantella, F. Caridi, G. Acri, G. Paladini, V. Venuti, V. Crupi, P. Faenza, D. Majolino, "Diagnostic investigation of the *Cycle of the New Church of Sarria* (Floriana, Malta) by Mattia Preti", Jour. of Phys.: Conference Series, vol.2204 2022 012023. IEEE International Conference on Metrology for Archaeology and Cultural Heritage, MetroArchaeo 2021, Milan 20-22 October 2021.

[18] M. Cutroneo, L. Torrisi, F. Caridi, R. Sayed, C. Gentile, G. Mondio, T. Serafino, E.D. Castrizio, "Silver/oxygen depth profile in coins by using laser ablation, mass quadrupole spectrometer and X-rays fluorescence", Appl. Surf. Sci. vol. 272 2013 pp. 25 – 29.

[19] L. Torrisi, F. Caridi, A. Borrielli, L. Giuffrida, A. Torrisi, G. Mondio, A. Mezzasalma, T. Serafino, M. Caltabiano, E.D. Castrizio, E. Paniz, M. Romeo, "LAMQS and XRF analyses of ancient Egyptian bronze coins", Rad. Eff. and Def. in Solids vol. 165 2010 pp.626 – 636.

[20] R. Larsen, N. Coluzzi, A. Cosentino, "Free XRF Spectroscopy Database of Pigments Checker", Int. J. Conserv. Sci. vol.7 2016 pp.659–68.

[21] A. Albergamo, A. F. Mottese, G. D. Bua, F. Caridi, G. Sabatino, L. Barrega, R. Costa, G. Dugo, "Discrimination of the Sicilian Prickly Pear (Opuntia Ficus-Indica L., CV. Muscaredda) According to the Provenance by Testing Unsupervised and Supervised Chemometrics", Jour. of Food Sci. vol.83 (2018) pp.2933-2942.

[22] I. Liritzis, N. Zacharias, I. Papageorgiou, A. Tsaroucha, E. Palamara, E, "Characterisation and analyses of museum objects using pXRF: An application from the Delphi Museum, Greece", Studia Antiqua et Archaeologica, vol.24 2018 pp. 31–50.

[23] K. Anssens, G. Van der Snickt, F. Vanmeert, S. Legrand, G. Nuyts, M. Alfred, L. Monico, W. Anaf, W. De Nolf, M. Vermeulen, J. Verbeeck, K. De Wael, "Non-Invasive and Non-Destructive Examination of Artistic Pigments, Paints and Paintings by Means of X-Ray Methods", Part of volume Analytical Chemistry for Cultural Heritage, Springer, 2017.

[24] G. Barone, V. Crupi, F. Longo, D. Majolino P. Mazzoleni, G. Spagnolo, V. Venuti, E. Aquilia, "Potentiality of non-destructive XRF analysis for the determination of Corinthian B amphorae provenance" X-Ray Spectrom. vol.40 2011 333–7.

[25] R. Linke, M. Schreiner, G. Demortier, M. Alram "Determination of the provenance of medieval silver coins: potential and limitations of x-ray analysis using photons, electrons or protons". X-Ray Spectrom. vol.32 2003 373–80.

[26] L. Fabrizi, F. Di Turo, L. Medeghini, M. Di Fazio, F. Catalli, C. De Vito, "The application of non-destructive techniques for the study of corrosion patinas of ten Roman silver coins: The case of the medieval Grosso Romanino" Microchem. J. vol.145 2019 419–27.

[27] J. Gržetić, V. Orlić, M. Radić,K. Radić, K. Ilijević, "Analysis of medieval Serbian silver coins from XIV and XV century by means of wavelength-dispersive X-ray spectrometry", Nucl. Instruments Methods Phys. Res. Sect. B Beam Interact. with Mater. Atoms vol.366 2016 161–70.

[28] G. M. Ingo, C. Riccucci, M. Pascucci, E. Messina, C. Giuliani, G. Fierro, G. Di Carlo, "Integrated analytical methodologies for the study of the corrosion products naturally grown on Roman Ag-based artefacts" Appl. Surf. Sci. vol.446 2018 279–86.

[29] M. Di Fazio, F. Di Turo, L. Medeghini, L. Fabrizi, F. Catalli, C. De Vito, "New insights on medieval Provisini silver coins by a combination of non-destructive and micro-invasive techniques" Microchem. J. vol.144 2019 309–18.

[30] R. Martina, M. Wiesinger, M. Schreiner, "Micro-Raman Characterisation of Silver Corrosion Products: Instrumental Set Up and Reference", e-Preservation Sci. vol.9 2012 1–8.

[31] K. Nowak, A. Stos-Gale, T. Stolarczyk, B. Miazga, "The Late Bronze Age 'metallurgists' graves' in south-western Poland. Tracing the provenance of the metal raw material using casting moulds", Journ. of Archaeol. Sci.: Rep. vol.42 2022 103393.

[32] E. Figueiredo, C. Bottaini, C. Miguel, A. Lackinger, J. Mirão, B. Comendador Rey, "Study of a Late Bronze Age Casting Mould and Its Black Residue by 3D Imaging, pXRF, SEM-EDS, Micro-FTIR and Micro-Raman". Heritage vol. 4 2021 pp.2960-2972.

[33] M.R. Notis, D. Wang, "Ancient Chinese Bronze

Casting Methods: The Dilemma of Choice" MRS Advances vol.2 2017 pp.1743–1768
[34] I. Liritzis, N. Laskaris, A. Vafiadou, I. Karapanagiotis, P. Volonakis, C. Papageorgopoulou, M. Bratitsi, "Archaeometry: An Overview", Scientific Culture, vol.6 2020 pp.49–98.