THE MATERIALS AND PAINTING TECHNIQUES OF GIULIO ARISTIDE SARTORIO IN THE PICTORIAL CYCLE "THE POEM OF HUMAN LIFE"(1906-07): KNOWLEDGE AND PREVENTION FOR A MUSEUM DISPLAY PROJECT

Francesca Caterina Izzo, Elisabetta Zendri●, Eleonora Balliana, Laura Falchi
Department of Environmental Sciences, Informatics and Statistics, Ca' Foscari University of Venice

Matteo Piccolo, Silvio Fuso
Fondazione Musei Civici Venezia, Galleria Internazionale d'Arte Moderna di Ca' Pesaro, Venice

Henk van Keulen
Cultural Heritage Agency, the Netherlands

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1. Introduction and research aim

In the spring of 1906 Giulio Aristide Sartorio (1860-1932) accepted to create a large series of paintings on canvas to be placed in the Central Hall of the Venice Biennale of 1907: "The Poem of Human Life". The artist proposed a highly dramatic view of human existence divided into four main scenes – called *Light*, *Darkness*, *Love*, *Death* – interspersed with ten vertical panels (the *Caryatids*). The complex iconography presented by Sartorio appears as a synthesis of the Mediterranean world and Northern culture. Free of architectural elements and worked in monochrome, the painting cycle stands out due to the exceptional arrangement of its figures in movement (Figure 1) [1].

The works of Aristide Sartorio are of considerable interest, both for their undoubted artistic value and for the particular technique used in the preparation of the painted layers. For this pictorial technique the artist used traditional procedures which he adapted to the new demands of his time; it is the latter that are the starting point in the search for suitable exhibition solutions for the entire cycle.

To complete the 240 m^2 of the cycle in just nine months, Sartorio used a special painting technique, described by the author as "...a mixture of wax, mineral turpentine and oils..called French encaustic…" [2,3] which enabled the painting to be completed in a very short time. Sartorio was known to work with home-made mixtures of oil paints (mixed with pigments and prepared himself in his studio) with the addition of several waxes, natural resins, mineral spirits and gums. His brushstrokes appear fluid and the resulting painted layers are characterised by a certain thickness (in some cases more than 2 cm); he did not apply any final layers of varnish (Figure 2).

● Corresponding author: elizen@unive.it

The artist's declarations represent important documentation regarding the use of specific materials which, although showing relative stability with the passing of time, may be significantly affected by exposure conditions of the artworks.

This cycle has experienced a complicated history of conservation since it was first moved. At the end of 1906, a few months after their completion, the canvases were sent by train from Rome to Venice; they were all installed just before the opening of the "Biennale D'Arte" exhibition (1907) and remained in situ until the following edition (1909). The works were later transferred to Ca' Pesaro, home of the International Gallery of Modern Art in Venice. In 1938, the entire cycle was transported to the National Gallery of Modern Art in Rome, where it remained until the early 1950s, before returning to Ca 'Pesaro. These frequent transfers (as well as subsequent ones), obviously implied the folding and rolling up of the canvases.

Figure 1. Giulio Aristide Sartorio, "The Poem of Human Life" (1906-07) – Light, cm 503x646, International Gallery of Modern Art Ca' Pesaro, Venice

In the museum of Ca 'Pesaro the paintings were only partially exhibited, up until the mid-1980s. They were probably displayed on different occasions and subsequently underwent some pictorial integration work, which included the mounting of new wooden frames. In 1995, the entire cycle was exhibited on the second floor of the museum, where it remained even after these rooms were transformed into an interim storage area for works of art (1996-2009). During this period, the cycle of paintings were barely accessible and exposed to inappropriate environmental conservation conditions - a large amount of dust, due to the presence of wooden structures, the poor state of the windows and clutter in the storage space, due to other construction and maintenance materials.

Figure 2. details of the painting technique from the "Darkness" panel, in which the fluidity of the paint/brushstrokes and the thickness of the resulting painted layers are appreciable.

When in 2011 the works were "liberated", different degradation phenomena were observed: small lacunae in the pictorial layers; the presence of large brown spots of fungal origin; wide-spread craquelures; efflorescence; the flattening and the thinning of the paint layers and damage to the wooden frames.

A conservation and maintenance project was needed to protect and make Sartorio's paintings freely accessible.

Today this extraordinary cycle of paintings is located in the new storage area of the Museum, where the environmental parameters (humidity, temperature, ozone level, light) in the deposit have been set in accordance with optimal conservation conditions as established by Italian legislation for the conservation of cultural heritage [4,5]; thus, they are constantly monitored. The cycle is currently undergoing necessary maintenance work and is anxiously awaiting to be returned to Ca' Pesaro to be exhibited.

The aims of the research are:

- to study the materials and the painting technique used by Sartorio in the pictorial cycle and to compare the obtained results with the artist's declarations;

- to identify the ideal conditions for its conservation and in addition suggest methods for monitoring its conservation state which can easily be managed while the cycle is on exhibition in the Museum.

2. Experimental stage

2.1. Preliminary observations of the cycle

A preliminary evaluation of the morphology of the pictorial layers and the state of conservation was performed by observing the different panels with visible light, oblique light, and ultraviolet light with the aid of the contact digital microscope Dino Lite 413TL-X (magnification 25-250 x) equipped with visible and ultraviolet light.

2.2. Sampling

Micro-fragments from the painted layers and the canvases were taken from the artworks for further laboratory examination. Some overpainted areas were sampled as well. Table 1 reports the number and type of samples taken from the pictorial cycle.

During this phase, only the four main scenes - *Light*, *Darkness*, *Love*, *Death* – were sampled, considering both the superior and the inferior panels which compose each single scene.

Table 1: typology of samples taken from the four panels

	Typology and number of microsamples		
Panel	Canvas/ground layer	painted layers	degraded/ overpainted areas
Darkness	2	5	2
Light	3	6	4
Death	2	5	4
Love	1	7	3

2.3. Analytical techniques

The pictorial fragments were analyzed to investigate the composition of the materials used by Sartorio, but also to identify the presence of any alteration products in the original layers and to detect any restoration materials used during the troubled conservative history of the panels.

The samples were firstly observed with an Olympus SZX16 optical microscope equipped for microphotography both in visible and UV light. Polished cross-sections of the samples considered to be the most significant were also prepared and then observed with a JEOL JSM 5600 LV scanning electronic microscope coupled with an OXFORD-Link Isis series 300 microanalysis system for elemental microanalysis(SEM-EDX).

X-ray fluorescence (XRF) analyses were carried out using a Minipal Philips XRF instrument, equipped with a low power Rh-tube operating at 40 kV and 2.2 μA and a peltier cooled Si-PIN detector.

Fourier-transform Infrared spectrometry was performed with a Thermo Nicolet Nexus 670 FTIR spectrophotometer combined with a Smart Orbit Single Reflection Diamond ATR accessory, from 4000 to 400 cm^{-1} for 64 scans with 4 cm^{-1} resolution.

The Gas Chromatography-Mass Spectrometry (GC-MS) analyses were performed with a Thermo Quest GC-8000 instrument with a Supelco column Equity®-5, 30 m, 0.25 mm, 0.5 μm interfaced with MS MD-800. The temperature program was set from 120°C to 300°C with a ramp of 10°C/min, held for 3 minutes. The inlet temperature was 300°C, the MS interface was at 270°C. The MS was run in Full Scan mode (m/z 40-600), 1.9 scans/sec. Solvent delay was set at 4.5 min. The transfer line was at 240°C and the source temperature at 220°C. Electron Ionisation (EI) energy was 70eV. Samples were prepared using m-(trifluoromethylphenyl) trimethyl-ammonium hydroxide and left to react overnight [6,7].

3. Results and discussion

3.1. Preliminary observations and determination of the state of conservation

3.1.1. Painted layers

The paint layers, as stated by the artist, were obtained by dispersing pigments in a mixture of wax, turpentine and poppy oil [2]. Although it was assumed that this would make the painting more elastic, this technique in fact produced a very dry stiff film of paint. However, even if the paint surfaces present widespread and often extensive craquelure, there do not seem to be any relevant detachments of the paint layer from the canvas, leaving only the problem related to the stiffness of the paint film itself.

The fractures on the pictorial surface are widespread, and are described by Sartorio himself as “cracks in the colours” (figure 3 a and b). The “cracks” are particularly evident in the areas painted with dark colours, but they are also present in the lighter areas. These fractures might, in part, be due to the paintings being rolled up or on rollers when they were transported from Rome to Venice in 1907, just after their execution. On the surface of the painting, the marks left from the materials (canvases and/or paper sheets) used for rolling them up are, in fact, clearly visible.

The thick brushstrokes, typical of the artist’s smooth and full-bodied technique (sometimes more than 1 cm thick), appear flattened and crushed (figure 3 c and d) in many areas. This is also probably related to the difficult history of conservation of the large canvases and their unsuitable transport conditions while being transferred.

On the canvases examined, the presence of numerous points of overpainting from previous restoration interventions was also highlighted through the use of UV light. Some of this over-painting was badly executed, since it covers both lacunae and parts of the original painted areas.

The presence of stains, mainly located in the lighter areas of the background and in the paint layers of the various scenes, may be related to biological degradation.

Finally, leakages or exudations of the paint film can be observed on the surface of the artworks, and in some cases is quite extensive and highly visible especially in UV light. At the moment, the origin of these coatings is not clear but it may be the result of the migration of the paint binder on the surface or of the products used during past restorations.

3.1.2. Canvases

As no evidence of relining is present on any of the examined paintings, it can be assumed that the canvases are the original ones used by Sartorio. The canvases appear to be all of the same typology, probably made of linen or tightly woven cotton of industrial manufacture as suggested by the regularity of the warp and weft (Figure 4b) [8, 9].

The canvases chosen by the artist are in fact characterised by a light grey primer, probably obtained with rollers, evident from the uniformity of the ground layer. The cut of the canvas along the edges, folded and nailed to the back, shows good consistency and uniformity in its preparation, typical of manufactured products. Figure 4d shows a detail of the outer edge of one of the canvases.

On the back of the canvases there are extensive areas of an amber colour, probably linked to the migration of the paint binder (Figure 4 a); several breaks – especially in correspondence with lacunae in the painted layers- were noticed as well.

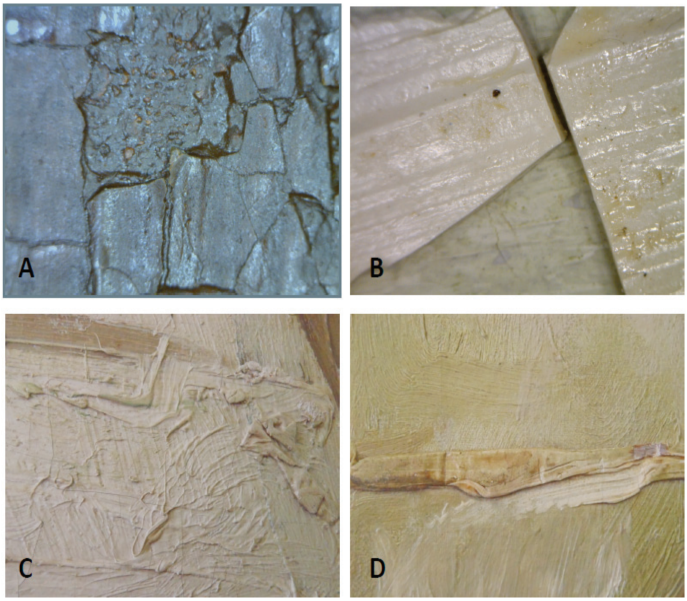

Figure 3. details of conservation state of the painted layers – A) craquelures and lacunae (50x), b) craquelure and detachement (200x), C) and D) flattened ares (30x)

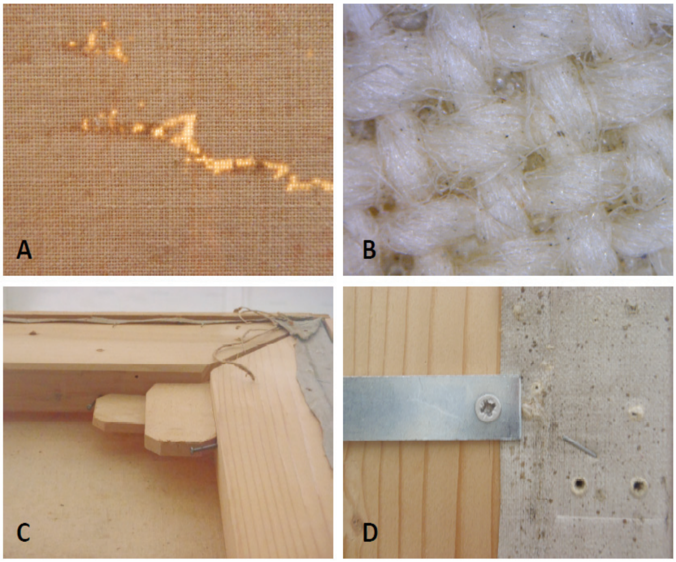

Figure 4. details of conservation state of the canvases: A) recto with visible lacunae (30x), B) warp and weft (200x) – details of the wooden stretchers: C) wooden joints and D) metallic joint

3.1.3. Wooden stretchers

Sartorio's vast cycle of paintings has no picture frames and the canvases are mounted on simple wooden stretchers linked by wooden joints (Figure 4 c). Several conservation problems were found relating mainly to the tension of the woods composing the frame, which in many points is broken; to remedy, metal plates have been used to join the broken wood together (Figure 4 d).

3.2. Physical-chemical study of materials and painting technique

All samples taken from the principal scenes were analysed as described in paragraph 2.3. The results indicate that the same materials and painting technique were employed by Sartorio in all four panels. Therefore, only the most emblematic examples are reported hereafter to describe the cycle of paintings.

The nature of the materials and the description of the painting technique are described starting from the innermost layers (canvas), working toward the outer layers.

3.2.1. Canvases and canvas preparation

As described previously, Sartorio's paintings were realised on industrially primed canvases presenting a light grey preparation. Figure 5 depicts the FT-IR-ATR spectra obtained from the recto of a fragment of a canvas (Figure 5A) and from the verso with the grey preparation (Figure 5B): the canvases appear to be composed of plant fibres, most likely linen or cotton, while the ground layers are characterised by the presence of lead white (basic lead carbonate) mixed with drying oil [10]. According to artists' handbooks of the period, industrially primed canvases were treated with several uniform layers of lead white bonded with linseed oil, applied with rollers to achieve good uniformity [8,9].

The presence of gypsum, oil and animal glue was detected in the white ground layers (Figure 5C), thus suggesting the existence of additional preparatory layers, presumably applied by the artist himself, and superimposed on the lead white/oil layers.

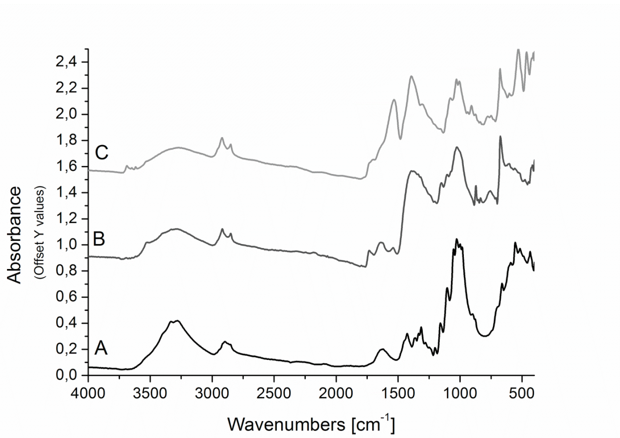

Figure 5. FT-IR-ATR spectra (4000-400 cm^{-1}) of: A) canvas of plant origin, B) industrial priming containing lead white and drying oil, C) grounding layers containing gypsum and animal glue.

3.2.2. Pictorial layers

The thick brushstrokes, typical of the smooth and full-bodied technique of the artist, are clearly visible when observing the polished cross-sections of the paint samples. The images shown in Figure 6 give an idea of the complexity of Sartorio's pictorial application of colours, the pictorial layers being composed of several superimposed layers of painting. The layers are marked by different thicknesses and contain several colouring pigments and aggregates, as evidenced in the SEM images in Figure 7.

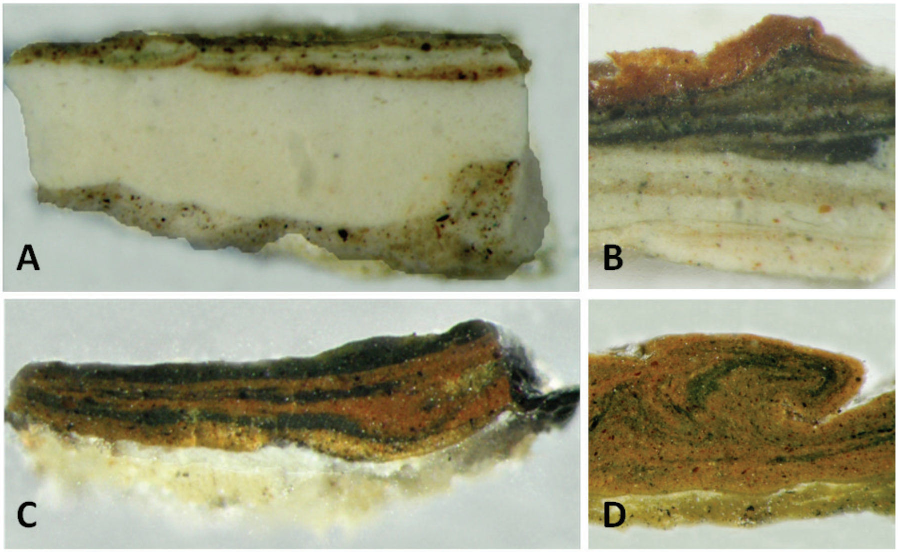

Figure 6: cross sections of paint samples from "Light" (A-30x), "Darkness" (B-35 x), "Love" (C-30x) and "Death" (D-35 x) panels

The optical images and SEM-EDX analysis give further evidence of the presence of numerous preparatory layers, previously analysed by FT-IR-ATR (Figure 7b).

The analysis of the elements present in the paint layers obtained by EDX and XRF analysis, revealed the presence of lead, iron, calcium, sulphur, carbon, silicon, aluminium, and zinc (see EDX spectra in Figure 7).

The presence of these elements, combined with the FT-IR-ATR results, allow us to suppose that the artist's palette included traditional and modern pigments, such as burnt Sienna (Figure 8b), yellow and red ochres, bone black, lead white (Figure 8a), zinc white and ultramarine blue (Figure 8c).

The results relating to the organic component of the painting materials highlight even further the complex nature of Sartorio's technique. The artist himself declared he employed "mixtures of wax, turpentine and oils" for his artworks, a statement which also finds confirmation in the analytical results. The medium used for executing the pictorial layers was in fact obtained by mixing drying oils with beeswax, whose typical IR absorption bands are present in the spectra reported in Figure 8 [10, 11,12].

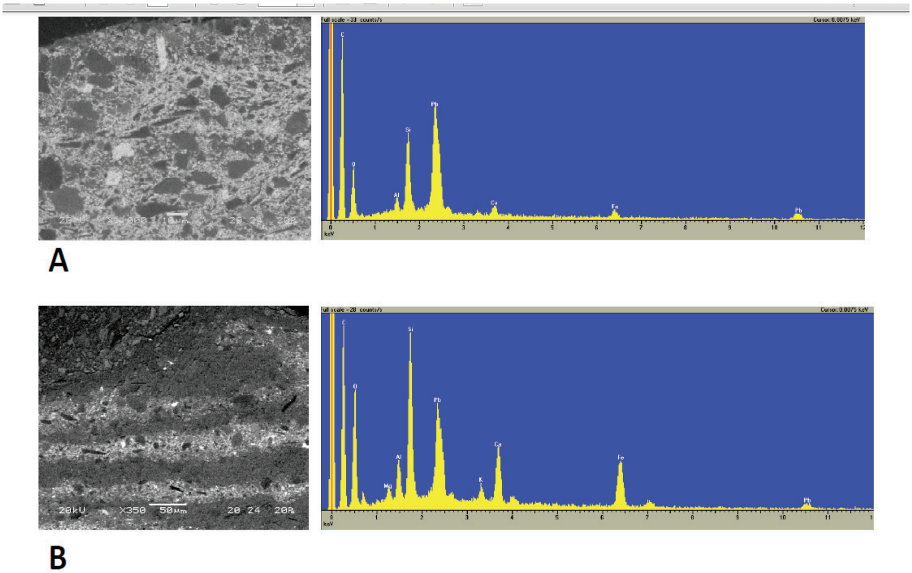

Figure 7. SEM images and EDX spectra of A) paint bulk from a sample of the "Love" panel (1000x) and B) paint stratigraphy of a sample from the "Death" panel (350x) in which lead, iron, silicon, calcium, oxygen, potassium, aluminium and carbon were detected

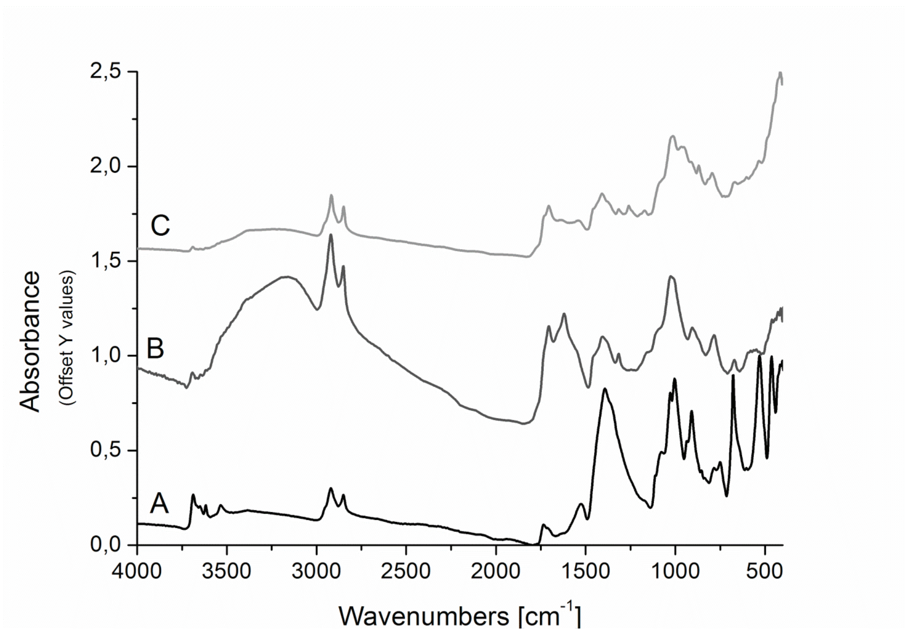

Figure 8. FT-IR-ATR spectra (4000-400 cm^{-1}) of: A) lead white in drying oil, B) Burnt Sienna in drying oil and C) ultramarine blue in linseed oil

These organic compounds were positively detected in all samples analysed by GC-MS, together with traces of an aromatic solvent (most likely mineral turpentine). Figure 9 reports two examples of chromatograms of paint films after transesterification and GC-MS analysis. All the characteristic components of drying oils are easily identified here (such as methyl esters): dicarboxylic acids (such as azelaic, suberic and sebacious acids), long chain saturated fatty acids (palmitic, stearic, lauric, myristic acids) and unsaturated oleic acid [13, 14]. The presence of beeswax is further confirmed by the detection of 15-hydroxy-octadecanoic acid from hydrocarbon chains with odd-numbered alkanes. Since Sartorio himself mixed his oils and wax with mineral spirit to obtain a paint that was ready to use and fluid, the proportions of the different compounds are not consistent, especially considering the differences in the thickness of the paint layers.

Furthermore, GC-MS results allowed to discriminate the use of different lipidic binders based on the ratios between palmitic and stearic acids (P/S) [13,14]. Sartorio seems to prefer to use a mixture of poppy oil (P/S values around 3.3-4, see Figure 9 a) and beeswax for the execution of light brushstrokes: this choice can be explained considering that poppy oil tends to yellow less with time compared to linseed oil, thus avoiding the unpleasant yellowing of light colours (such as white, light blue, green) [8,9]. Linseed oil (P/S values around 1.3-1.7) was detected in correspondence of the dark colours; it was moreover found, that for executing the drawings the artist diluted carbon black and burnt Sienna with boiled linseed oil, as suggested by the ratios between azelaic and suberic acids (A/Sub), which are around 2 [12,13,14]. These findings once more confirmed the declaration of the painter about his painting technique.

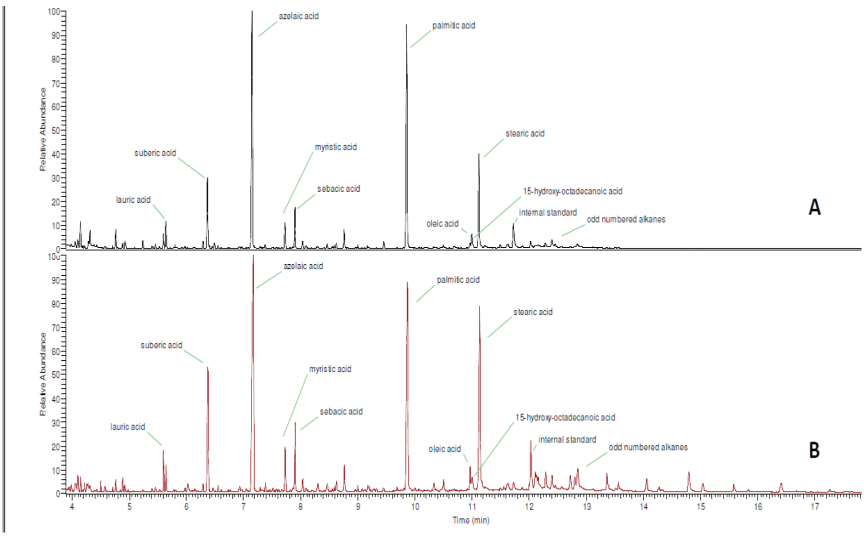

Figure 9: Total ion current chromatogram of A) a white paint sample and B) a dark-brown paint sample from “Light” panel and after transesterification and GC-MS analysis (internal standard = nonadecanoic acid)

3.2.3. Products resulting from degradation of the paintings, from previous restoration interventions and from transport

The large canvases by Sartorio present different degradation products resulting from the natural ageing of the materials used by the artist. In particular, oxidation and cross linking products of the layer composed of drying oils were identified, together with the formation of metallic soaps. These carboxylates can be formed after hydrolysis of the fatty acid moieties of the triglycerides of drying oil with metal-based pigments [10,15]: in Sartorio's cycle, lead and zinc soaps were detected in the whitish efflorescence visible on the paintings' surfaces. Lead carboxylates probably migrated from the lead/oil-based preparation and from the painted layers to the surface layers. The presence of zinc white, furthermore, might explain the presence of unsaturated fatty acids (in particular oleic acid), as observed elsewhere [16, 17, 18]. It seems that zinc oxide in proximity of a lipidic medium forms a packed structure which is able to trap unsaturated fatty acids in the painted layer. This effect can also occur years after the oxidation process is complete, probably because of the stability in the zinc oxide-oleic acid structures.

In addition, the materials and products used for transporting the canvases appear to be in many points inconsistent and show evidence of degradation processes in act. Some areas of the paintings have an extremely fragile and rigid surface, due to the presence of a glue (most likely rabbit skin glue, visible in the spectrum reported in Figure 8b). The glue was presumably applied on the surface of the paintings to glue textiles/paper and then to roll up the canvases for transfer.

The presence of paraffin wax and watercolours, detected by FT-IR and GC-MS in several damaged areas, is due to previous consolidation and retouching work.

4. Future perspectives: *Preventive conservation and monitoring project for Sartorio's cycle*

The chemical analysis of the paint samples revealed the use of lipidic materials mixed with beeswax. Based on the results obtained, the ageing processes involving lipidic compounds are virtually completed, assuring a condition of relative stability of the paint film [11,12,19]. Future transformation processes will therefore be eventually linked to specific environmental conditions regarding conservation, such as: daily or seasonal thermo hygrometric variations, irradiation of the paint film by natural and artificial light, as well as by the presence of gaseous pollutants (NO_2, O_3, VOC) [20-25].

Based on the present state of conservation of the paintings, a project of preventive conservation is here proposed, aimed at:

- monitoring environmental conditions for the correct conservation of the pictorial cycle ("passive" conservation);
- reducing direct interventions on the paintings ("active" conservation) and promoting minimal and focused interventions;
- reducing the economic impact of restoration treatments.

4.1. Preventive conservation: Environmental monitoring

Considering the huge dimensions of Sartorio's cycle (240 m^2 in total) and the possibility the canvases will be exhibited in a museum or in a historic building (where control of the microclimate is often quite complex) in the future, the following are some proposals for guidelines regarding what are considered to be the most important microclimatic parameters for a good conservation environment.

Based on well-known parameters [4,5, 20-25], values below 60% of relative humidity (HR%) and 25°C of temperature (T) respectively, are indicated for the conservation of paintings on canvas as ideal exhibition conditions. These values are generally recommended for all paintings on canvas, considering not only the necessity of controlling possible degradation processes of the pictorial film, but also the physical-mechanical behaviour of the artworks in their entirety (interaction of canvas and wooden frame), otherwise subjected to dimensional changes that may affect their stability [26,27].

The monitoring of RH% and T must also involve the back of the canvases, avoiding their direct contact with the walls and thus reducing the occurrence of condensation.

The monitoring of humidity and temperature can be performed with the help of special probes installed directly in the room of the Museum, which are able to measure the two parameters continuously. This will make it possible to monitor environmental conditions over long periods of time and also to assess the incidence of anthropogenic impact as a result of special exhibitions or in relation to opening times and influx of visitors to the Museum.

The monitoring will also include the control of gaseous species responsible for the degradation of the paint film, with particular attention given to O_3, NO_2 and VOC which may, for example, trigger chemical changes in the lipidic matrix [20-25].

4.2. Monitoring of the state of conservation of the paintings

Control of the state of conservation will be carried out through non-invasive techniques with periodic measurements on painted areas taken as references for enabling the identification of possible degradation processes.

Taking into account that degradation processes of pictorial films generally involve morphological variations in the film surface, observation with a contact microscope of selected points (considering thickness and typology of the painted layers), associated with colorimetric measurements (CIELab method, evaluation of tristimulus parameters L*, a*, b*) will be useful to identify degradation processes due to both endogenous (degradation of paint materials) and exogenous (dust deposition, lighting) factors.

Whenever any relevant morphological and/or chromatic variations occur, microsamples will be taken and analysed to determine the entity and the origin of the actual degradation processes and to consequently modify the environmental factors and conditions responsible for these transformations.

In addition, to monitor alterations in the wooden parts, in relation to the thermo-hygrometric conditions of the exhibition environment and intervention in the event of significant changes, dynamometers will be installed in points previously affected by breakdown of the wooden frames for controlling the tension of the canvases.

Knowledge of the materials and techniques used by Sartorio gives the possibility of suggesting some general guidelines for correct "musealization", considering as a priority, the prevention of future degradation processes, which are usually due to exhibition conditions themselves and excessive exhibition-related stress.

This research shows how any museum project must consider the specific technical and material characteristics of artworks prior to their exhibition.

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Biographical notes

Francesca Caterina Izzo graduated in “Chemical Sciences and Technologies for the Conservation of Cultural Heritage” at Ca’ Foscari University of Venice in 2007. During her European PhD in Chemical Sciences, she collaborated with RCE (The Netherlands Cultural Heritage Agency) into the Modern Oil Project and focusing on the organic analyses of oils and additives used in manufactured oil paints. Since 2012 she has been working as a researcher in Conservation Science for Contemporary Art in Venice, collaborating with several Italian and international organizations and institutions. She collaborates also with restorers, conservators, public and private collections. She has been involved in several European projects dealing with the Science, Education and Conservation of Cultural Heritage.

Elisabetta Zendri graduated in Industrial Chemistry in 1988 at the Ca’ Foscari University of Venice. Since 2001 she has been associate professor in the same University. She has been in charge of several projects: MIUR-COFIN, MIUR-FIRB and two MIUR-PRIN projects on materials and technologies for the conservation of modern painting. She is the scientific coordinator for Ca’ Foscari, the MACC Modern Art Conservation Centre. Her research activities are developed in collaboration with national and international Universities. She has published more than 140 publications in national and international journals.

Henk van Keulen is a conservation scientist employed by the Cultural Heritage Agency of the Netherlands (RCE) since 1994. He has trained in analytical chemistry and specifically in Gas Chromatography Mass Spectrometry. He is currently engaged in the analyses of traditional and modern organic materials from different source, such as paintings, furniture and modern art. His experience and knowledge is applied in projects such as POPART (Preservation of Plastic Artefacts in Museum Collections), 20th Century Oils, RadICal (Recent Advances in Characterizing Asian Lacquer, Getty Center, Los Angeles) and Dry Cleaning of Unvarnished Water sensitive Oils.

Eleonora Balliana obtained a Degree in Conservation of stone materials from the International University of Art of Venice in 1997. She graduated in Chemical Sciences and Technologies for Conservation and Restoration at Ca' Foscari University of Venice in 2007. Since 2009 she has been a researcher in Conservation Science at Ca Foscari University (Faculty of Science). Since then she has been working in the Laboratory of Conservation Sciences for Cultural Heritage Her topics of interest include: the study of the art materials and interaction with the environment, the characterization and study of degradation processes of plaster, natural stone, the development and characterization of new low-impact and sustainable solutions for the cultural heritage sector.

Laura Falchi graduated in "Chemical Sciences and Technologies for the Conservation of Cultural Heritage" at Ca' Foscari University of Venice. She has increased her professional knowledge by working as a trainee with two companies in the building industry. In September 2010 she started her Ph.D studies Chemical Science at University Ca' Foscari and in 2013 defended her PhD thesis on the study of new water-repellent systems for artificial stone materials.

Silvio Fuso graduated in Philosophy at the University of Padua, Italy. At the end of the 70s he directed, with the painter Mario Deluigi, the International University of Art (UIA) in Venice. Since the early 80s he worked as an exhibition curator at the Fortuny Museum in Venice, where he also conceived and was in charge of the video graphic sector. From 1994 to 2006, he was Director of the Fortuny Museum, where he organized exhibitions, workshops and events devoted in particular to photography, video and design. In 2007 he became Director of the International Gallery of Modern Art in Venice.

Matteo Piccolo graduated in Conservation of Cultural Heritage at the University of Udine and has a diploma in Archival Science, Palaeography and Diplomatics from the School of State Archives of Venice. He is the author of several publications and essays in the field of art history, relating in particular to the XIX and XX century. He is a curator of the International Gallery of Modern Art in Venice, where he contributed to the editing of the general catalogue of sculptures and has organized many exhibitions. For some years he has been vice-president of the "Centro Studi Storici di Mestre".