Allegato 8

[redacted]

Alessia Coccato

[redacted]

Autorizzo il trattamento dei miei dati personali, ai sensi del D.lgs. 196 del 30 giugno 2003.

IVRY-SUR-SEINE, 27/2/2019 [redacted]

Index of the CV

Education and diplomas

November 2012 - May 2017

PhD in Archaeology

Archaeometry Research group, Department of Archaeology, Ghent University, Ghent (Belgium)
Supervisors: Prof. Dr. Peter Vandenabeele, Prof. Dr. Danilo Bersani
Dissertation title: "Application of Raman and X-ray fluorescence spectroscopies to Cultural Heritage materials. The non-destructive examination of paintings, pigments and their degradation" 16/05/2017

- Acquisition and improvement of knowledge, skills and expertise regarding the application of Raman and XRF spectroscopies to cultural heritage materials: bibliographical research, trainings to operate safely the instrumentation, both inside the laboratory and during in situ campaigns, trainings regarding data treatment and post processing of results, fruitful discussion with the colleagues, preparation of analytical reports to be shared in an interdisciplinary environment, preparation of posters, slides and papers. Both dedicated courses/workshops and daily life as a PhD student contributed to the establishment of the skills.
- Acquisition of transferable skills regarding the use of informatic devices, personal effectiveness, time management through specific courses and personal research.
- Experience in communication, in the form of guiding/supervising undergraduate students, outreach to the lay public during "open days" and lectures, participation to international conferences.
- Experience in interdisciplinary communication thanks to the participation to complex projects, involving art historians, archaeologists, chemists, conservators, geologists, physicists, etc.
- Improvement in spoken and written English proficiency thanks to the international environment in the laboratory, and at international events. Basic knowledge of other languages (Dutch, French) practised with colleagues and friends, as well as outside the research environment.

September 2010 – October 2012

Master of Science in Conservation and restoration of the Cultural Heritage

Faculty of Mathematical, Physical and Natural Sciences, University of Parma (Parma, Italy)
Supervisors: Prof. Dr. Danilo Bersani, Dr. Stefanos Karampelas
Dissertation title: "Non-destructive studies of gem quality and neolithic jade materials" 04/10/2012, 110/110 cum laude

- Consolidation of knowledge and acquisition of skills in the framework of interdisciplinary research on archaeological artefacts. Bibliographical research, trainings to operate the instrumentation, to process and interpret the acquired data, discussion with the colleagues, elaboration of reports and of the master thesis. Presentation of the work as a poster, and publication in an international journal.
- Experience of working inside a well-established analytical lab. Acquisition of analytical and organizational skills, in order to perform all the analysis in a restricted time span (6 weeks of lab work), and to deliver the thesis on time.
- Improvement in spoken and written English proficiency thanks to the international environment, and to the stay abroad.

September 2007 – October 2010

Bachelor degree in Technology for the conservation and restoration of the Cultural Heritage

Faculty of mathematical, physical and natural sciences, University of Parma (Parma, Italy)
Supervisor: Prof. Dr. Danilo Bersani
Dissertation title: "Identificazione della composizione dei granati tramite spettroscopia Raman" (Study of Garnets composition by mean of Raman Spectroscopy) 01/10/2010, 110/110 cum laude

- Consolidation of knowledge and acquisition of skills in the field of Raman spectroscopic applications to geological materials of interest for cultural heritage. Bibliographical research and trainings to collect and interpret the spectra. Elaboration of a flow chart for the amelioration of an existing MatLab routine in terms of obtained results and user interface.
- Acquisition of technical and organizational skills, in order to be able to defend the thesis within the academic year.
- Elaboration of the bachelor thesis, presentation of the results at international conferences (posters, talk).

Professional experiences

October 2017 – ongoing

Consultant in Archaeometry and Conservation Science

FAI France et Association pour le Patrimoine d'Italie; Association Art, Culture et Foi, Saint-Germain-en-Laye; Department of Chemistry, Life Sciences and Environmental Sustainability and Department of Mathematical, Physical and Computer Sciences, University of Parma

- Interdisciplinary study of a mastic incrustation sculpture of unknown origin, but supposedly 12th century
- Historical researches on the former owners of the sculpture
- Proposition of an archaeometrical approach to evaluate the compatibility of the used materials with a 12th century dating
- Characterisation of the pigments and extenders in the coloured mastic
- Identification of the timeframe of creation of the sculpture, based on the presence of patented materials and on the historical information in archives and oral witnesses
- Further art historical researches strongly benefit from the analytical results, as the target period is defined clearly
- In the framework of renovation works, the question of illumination of the sculpture is approached due to the presence of photosensitive pigments

November 2012 - May 2017

Doctoral researcher

Archaeometry Research group, Department of Archaeology, Ghent University, Ghent (Belgium)
Supervisors: Prof. Dr. Peter Vandenabeele, Prof. Dr. Danilo Bersani

- Interdisciplinary research activity regarding the non-destructive characterization of cultural heritage materials: pigments and their degradation, mediaeval panel paintings, and archaeological objects.
- Raman characterization of selected pigments and materials of relevance in archaeometry, such as carbon-based black pigments, and green pigments and reaction compounds. Collaboration with geologists and physicists, interdisciplinary literature search, definition of guidelines to distinguish among different pigments and publication of reference spectra.

- Application of total-reflection XRF (TXRF) to the non-destructive characterization of microscopical pigment samples, such as those available from manuscripts and paintings undergoing conservation treatments. Preparation of diluted solutions of known concentration, characterization of the instrument in terms of lower limits of detection, relative sensitivity curves, and study of other aspects of the sample preparation and measurement (cleaning procedure, effect of sample positioning, etc.). Setting up a standardless procedure for relative quantification of the detected elements, and comparison with the results of a commercial quantification software. Application to pure pigment powders.
- Participation to the European FP7 project "Measurement, Effect Assessment and Mitigation of Pollutant Impact on Movable Cultural Assets. Innovative Research for Market Transfer - MEMORI" in the work package dedicated to pigments. Extended interdisciplinary review of literature concerning pigment degradation. Exposure experiments of selected pigments to acetic acid, and definition of safety thresholds in terms of doses for those pigments. Elaboration of reports for the European Commission.
- Participation to the interdisciplinary conservation treatment of "The Adoration of the Mystic Lamb", led by the Belgian Royal Institute for Cultural Heritage (KIK-IRPA). Non-destructive, in situ study (digital microscopy, Raman and XRF spectroscopies) of the used materials in order to help conservators and art historians, and to deepen the knowledge on the material history of the masterpiece (past restorations, recent overpainting campaigns, etc.).
- Cooperation with University of Evora. Study of the Altarpiece in Funchal's cathedral (Madeira, Portugal). Performing in situ Raman analyses on paintings undergoing restoration. Micro-Raman spectroscopy on selected cross sections to confirm and complete the data obtained by XRD, FT-IR, SEM-EDS. Performing in situ Raman analyses on a collection of glyptics, combination of molecular and elemental data (portable XRF) to confirm the material identification and chronology.
- Cooperation with University of Messina and University of Parma in the study of Caravaggio and Caravaggeschi oil on canvas paintings. Performing in situ Raman analyses on paintings, as the results obtained by portable XRF were affected by a lead containing preparation layer. Use of different laser sources (1064, 785 and 532 nm) and comparison of different instruments.
- Cooperation with University of Catania and University of Parma in the study of the wall paintings in Sala Vaccarini (Catania, Italy). Performing in situ Raman analyses on the decorated vault to identify pigments and painting technique. Use of different laser sources (1064, 785 and 532 nm) and comparison of different instruments.
- Collaboration to the interdisciplinary project KongoKing, led by Ghent University, dedicated to the study of language and material culture of the Kongo Kingdom. First multi-technique study of European glass beads found on the Western coast of Africs. Non-destructive characterization of the glass matrix, colourants and opacifiers by means of portable Raman and XRF instrumentation, application of chemometrics to XRF data, and of additional analytical techniques for special cases. Confirmation, on analytical bases, of the geographical origin of the objects proposed by the archaeologists.
- Participation to international conferences, presentation of the work by means of posters and talks. Publication in scientific peer-reviewed journals.
- Teaching activities at the Department of Analytical chemistry of Ghent University: supervision of "Bachelor projects" (TXRF comparison of archaeological ceramic samples with known productions to evaluate provenance; use of Raman spectroscopy in the plastic recycling industry); supervision of a bachelor thesis on the use of TXRF in the study of archaeological soil samples; supervision of the practical course "Analysis and Abatement of Water Pollution" of the Master of Science Environmental Sanitation.

May – June 2012

Intern

Gübelin Gem Lab (Luzern, Switzerland) and Collection Centre of the Swiss National Museum (Affoltern am Albis, Switzerland); Department of Physics and Earth sciences, University of Parma (Parma, Italy)
Supervisors: Prof. Dr. Danilo Bersani, Dr. Stefanos Karampelas

- Non-destructive characterization of lithic materials of gemmological (jadeite and omphacite) and archaeological interest (neolithic green stone axeheads from archaeological sites in Switzerland).
- Bibliographical search and multi-technique study: classical gemmology; UV-VIS, FT-IR (transmission and reflection) and Raman spectroscopies; photoluminescence and ED-XRF analyses.
- Preparation of the Master thesis, presentation of the work as a poster at an international conference and publication in a scientific journal.

May – September 2010

Intern

Department of Physics and Earth sciences, University of Parma (Parma, Italy)
Supervisors: Prof. Dr. Pier Paolo Lottici, Prof. Dr. Danilo Bersani

- Raman spectroscopic investigation of garnet samples, correlation of the vibrational spectra with elemental data, improvement of the existing MatLab routine to obtain the composition of garnets from their Raman spectrum.
- Bibliographical search, acquisition of data and comparison with previously published information. Elaboration of a flow chart to improve the performance of the routine, thanks to the selection of more specific parameters.
- Preparation of the Bachelor thesis, presentation of the results as a poster and as a talk at international conferences.

Projects on polychrome artefacts, pigments and their degradation

Measurement, Effect Assessment and Mitigation of Pollutant Impact on Movable Cultural Assets. Innovative Research for Market Transfer "MEMORI" - European FP7 project

Objectives:

- definition of safety thresholds (dose = concentration * number of days) for pigments exposed to acetic-acid loaded atmospheres (WP5), in a preventive conservation logic
- extensive literature search on traditional pigments sensitivity to various factors
- create a summary on cultural heritage materials' sensitivity (collaboration with WP10)

Outcomes:

- intermediate reports for the consortium and the European Commission
- conference contributions:

1. 7th Raman in Art and Archaeology (Ljubljana, Slovenia), 2013 and final MEMORI conference in Madrid, Spain, 2013: Coccato, A.; De Laet, N.; Lycke, S.; Van Pevenage, J.; Moens, L.; Vandenabeele, P. Raman study of pigment degradation due to acetic acid vapours. (poster)
2. 4th Chemistry for Cultural Heritage (Bruxelles, Belgique), 2016: Coccato, A.; Moens, L.; Vandenabeele, P.; On the sensitivity of pigments towards climatic factors and various pollutants: a review. (poster)

3. Wood Science and Technology II: Microclimates for Panel Paintings (Maastricht, Pays Bas), 2016: Thickett, D.; M. Odlyha, A. Coccato, T. Grøntoft, Bonaduce, I.; Vandenabeele, P.; Colombini, M. Advances in Microclimate Frame Research. (oral)

- Publication:

1. 2017: Coccato, A.; Moens, L.; Vandenabeele, P. 'On the stability of mediaeval inorganic pigments: a literature review of the effect of climate, material selection, biological activity, analysis and conservation treatments.' Heritage Science.

- PhD thesis :
  - Subchapter 2.1 On the stability of mediaeval inorganic pigments: a literature review of the effect of climate, material selection, biological activity, analysis and conservation treatments
  - Paragraph 4.3.3 Pigments degradation: acetic acid pigments degradation studied with Raman spectroscopy

GOA (Geconcerteerde onderzoeksacties) of Ghent University: interdisciplinary research on the Ghent Altarpiece

Objectives:

- Cooperation with the Royal Institute of Cultural Heritage of Belgium
- Support the conservation treatment by means of in situ, non-invasive analyses on the painted surfaces and frames
- Characterisation of painting materials in overpainted areas
- Elemental quantification at the major, minor, trace level of paint micro-samples (cotton swab method) by means of Total reflection X-rays Fluorescence analyses (TXRF)

Outcomes:

- Conference contributions:
  - Chemistry Conference for Young Scientists (Blankenberge, Belgium), 2014: Coccato, A.; Lauwers, D.; Moens, L.; Vandenabeele, P. The multidisciplinary study of the Ghent altarpiece: analytical chemistry and art. (poster)
  - ICDI Symposium–Mechanisms of Innate Immunity, Cell Death and Inflammation (Ghent, Belgique), 2014: Vandenabeele, P.; Coccato, A.; Lauwers, D.; Rousaki, A.; Moens, L. Archaeometrical Study of the Ghent Altarpiece (oral)
  - 4th Chemistry for Cultural Heritage (Bruxelles, Belgique), 2016: Rosier, F.; Dubois, H.; Van der Snickt, G.; Sanyova, J.; Coudray, A.; Glaude, C.; Janssens, K.; Lauwers, D.; Coccato, A.; Vandenabeele, P. Identification of restorations on the Cumean Sibyl of the brothers Van Eyck's Ghent Altarpiece (1432). (poster)
- PhD thesis :
  - Subchapter 3.3 Handheld X-ray fluorescence, paragraph 3.3.1 Non-invasive approach: Overpaints on the Ghent Altarpiece
  - Subchapter 5.1 Raman and XRF spectroscopies in archaeometrical research: in situ multi-technique study of the frames of the Ghent Altarpiece
- Vulgarisation :
  - 2015: open days of the Department of analytical Chemistry, Ghent University.
  - 2015: presentation of the archaeometrical research on the Ghent Altarpiece and demonstration of instruments for the art history high-school teachers of the region of East Flanders, Belgium.
  - 2016: Lecture on "Science and Art" at the Università delle Tre Età, Lonate Pozzolo, Italy.

Total reflection X-rays Fluorescence analyses for pigments characterisation

Objectives:

- Instrumental characterisation for the purpose of studying powder samples
- Optimisation of the cleaning procedure for measurement supports (reagents and time consumption)
- Setting up a quantification method based on the instrumental parameters and comparison with the provided quantification software
- Elemental quantification of major, minor, trace elements in powdered pigments

Outcomes:

1. Conference contributions:
1. 'Chemistry Conference for Young Scientists', Blankenberge, Belgique, 2014: Coccato, A.; Lauwers, D.; Moens, L.; Vandenabeele, P. The multidisciplinary study of the Gand altarpiece: analytical chemistry and art. (poster)
2. Non-destructive and microanalytical techniques in art and cultural heritage (Catane, Italy), 2015: Coccato, A.; Rousaki, A.; Moens, L. Vandenabeele, P. Optimization of TXRF for the analysis of paint samples. (poster)
3. 2nd International Conference on Innovation in Art (Gand, Belgique), 2016 : Coccato, A.; Vekemans, B.; Vincze, L.; Moens, L.; Vandenabeele, P. Optimization of Total Reflection X-ray Fluorescence analysis of pigments (poster)

- Publication:

1. 2016: Coccato, A.; Vekemans, B.; Vincze, L.; Moens, L.; Vandenabeele, P. Pigment particles analysis with a total reflection X-ray fluorescence spectrometer: study of influence of instrumental parameters. Applied Physics A

- PhD thesis
  - Subchapter 3.4 Total-reflection X-ray fluorescence

Raman spectroscopic characterisation of carbon-based black pigments

Objectives:

- Review of the geologic and archaeometrical literature to identify nomenclature issues and discrepancies between the materials of interest
- Understanding of carbon spectral parameters
- Proposition of a spectral treatment and nomenclature to avoid misunderstandings
- Proposition of guidelines to differentiate among different carbon-based black pigments

Outcomes:

- Conference contributions:

1. 7th International Congress on the Application of Raman Spectroscopy in Art and Archaeology (Ljubljana, Slovenia) 2013: Coccato, A.; Moens, L. Vandenabeele, P. Raman spectroscopic investigation of black pigments. (poster)
2. XI International GeoRaman Conference, St. Louis, USA, 2014: Coccato, A.; Jehlicka, J.; Moens, L. Vandenabeele, P. Raman spectroscopy for the investigation of carbon-based black pigments. (poster)

- Publication:

1. Coccato, A.; Jehlicka, J.; Moens, L.; Vandenabeele, P.; 2015. Raman spectroscopy for the investigation of carbon-based black pigments. Journal of Raman Spectroscopy.

- PhD thesis:

1. Paragraph 4.3.2 Raman Spectroscopy for the investigation of Carbon-based black pigments

Raman spectroscopic characterisation of green materials of interest for Cultural Heritage

Objectives:

- Interdisciplinary literature review on green compounds (pigments, corrosion products)
- Acquisition of extended-range Raman spectra with both a 532 and a 785 nm excitation
- Comparative study of a Ghent Altarpiece cross section sample with different instrumentation
- Creation of a downloadable database of reference spectra

Outcomes:

- Downloadable database
- Conference contribution

1. 8th International Congress on the Application of Raman Spectroscopy in Art and Archaeology, Wroclaw, Poland, 2015: Coccato, A.; Moens, L. Vandenabeele, P. Raman database of green pigments. (poster)

- Publication

1. Coccato, A.; Bersani, D.; Coudray, A.; Sanyova, J.; Moens, L.; Vandenabeele, P.; 2016. Raman spectroscopy of green minerals and reaction products with an application in Cultural Heritage research. Journal of Raman Spectroscopy

- PhD thesis
- Paragraph 4.3.1 Raman spectroscopy of green minerals and reaction products with an application in Cultural Heritage research

In situ and laboratory Raman spectroscopy of the painting materials of the Funchal's Altarpiece, Madeira, Portugal

Objectives:

- Support the conservation-restoration treatment
- Provide complementary information on the painting materials (XRF, micro-XRD, FTIR, SEM-EDS performed at Evora University, HERCULES laboratory)

Outcomes:

- Conference contributions

1. Chemistry Conference for Young Scientists (Blankenberge, Belgium), 2014: Lauwers, D.; Coccato, A.; Candeias, A.; Mirão, J.; Moens, L.; Vandenabeele, P. Archaeometrical study of the main altarpiece of the cathedral of Funchal (Madeira). (poster)
2. 2nd International Conference on Innovation in Art (Ghent, Belgique), 2016: Gomes, S.; Lorena, M.; Vandenabeele, P.; Lauwers, D.; Coccato, A.; Valadas, S.; Candeias, A. Green colour in the 16th century Portuguese paintings of the Funchal's Cathedral altarpiece. (poster)

- PhD thesis
- Paragraph 4.4.1 In situ Raman spectroscopic study of Funchal's Altarpiece

Rock art from Patagonia

Objectives:

- Raman spectroscopy and TXRF characterisation of rock art samples from Patagonia

Outcomes:

- Conference contributions

1. 8th International Congress on the Application of Raman Spectroscopy in Art and Archeology, Wroclaw, Pologne, 2015: Rousaki, A.; Coccato, A.; Bellelli, C.; Carballido Calatayud, M.; Palacios, O.; Custo, G.; Moens, L.; Vandenabeele, P.; Vázquez, C. Micro-Raman analysis of prehistoric rock art in Patagonia (Argentina). (oral)

In situ Raman spectroscopic analysis of the painted vault of Sala Vaccarini, Catania, Italy

Objectives:

- In situ materials characterisation to understand the painter's palette and technique
- Comparison of portable Raman spectrometers (532 and 785 nm; 1064 nm) for the purpose of wall paintings analyses

Outcomes:

- Conference contributions

1. 2nd International Conference on Innovation in Art (Gand, Belgique), 2016: Barone, G.; Bersani, D.; Coccato, A.; Lauwers, D.; Mazzoleni, P.; Raneri, S.; Vandenabeele, P.; Manzini, D.; Agostino, G.; Neri, N.F. Non-destructive Raman investigations on wall paintings at Sala Vaccarini in Catania (Sicily). (poster)
2. XII International GeoRaman Conference (Novosibirsk, Russie) 2016: Bersani, D.; Coccato, A.; Lauwers, D.; Vandenabeele, P.; Barone, G.; Raneri, S.; Mazzoleni, P.; Quartieri, S.; Sabatino, G.; Manzini, D. Raman analysis of paintings: comparison between different excitation wavelengths in mobile systems. (poster)

- Publication

1. Barone, G.; Bersani, D.; Coccato, A.; Lauwers, D.; Mazzoleni, P.; Raneri, S.; Vandenabeele, P.; Manzini, D.; Agostino, G.; Neri, N.F.; 2016. Nondestructive Raman investigation on wall paintings at Sala Vaccarini in Catania (Sicily). Applied Physics A.

interdisciplinary study of the "Deposition from the Cross" sculpture in Saint-Germain-en-Laye, France

Objectives:

- Dating and authenticating a mastic incrustation sculpture of unknown origin, but clearly related with the Romanesque masterpiece "Deposition from the Cross" by Antelami (Parma Cathedral, Italy)
- Identification of the materials of the mastic (pigments and extenders)
- Discussion of the identified materials with respect to the art historical and historical hypotheses
- Contribution to the preservation and valorisation of the sculpture

Outcomes:

- Vulgarisation

1. Round table on the Antelami haut-relief in the parish of Saint-Germain-en-Laye, 27/10/2017
2. Round table on the Antelami haut-relief in the parish of Saint-Germain-en-Laye, 02/02/2019
3. Educational panel to display the performed research and results (in preparation)

- Conference contributions

1. Geosciences for the environment, natural hazard and cultural heritage (Catania, Italy), 12–14 September 2018: Coccato A.; Mantovani L.; Ferrari R.; Bersani D.; Tribaudino M.; Lottici P.P. The Deposition from the cross in the church of Saint-Germain-en-Laye (France): a masterpiece of romanesque sculpture? Materials characterization to solve a 20th c. mystery. (oral)
2. Scientific Symposium Frontiers in Heritage Science in the framework of the World Meeting on Heritage, Sciences and Technologies (Paris, France) February 2019. Coccato A.; Mantovani L.; Ferrari R.; Bersani D.; Tribaudino M.; Lottici P.P. The Deposition from the cross in the church of Saint-Germain-en-Laye (France): a masterpiece of romanesque sculpture? Materials characterization to solve a 20th c. mystery. (poster)

- Publication

1. Coccato A.; Mantovani L.; Ferrari R.; Bersani D.; Tribaudino M.; Lottici P.P. The Deposition from the cross in the church of Saint-Germain-en-Laye (France): a masterpiece of romanesque sculpture? Materials characterization to solve a 20th c. mystery. (submitted to Journal of Cultural Heritage, revision in progress)

- Others

1. Report on preventive conservation strategies for the choice of optimal illumination in the framework of the renovation works in the parish church of Saint-Germain-en-Laye (in preparation)
2. Final report on the archaeometrical study and bibliography for the local archives (in preparation)

Projects on glassy materials of archaeological and gemmological interest

In situ Raman spectroscopic characterisation of the collection of glyptics in the museum Quinta das Cruzes, Funchal, Portugal

Objectives:

- Providing Raman spectroscopic data and combining them with the portable X-ray fluorescence results
- Evaluation of different excitations to study glassy materials in situ
- Re-assessment of the gemmological study on the basis of analytical techniques

Outcomes:

- Conference contribution:

1. Non-destructive and microanalytical techniques in art and cultural heritage (Catane, Italy), 2015: Lauwers, D.; Coccato, A.; Mirao, J.; Vandenabeele, P.; Candeias, A.Evaluation of portable Raman spectroscopy and handheld X-ray fluorescence spectroscopy for the analysis of glyptics. (poster)

- Publication

1. Lauwers, D.; Candeias, A.; Coccato, A.; Mirao, J.; Moens, L.; Vandenabeele, P.; 2016. Evaluation of portable Raman spectroscopy and handheld X-ray fluorescence analysis (hXRF) for the direct analysis of glyptics. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy.

KongoKing: Political centralization, economic integration and language evolution in Central Africa. An interdisciplinary approach to the early history of the Kongo kingdom. (ERC FP7)

Objectives:

- First analytical study of European-made trade glass beads from archaeological excavations in Central Western Africa
- Typological study and comparison with other trade beads
- Multi-analytical (Raman and XRF spectroscopies) characterisation of glass (transparent, white, yellow, red, green, blue, black)
- Understanding of the glass network (formers, stabilizers, flux) from the Raman spectra
- Identification of the colourants and opacifiers by a combination of molecular and elemental info
- Statistical data treatment of the elemental data to assess chemical grouping with respect to archaeological typologies
- Contribution to the dating and provenancing of the artefacts and to the knowledge on industrial and artisanal practices

Outcomes:

- Conference contributions:

1. 8th International Congress on the Application of Raman Spectroscopy in Art and Archaeology, Wroclaw, Poland, 2015: Coccato, A.; Rousaki, A.; Verhaeghe, C.; Clist, B.; Bostoen, K.; Vandenabeele, P.; Moens, L. Combined spectroscopic analysis of beads from the tombs of Kindoki, Mbanza Nsundi, Lower Congo. (oral)
2. 2nd International Conference on Innovation in Art, Ghent, Belgium, 2016: Coccato, A.; Rousaki, A.; Costa, M.; Clist, B.; Bostoen, K.; Vandenabeele, P. Combined historical, physical anthropology, archaeological, and archaeometrical approaches to understand glass beads from Kongo Central province, Democratic Republic of the Congo (DRC). (oral)
3. XII International GeoRaman Conference, Novosibirsk, Russia, 2016: Coccato, A.; Rousaki, A.; Costa, M.; Clist, B.; Bostoen, K.; Moens, L.; Vandenabeele, P. Raman (532 and 785 nm) study of glass beads from the Kongo Central province, Democratic Republic of the Congo (DRC). (poster)

4. Society of Africanist Archaeologists (SAfA) 23rd Biennial meeting, Toulouse, France, 2016: Costa, M.; Coccato, A.; Rousaki, A.; Verhaeghe, C.; Clist, B.; Bostoen, K.; Moens, L.; Mirão, J.; Vandenabeele, P. Analysis of beads from Congo by means of a non-destructive multi-analytical approach. (poster)
5. Non-Destructive and Microanalytical Techniques in Art and Cultural Heritage, Bilbao, Spain, 2017: Laforce, B.; Rousaki, A.; Coccato, A.; Barrocas Dias Teixeira da Costa, M.; Clist, B.O.; Karklins, K.; Bostoen, K.; Vekemans, B.; Moens, L.; Vincze, L.; Vandenabeele, P. Unraveling the composition of coloured glass by the comparison of complementary spectroscopic methodologies: the case of beads from the Kongo Kingdom. (poster)

- Publications

1. 2016: Rousaki, A.; Coccato, A.; Verhaeghe, C.; Clist, B.O.; Bostoen, K.; Vandenabeele, P. and Moens, L.; 2016. Combined Spectroscopic Analysis of Beads from the Tombs of Kindoki, Lower Congo Province (Democratic Republic of the Congo). Applied spectroscopy
2. 2017: Coccato, A.; Costa, M.; Rousaki, A.; Clist, B.; Karklins, K.; Bostoen, K.; Manhita, A.; Cardoso, A.; Barrocas Dias, C.; Candeias, A.; Moens, L.; Mirão, J.; Vandenabeele, P. Micro-Raman spectroscopy and complementary techniques (hXRF, VP-SEM-EDS, μ-FTIR, Py-GC/MS) applied to the study of beads from the Kongo Kingdom (Democratic Republic of the Congo). Journal of Raman Spectroscopy.

Projects on lithic materials of archaeological and gemmological interest

JADE. Grandes haches alpines du Néolithique européen du Morbihan à la Bulgarie, et de l'Irlande à la Sicile pendant les Ve et IVe millénaires av. J.-C.

Objectives:

- Multi-analytical study (Raman and IR spectroscopies, UV-Vis-NIR spectroscopy, ED-XRF, classical gemmology) of raw materials from alpine jadeitite and omphacitite quarries
- Identification of green lithotypes used in the making of axe heads during the Neolithic period
- Identification of gem-quality green stones
- Discussion on the best analytical techniques to differentiate between jadeite and omphacite (Raman spectroscopy vs. elemental analyses)

Outcomes:

- Conference contribution:

1. 7th International Congress on the Application of Raman Spectroscopy in Art and Archaeology (Ljubljana, Slovenia), 2013: Coccato, A.; Karampelas, S.; Wörle, M.; van Willingen, S.; Pétrequin, P. Identification of Neolithic jade found in Switzerland studied using Raman spectroscopy: Jadeite– vs. Omphacite– jade. (poster)

- Publication:

1. Coccato, A.; Karampelas, S.; Wörle, M.; Willigen, S. and Pétrequin, P.; 2014. Gem quality and archaeological green 'jadeite jade' versus 'omphacite jade'. Journal of Raman Spectroscopy

Raman spectroscopy for the quantitative analysis of garnets

Objectives:

- Optimization of a software to obtain the chemical composition of garnets in terms of end members based on the Raman spectroscopic features
- Acquisition of Raman spectra on garnets of known chemical composition (EMPA and SEM-EDS analyses)
- Understanding of the existing softwares, of the vibrational features of garnets and proposition of a novel approach
- Assessment of the software performance
- Use of the new software to non-invasively characterize garnets in archaeological objects (soapstone mill), and to study their provenance by comparison with geological reference materials

Outcomes:

- Conference contributions:

1. X International GeoRaman Conference (Nancy, France), 2015: Coccato, A.; Cerasoli, T.; Bersani, D.; Lottici, P.-P.; Salvioli-Mariani, E.; Conversi, R. Micro-Raman spectroscopy for quantitative analysis of garnets: application to the provenance study of artifacts in 'pietra ollare'. (oral)
2. 6th International Congress on the Application of Raman Spectroscopy in Art and Archaeology (Parme, Italy) 2011: Bersani, D.; Cerasoli T.; Coccato A. Characterization and provenance studies of garnet chlorite schist archaeological artifacts using micro-Raman spectroscopy. (poster)

Publications

- Coccato, A.; Mantovani, L.; Ferrari, R.; Bersani, D.; Tribaudino, M.; Lottici, P.P. The Deposition from the cross in the church of Saint-Germain-en-Laye (France): a masterpiece of romanesque sculpture? Materials characterization to solve a 20th c. mystery. (submitted to Journal of Cultural Heritage, revision in progress)
- Coccato, A.; Costa, M.; Rousaki, A.; Clist, B.; Karklins, K.; Bostoen, K.; Manhita, A.; Cardoso, A.; Barrocas Dias, C.; Candeias, A.; Moens, L.; Mirão, J.; Vandenabeele, P.; 2017. Micro-Raman spectroscopy and complementary techniques (hXRF, VP-SEM-EDS, μ-FTIR, Py-GC/MS) applied to the study of beads from the Kongo Kingdom (Democratic Republic of the Congo). Journal of Raman Spectroscopy (in press).
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- Coccato, A.; Vekemans, B.; Vincze, L.; Moens, L. and Vandenabeele, P.; 2016. Pigment particles analysis with a total reflection X-ray fluorescence spectrometer: study of influence of instrumental parameters. Applied Physics A, 122(12), p. 1051.
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- Lauwers, D.; Candeias, A.; Coccato, A.; Mirao, J.; Moens, L. and Vandenabeele, P.; 2016. Evaluation of portable Raman spectroscopy and handheld X-ray fluorescence analysis (hXRF) for the direct analysis of glyptics. SpectroChemistry Acta Part A: Molecular and Biomolecular Spectroscopy, 157, p. 146.
- Rousaki, A.; Coccato, A.; Verhaeghe, C.; Clist, B.O.; Bostoen, K.; Vandenabeele, P. and Moens, L.; 2016. Combined Spectroscopic Analysis of Beads from the Tombs of Kindoki, Lower Congo Province (Democratic Republic of the Congo). Applied spectroscopy, 70(1), p.76.
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Contributions to conferences

Orals

- 2018: Geosciences for the environment, natural hazard and cultural heritage (Catania, Italy),
  Coccato, A.; Mantovani, L.; Ferrari, R.; Bersani, D.; Tribaudino, M.; Lottici, P.P. The Deposition from the cross in the church of Saint-Germain-en-Laye (France): a masterpiece of romanesque sculpture? Materials characterization to solve a 20th c. mystery.
- 2016: 2nd International Conference on Innovation in Art (Ghent, Belgium)
  Coccato, A.; Rousaki, A.; Costa, M.; Clist, B.; Bostoen, K.; Vandenabeele, P. Combined historical, physical anthropology, archaeological, and archaeometrical approaches to understand glass beads from Kongo Central province, Democratic Republic of the Congo (DRC).
- 2015: 8th International Congress on the Application of Raman Spectroscopy in Art and Archaeology (Wroclaw, Poland)
  Coccato, A.; Rousaki, A.; Verhaeghe, C.; Clist, B.; Bostoen, K.; Vandenabeele, P.; Moens, L. Combined spectroscopic analysis of beads from the tombs of Kindoki, Mbanza Nsundi, Lower Congo.
- 2014: ICDI Symposium – Mechanisms of Innate Immunity, Cell Death and Inflammation (Ghent, Belgium)
  Vandenabeele, P.; Coccato, A.; Lauwers, D.; Rousaki, A.; Moens, L. Archaeometrical Study of the Ghent Altarpiece
- 2014: XI International GeoRaman Conference (St. Louis, USA)
  Vandenabeele, P.; Van Pevenage, J.; Lauwers, D.; Coccato, A.; Rousaki, A.; Lycke, S.; Moens, L. In situ Raman analysis: the ultimate solution for archaeometry?
- 2012: X International GeoRaman Conference (Nancy, France)
  Coccato, A.; Cerasoli, T.; Bersani, D.; Lottici, P.-P.; Salvioli-Mariani, E.; Conversi, R. Micro-Raman spectroscopy for quantitative analysis of garnets: application to the provenance study of artifacts in "pietra ollare".

Posters

- 2019: Scientific Symposium Frontiers in Heritage Science, in the framework of the World Meeting on Heritage, Sciences and Technologies (Paris, France)
  Coccato, A.; Mantovani, L.; Ferrari, R.; Bersani, D.; Tribaudino, M.; Lottici, P.-P. The Deposition from the cross in the church of Saint-Germain-en-Laye (France): a masterpiece of romanesque sculpture? Materials characterization to solve a 20th c. mystery.
- 2017: Non-Destructive and Microanalytical Techniques in Art and Cultural Heritage (Bilbao, Spain)
  Laforce, B.; Rousaki, A.; Coccato, A.; Barrocas Dias Teixeira da Costa, M.; Clist, B.O.; Karklins, K.; Bostoen, K.; Vekemans, B.; Moens, L.; Vincze, L.; Vandenabeele, P. Unraveling the composition of coloured glass by the comparison of complementary spectroscopic methodologies: the case of beads from the Kongo Kingdom.
- 2016: 4th International Congress Chemistry for Cultural Heritage (Brussels, Belgium)
  Coccato, A.; Moens, L. Vandenabeele, P.; On the sensitivity of pigments towards climatic factors and various pollutants: a review.
  Rosier, F.; Dubois, H.; Van der Snickt, G.; Sanyova, J.; Coudray, A.; Glaude, C.; Janssens, K.; Lauwers, D.; Coccato, A.; Vandenabeele, P. Identification of restorations on the Cumean Sibyl of the brothers Van Eyck's Ghent Altarpiece (1432)
- 2016: Society of Africanist Archaeologists (SAfA) 23rd Biennial meeting (Toulouse, France)
  Costa, M.; Coccato, A.; Rousaki, A.; Verhaeghe, C.; Clist, B.; Bostoen, K.; Moens, L.; Mirão, J.; Vandenabeele, P. Analysis of beads from Congo by means of a non-destructive multi-analytical approach.
- 2016: XII International GeoRaman Conference (Novosibirsk, Russia)
  Coccato, A.; Rousaki, A.; Costa, M.; Clist, B.; Bostoen, K.; Moens, L.; Vandenabeele, P. Raman (532 and 785 nm) study of glass beads from the Kongo Central province, Democratic Republic of the Congo (DRC).

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- 2016: 2nd International Conference on Innovation in Art (Ghent, Belgium)
  Coccato, A.; Vekemans, B.; Vincze, L.; Moens, L.; Vandenabeele, P. Optimization of Total Reflection X-ray Fluorescence analysis of pigments.
  Gomes, S.; Lorena, M.; Vandenabeele, P.; Lauwers, D.; Coccato, A.; Valadas, S.; Candeias, A. Green colour in the 16th century Portuguese paintings of the Funchal's Cathedral altarpiece.
  Barone, G.; Bersani, D.; Coccato, A.; Lauwers, D.; Mazzoleni, P.; Raneri, S.; Vandenabeele, P.; Manzini, D.; Agostino, G.; Neri, N.F. Non-destructive Raman investigations on wall paintings at Sala Vaccarini in Catania (Sicily).
- 2015: 8th International Congress on the Application of Raman Spectroscopy in Art and Archaeology (Wroclaw, Poland)
  Coccato, A.; Moens, L. Vandenabeele, P. Raman database of green pigments
  Rousaki, A.; Coccato, A.; Bellelli, C.; Carballido Calatayud, M.; Palacios, O.; Custo, G.; Moens, L.; Vandenabeele, P.; Vázquez, C. Micro-Raman analysis of prehistoric rock art in Patagonia (Argentina).
- 2015: Non-destructive and microanalytical techniques in art and cultural heritage (TECHNART) (Catania, Italy)
  Coccato, A.; Rousaki, A.; Moens, L. Vandenabeele, P. Optimization of TXRF for the analysis of paint samples.
  Lauwers, D.; Coccato, A.; Mirao, J.; Vandenabeele, P.; Candeias, A. Evaluation of portable Raman spectroscopy and handheld X-ray fluorescence spectroscopy for the analysis of glyptics.
- 2014: XI International GeoRaman Conference (St. Louis, USA)
  Coccato, A.; Jehlicka, J.; Moens, L. Vandenabeele, P. Raman spectroscopy for the investigation of carbon-based black pigments.
- 2014: Chemistry Conference for Young Scientists (Blankenberge, Belgium)
  Coccato, A.; Lauwers, D.; Moens, L.; Vandenabeele, P. The multidisciplinary study of the Ghent altarpiece: analytical chemistry and art.
  Lauwers, D.; Coccato, A.; Candeias, A.; Mirão, J.; Moens, L.; Vandenabeele, P. Archaeometrical study of the main altarpiece of the cathedral of Funchal (Madeira).
- 2013: MEMORI Conference (Madrid, Spain)
  Coccato, A.; De Laet, N.; Lycke, S.; Van Pevenage, J.; Moens, L.; Vandenabeele, P. Raman study of pigment degradation due to acetic acid vapours.
- 2013: 7th International Congress on the Application of Raman Spectroscopy in Art and Archaeology (Ljubljana, Slovenia)
  Coccato, A.; Karampelas, S.; Wörle, M.; van Willingen, S.; Pétrequin, P. Identification of Neolithic jade found in Switzerland studied using Raman spectroscopy: Jadeite- vs. Omphacite- jade.
  Coccato, A.; Moens, L. Vandenabeele, P. Raman spectroscopic investigation of black pigments.
  Coccato, A.; De Laet, N.; Lycke, S.; Van Pevenage, J.; Moens, L.; Vandenabeele, P. Raman study of pigment degradation due to acetic acid vapours.
- 2011: 6th International Congress on the Application of Raman Spectroscopy in Art and Archaeology (Parma, Italy)
  Bersani, D.; Cerasoli T.; Coccato A. Characterization and provenance studies of garnet chlorite schist archaeological artifacts using micro-Raman spectroscopy

Activities

Participation to courses and workshops

- 2017: 2nd IperionCH summer school, C2RMF (Paris, France)
- 2016 – 2017: Course of French conversation (level 8 - 9), Centrum voor Volwassenenonderwijs "Het Perspectief" (Ghent, Belgium)
- 2015: Introductory statistics. Basics of statistical inference, Institute for Continuing Education in Science – Center for Statistics, Ghent University (Ghent, Belgium)
- 2014 – 2015: Course of Dutch language (levels 1 - 5), Centrum voor Volwassenenonderwijs "Het Perspectief" (Ghent, Belgium)
- 2014: Cluster analysis, PCA and factor analysis, Katholieke Universiteit Leuven (Leuven, Belgium)
- 2014: 8th From PhD to Job market - Humanities and Social Sciences, workshop organized by the Doctoral School of Arts, Humanities and Law, Faculty of Arts and Philosophy, Ghent University (Ghent, Belgium)
- 2014: Personal Effectiveness, workshop organized by the Doctoral School of Arts, Humanities and Law, Faculty of Arts and Philosophy, Ghent University (Ghent, Belgium)
- 2013: Course X-ray and Laser Spectroscopy, Master of Chemistry, Prof. Dr. L. Vincze, Ghent University (Ghent, Belgium)
- 2013: Painting Techniques of the Flemish Primitives, workshop organized by the Doctoral School of Arts, Humanities and Law, Faculty of Arts and Philosophy, Ghent University (Ghent, Belgium)
- 2013: Advanced Academic English: Conference Skills - Effective Slide Design, workshop organized by the Doctoral School of Arts, Humanities and Law, Faculty of Arts and Philosophy, Ghent University (Ghent, Belgium)
- 2012: II School of Raman spectroscopy in Earth Science, Università Milano-Bicocca (Milan, Italy)
- 2010: Course in preparation for the TOEFL certification, Centro Linguistico di Ateneo, Università degli Studi di Parma (Parma, Italy)

Teaching

- Supervision of a professional bachelor internship
  - 'Optimization of sample pretreatment procedures for TXRF analysis for archaeometrical applications: a case study on Yustyd dwelling soil samples.' Joyce Vaerewyck (2013-2014)
- Supervision of practical activities, Department of analytical chemistry, Ghent University, Belgium
  - 'Analysis and Abatement of water pollution' (Master 'Environmental Sanitation', 2013–2014)
  - 'Raman spectroscopy: an ideal tool in the recycle business?' (Bachelor project, 2013–2014 and 2015–2016)

Vulgarisation

- 2017 - present: activities linked to the research project on the Deposition from the Cross in St-Germain-en-Laye.
- 2016: Beni Culturali: Tutela – Valorizzazione – Conservazione. La legge e la scienza. Magni D.; Coccato, A. (Università delle Tre Età, Lonate Pozzolo, Italy)
- 2015 — 2016: participation to the outreach activities of the Department of Analytical chemistry of Ghent University (Open door days, Day of Science).

Others

Associazione Nazionale degli Esperti di Diagnostica e di Scienze e Tecnologie Applicate ai Beni Culturali - ANEDbc (2016, 2017, 2018)

Skills

Organizational skills

- Good planning skills for both short and long termed projects, as the preparation of university exams, of publications and written reports, to respect the set deadlines.
- Experience in preparing and planning measurement campaigns outside the lab, including the practical aspects (transport of the instrument and positioning system, availability of power supplies, safety measures to be taken, etc.).
- Participation in the organization of international conferences, with tasks mainly related to the registration of the participants and logistics.
- Ability to work in a team, and to split the tasks according to personal skills. The experience in team work was achieved in performing complex research projects, and in the organization of conferences.
- Knowledge of personal effectiveness instruments, such as the Pomodoro technique, use of online calendars and apps to improve productivity, etc.

Practical/technical skills

- Experience in the use of non-destructive techniques to obtain complementary data on the studied materials.
    - Technique of choice: Raman spectroscopy
    - Complementary techniques (in order of familiarity): XRF, XRD, FT-IR spectroscopies, UV-Vis and photoluminescence spectroscopies.
- Experience in the operation of portable instrumentation, Raman and XRF, including preparation of the measurement setup (tripods, mechanical systems, counterweights, etc.).
- Basic experience of chemical laboratory practice, which is strictly related with the preference for non-invasive and non-sample-consuming techniques.
- Experience in the study of pure pigments, degraded pigments, glassy materials, lithic materials and stratified materials such as paintings (bulk and surface non-invasive analysis; study of cross sections).
- Acquisition of a critical mindset regarding the possibilities and drawbacks of the used techniques in relation to the studied material and to the research question, and when cross-checking and combining information from different techniques (molecular vs. elemental, surface vs. bulk, sensitivity, etc.).
- Planning and organization skills, both for research to be conducted inside the lab and for measurement campaigns on site (museums, historical buildings).
- Awareness of safety issues related to the use of lasers and ionizing radiation.

Communication skills

- Good communication skills in Italian and in English, thanks to the experience as undergraduate and PhD student: written exams, final theses, brief and extended analytical reports, reports for the European Commission, scientific papers for peer review; oral exams, lectures and trainings to undergraduate and graduate students, communication with the lay public, oral presentations at conferences.
- Experience in sharing the results with colleagues from different disciplines. Experience in sharing relevant information with co-workers to contribute to their personal development and autonomy in their tasks.
- Experience in sharing the knowledge in the form of training students and new colleagues.
- Experience in the preparation of slides to effectively support the speech, and of posters, thanks to specific courses of the Doctoral Schools (Ghent University), and to valuable feedback from experienced colleagues.
- Ability to control the stress related to speaking in public.

Annex: Summary and conclusions of the doctoral thesis

"Application of Raman and X-ray fluorescence spectroscopies to Cultural Heritage materials. The non-destructive examination of paintings, pigments and their degradation" Ghent, Belgium - 16/05/2017

This thesis focusses on the analytical investigation of the material aspects of polychrome objects from our Cultural Heritage. Pigments are the main objective of this study, for many reasons, which will be summarized in the next paragraphs.

First of all, polychrome objects, such as paintings, constitute a great deal of our Cultural Heritage. While carrying symbolic, aesthetic, cultural values, these objects are made of matter. This aspect is often underestimated, as paintings are regarded mainly as two-dimensional images.

However, the material composition of polychrome artefacts, which can be simplified in support/binders and varnishes/pigmenting agents, depends on cultural, social, political and economic factors. In fact, the commissioner's ideas and wealth, cultural environment, traditional artisanal practices, and the painter's skills are all affecting and shaping the appearance of the object.

The choice and handling of pigments has art historical, technical, social, cultural, etc. implications (Chapter 1). The understanding of the material aspects of polychromies, including a precise identification of the used pigments, based on chemical characterization, here achieved non-destructively, is a powerful tool to appreciate social, economic and cultural assets in the past.

Moreover, for the purpose of preservation and conservation of our Cultural Heritage, it is important to study degradation processes (Chapter 2), so that they can be understood, and actions can be taken to limit, stop, and prevent further damage, in order to preserve the masterpieces for future generations.

It appears that, after these considerations, the boundary between material science, conservation and art history is dissolving, and offers the chance to contribute to answer questions about chronology, authentication, creative process, material history and preservation of our Cultural Heritage (Table 1.1). It is important to note that a clear statement of the research question is fundamental in defining and guiding the analytical approach. For example, elemental techniques cannot be used to distinguish between the two titanium whites anatase (after 1923) and rutile (after 1947) (see Table 3.2), while they can successfully detect titanium, and point out the presence of a modern overpaint (Sub-chapter 3.3). Another example can regard the need for the characterization of the top-layer (including overpaints), in contrast to the investigation of hidden paint layers (support, underdrawing, pentimenti, original layer under overpaints (Sub-chapter 3.3)).

Moreover, as our Cultural Heritage is irreplaceable, the range of analytical approaches that can be exploited is limited. In fact, sampling is not always permitted, and transportation of the object to a laboratory is not always feasible, or allowed. According to the type of information needed to answer the research question, non-invasive and non-destructive analysis have to be preferred. Moreover, thanks to the development of mobile instrumentation, direct analysis becomes possible inside the laboratory, and even in situ.

Non-destructive analysis, although sometimes requiring a minute sample, offer the possibility of a multi-technique study, that allows cross-checking the results, and the optimization of the extracted information. Non-invasive analysis is performed without sampling and without measurement-related damage, therefore the object's integrity is fully safeguarded. Direct analysis, finally, is in principle non-invasive, with the added values of minimizing the risks related to the transportation and handling of precious objects, and of allowing the study of unmoveable objects (e.g. wall paintings). A multi-technique approach is also always recommended, to optimize the characterization.

Nevertheless, the material characterization alone cannot be sufficient, as the chemical information needs to be combined and included in the bigger picture, together with the knowledge from humanities, history and social sciences. Communication among experts from these different fields is a critical point. The required commitment is noteworthy from all sides, but the achievable results, in terms of interdisciplinary study of a work of art, seem worth the effort.

The reasons why paintings should be regarded and studied as unique and irreplaceable material entities by using an interdisciplinary approach were discussed in Chapter 1, while Chapter 2 focussed on the materials under investigation in this thesis, which are pigments in use during the Middle Ages, with specific attention to their sensitivity to degradation.

Chapters 3, 4 and 5, on the other hand, give some insights on how to perform minimally-invasive non-destructive, non-invasive and direct analysis to achieve the characterization of pigments.

The techniques of choice (XRF and Raman spectroscopies, Chapters 3 and 4, respectively) are well known in the field of archaeometry, for their effectiveness in providing useful results, their versatility in tackling a variety of research questions, and the possibility of performing direct analysis by means of mobile instrumentation. They are used for studying pigments and paintings, alone (Chapters 3 and 4) or in combination (Chapter 5), and specific advantages and pitfalls can be highlighted in this thesis.

To begin with, handheld X-ray fluorescence (hXRF) analyses are performed on supposedly overpainted areas of the outer wings of the Ghent Altarpiece (Sub-chapter 3.3). The detection of elements such as Ti, Cr, Zn confirmed the presence of overpaint. However, this information was not sufficient for the conservators, who needed to know as well the spatial distribution of the overpaints, as well as the conservation state of the underlying paint layers. HXRF can provide quickly nondepth-specific elemental results, but it is not sufficient in the framework of a conservation treatment. In that case, the participation of University of Antwerp, with their macro-XRF scanning system, allowed the successful implementation of the preliminary results into the conservation practice.

A different application of elemental techniques for the study of pigments is based on total-reflection XRF (TXRF, Sub-chapter 3.4). Although this approach requires a (minute) sample, it allows for quantification of major, minor and trace elements. However, the quantification technique is optimised for liquid samples, which is not the case of pigment grains sampled on precious polychrome objects. These non-conventional samples require specific measures in order to achieve results. Moreover, the quantification step is investigated by comparing the results of commercial software with those from calculations. This work provides preliminary observations for the successful application of TXRF for (quantitative) pigment analysis.

These two examples of use of XRF analysis for the study of Cultural Heritage materials prove the effectiveness of these techniques for answering specific research questions, like the identification of pigments based on key elements. However, they might not be sufficient, as in the characterization of green and black pigments, and of degradation processes. In these cases, molecular and structural aspects need to be considered as well, as the elemental information obtained by means of XRF is not always adequate to identify the materials positively, and additional analyses are necessary (Sub-chapter 3.5).

In some of these cases, Raman spectroscopy proves to be a much better tool to tackle pigments characterization; however, it is important to have access to databases of reference spectra for comparison. During this research project, it was observed that, on the one hand, the variety of green pigments available to artists through time was much wider than what expected (i.e. green earths, malachite, verdigris, see Chapter 2) based on scientific analysis of paintings. On the other hand, although Raman spectroscopy is well suited for discriminating among different green salts, a coherent database for the archaeometrist was still missing (Paragraph 4.3.1). The collected Raman spectra (including the instrumental parameters used) are made available to the community, for facilitating the identification of green materials. Moreover, we show, through the study of a paint sample, how the identification of pigments by comparison with reference spectra needs to be tackled cautiously, as different instrumental set-ups and parameters affect the recorded spectra.

Next to the creation of a database of green materials, a wide range of carbonbased black pigments is studied (Paragraph 4.3.2), to evaluate the use of Raman spectroscopy to obtain a greater extent of information about the nature of the used black pigment (raw material, degree of disorder, etc.). In this case, geological literature is the starting point, but nomenclature issues are tackled with respect to the archaeometrical context of this research. Some guidelines to better understand the type of carbon under investigation are provided. However, often fluorescence due to the presence of organic binders hampers the interpretation.

Finally, thanks to the molecular sensitivity of Raman spectroscopy, it is possible to confirm the suggested reaction pathways, and to identify the occurrence of degradation, even if it does not affect the optical properties (i.e. colour) of the materials (Paragraph 4.3.3). The study of pigment degradation upon exposure to acetic acid is completed, and the lowest doses of acetic acid to cause the appearance of detectable amounts of degradation products are converted to safety thresholds for the studied pigments. It is however important to note that pigments are rarely directly exposed to the atmosphere, due to the presence of binders and varnishes. These materials, as well as others of relevance for Cultural Heritage, were also studied in terms of acetic acid sensitivity during the MEMORI project, to help museum curators in identifying potentially harmful conditions for complex objects, based on the most sensitive material.

Next to the use of laboratory instruments, a portable Raman spectrometer was used to study the Altarpiece in Funchal, Portugal. Direct access to the paintings was ensured by scaffoldings. Positioning and focusing was achieved by holding the probehead by hand, and the environmental light interference was minimized thanks to the use of light blockers. The measurements were performed during the conservation campaign, which included the possibility of analysing unvarnished areas. Direct Raman analysis proved successful in the study of the painter's palette, with the exception of the green pigment. Although green copper-based pigments give better results when excited with a green laser compared to a red one (see Paragraph 4.3.1), the fluorescence due to the organic binder overwhelms any present Raman band. The use of the red laser, although reducing the fluorescence, is also not effective for this task, which remains a challenge for in situ Raman spectroscopy. XRF analyses performed on the same spot can help in identifying the used materials, but the full characterization of the pigments, as well as of the stratigraphic structure, was finally achieved on cross sections.

So far, it appears that hXRF is a fast technique, suitable for in situ measurements, which supports the identification of pigments based on the presence of key elements, while it cannot provide information about the composition of single layers, due to the penetrating power of this radiation (Subchapter 3.3). On the other hand, TXRF can allow for quantification of major, minor and trace elements, but it requires a sample. XRF techniques are not sensitive to low Z elements, like carbon, and do not allow for the identification of the compound (Sub-chapter 3.4).

Then again, Raman spectroscopy is successfully used to characterize a variety of compounds used in works of art, including pigments but excluding metals. The availability of databases is crucial to successfully identify the materials (Paragraph 4.3.1 and 4.3.2). Raman spectroscopy is a sensitive, specific, and versatile technique, which can be used as well to monitor and understand degradation processes (Paragraph 4.3.3), but it suffers from fluorescence from the binders and varnishes, and from interferences from environmental light, in case of direct analysis. These two aspects need to be kept in mind, as better results are obtained if the varnish is removed (or thinned, as during conservation treatments), and when stray light is somehow blocked (Paragraph 4.4.1 and Sub-chapter 5.1). Moreover, the combination of the molecular information obtained by means of Raman spectroscopy with complementary data (e.g. elemental) improves significantly the success rate of material identification.

XRF and Raman spectroscopic techniques can be considered as complementary from different points of view: they provide, respectively, elemental and molecular information, and information from a certain volume (including underlaying layers) and from the surface only; one is sensitive to heavierelements (Z>12), while the other to compounds (Chapter 5).

The combined use of the two techniques is, therefore, even more powerful in the characterization of materials present in Cultural Heritage materials. In fact, this is exemplified by the study of painted frames of the Ghent Altarpiece (Subchapter 5.1). HXRF analyses confirmed the presence of precious metals (Ag) in the original frames of the Ghent Altarpiece, and the use of a cheaper bronze-like paint in the restored parts. By means of Raman spectroscopy, the used pigments are characterized in both, the original and restored areas.

As a final consideration, the possibility of non-invasively obtaining information on different aspects of the polychromy, by means of XRF and Raman spectroscopies, is extremely valuable before, during, and after a conservation treatment. The characterization of the materials used for obtaining the illusionistic effects that

leave us speechless in front of a masterpiece is a valuable tool to appreciate the object in its material aspects as well.

On the one hand, as it concerns the progress in the analytical techniques, and their application to Cultural Heritage materials, it seems that direct analysis can be of great help in this field of research. The availability of macro-XRF scanners, which allow for obtaining the elemental distribution images, is pushing forward to the development of analogous systems for Raman spectroscopy. However, the issues of binder/varnish fluorescence, the need for accurate positioning and focussing, and the time needed for the analysis are all major aspects to tackle before in situ Raman mapping can become an established technique. Some devices and concepts are already available (longer wavelength lasers to reduce fluorescence, and sensitive detectors in the infrared region; spatially-offset Raman spectroscopy (SORS) to investigate layers underneath the surface), and will likely support this advancement in the future. SORS could also help in investigating the underdrawings, but as the pigmented layers on top of it are inhomogeneous, and the layered structure complex (in terms of materials, number and thickness of layers), this might pose additional challenges, which require further research.

Finally, as it regards pigments identification, accessible databases of reference spectra will help the archaeometrist in correctly identifying the materials. However, it will be fundamental to provide spectra recorded with a variety of laser excitations, as well as the instrumental parameters and measurement details, as these are likely to affect the Raman spectrum, as shown in Chapter 4. Also, considering the increase in number of reference spectra, to facilitate identification, the creation of searching algorithms and auto-identification softwares seems an interesting aspect to consider. The cooperation with engineers and computer science experts will expand once again the range of subjects involved in this interdisciplinary approach, advancing the chances of successfully identifying the materials, and limiting the time needed for it. On the other hand, for the study of pigments degradation, Raman spectroscopy can be successfully applied to explore a variety of processes involving molecular and structural changes.

In all cases, the possibility of in situ analyses can enhance the impact of the chemical information on the overall understanding of a work of art, including conservation approaches.

On the other hand, the understanding of artisanal practices, technological skills, and painter's mastery in handling materials, is a fascinating, complex, yet underestimated field of research. It requires a multifaceted, interdisciplinary approach that includes the knowledge of painting materials, their properties and reactivity, of technical art history, of the type of questions that might arise when investigating our Cultural Heritage, and of the analytical techniques that are suitable to tackle a specific subject. Again, the communication among the different fields of expertise is necessary, in order to achieve a complete and detailed understanding of the masterpiece as a whole.

I am convinced that any further development in archaeometry and conservation science will only be possible if all parties agree on making the effort to understand each other, and share the knowledge, as this can only improve the depth and completeness of our understanding of works of art.

Jury members: dr. Kepa Castro Ortiz de Pinedo (University of the Basque Country, Faculty of Science & Technology); dr. Claudia Conti (Istituto per la Conservazione e la Valorizzazione dei Beni Culturali, Milano); Prof. dr. Philippe Crombé (Ghent University, Department of Archaeology); Prof. dr. Wim De Clercq (Ghent University, Department of Archaeology); Prof. dr. José António Paulo Mirão (University of Évora, HERCULES laboratory/Department of Geosciences); Prof. dr. Maximiliaan Martens (Ghent University, Department of Art, music and theatre sciences); Prof. dr. Jean Bourgeois (Ghent University, Department of Archaeology).