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Master Thesis

**Characterization of materials and techniques
employed by Štěpán Zavřel in some of his
drawings conserved in Štěpán Zavřel Museum in
Sarmede (Treviso)**

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Aim

Štěpán Zavřel (1932-1999) is considered one of the most important books' illustrators of the second half of the 20th century. His artworks had a great influence on that field, in particular on children's illustrated books. Zavřel was one of the first artists who underlined the connection between art and books and to define it as an important tool for children's education.

This study aims to gain information on the Štěpán Zavřel's artworks, in order to take a deeper look at the rich production of the Czech illustrator and investigate the materials and techniques that he employed. Along his career, he experimented different techniques, in particular graphics and watercolour, approaching to the creation of frescoes during the last years of his life as well. Following the indications that can be found in some publications and the direct experience of his friends and pupils who knew him personally, the materials he used were taken into account and studied in order to provide valuable insight into the specific colours, binders and technique themselves, trying to understand if they correspond to what the artist declared. Additionally, this analysis will be an important tool to understand the possible related degradation phenomena, which are present or that can be observed in the future. Specifically, seven drawings and two paintings on canvas conserved at Štěpán Zavřel Museum in Sarmède (Treviso, Italy) were analysed employing a multi-analytical approach. Non-invasive techniques were chosen, in order to perform *in-situ* analysis, even if five micro-samples were collected from two of the drawings to gain more specific information about the materials. Technical photography allowed to have information about the morphology and the overall state of conservation; Fiber Optics Reflectance Spectroscopy (FORS) and Raman Spectroscopy were performed in correspondence of different colours to identify pigments or dyes employed by the artist and possibly, their degradation and variation of the colours. On the other hand, the five samples were investigated by means of microscopy, micro – Raman spectroscopy for the characterization of pigments and Fourier Transform Infrared Spectroscopy – Attenuated Total Reflection (FTIR – ATR) to investigate the binders' nature. Additionally, in order to study the declared artistic techniques and materials, a series of paint mock-ups was created and analysed by means of FORS and the spectra were compared to the ones obtained for the drawings and paintings. Finally, Principal Component Analysis (PCA) was performed in order to discriminate between different supposed binders and so to confirm or not the composition of artistic materials and techniques.

The results of the study showed a colour palette which is coherent to the colours generally used in the second half of the 20th century and except for one case, the analysis mainly confirmed the employed techniques declared by Zavřel. In general, the conservation state was good for all the artworks, even if colour detachments were visible on four of the seven selected drawings.

The information gained through the investigation would be important for Zavřel's artworks conservation and future interventions and they will be essential for a first approach to the study of Zavřel's artistic processes.

I. Introduction

1. Štěpán Zavřel and his artistic production

1.1 Štěpán Zavřel

Štěpán Zavřel (*Figure 1*) was born in Prague in 1932. His parents, Vaclav and Marie came from the area between Bohemia and Moravia and they worked as tailors. They decided to move to Prague and their three children, Marie, Štěpán and Ludmila were born and grew up there. Since Štěpán's childhood, a passion for drawing was evident and he liked to invent stories with illustrations for his younger sister Ludmila, who he loved very much, to the point that she will become the main character of one of his illustrated tales later (*Il sale vale più dell'oro*, 1967).

Štěpán grew up during a complex historical period, he was a teenager during the Second World War and that experience left a mark on him, he experimented the fear and the horrible things that war produces in a person and he would have been remembered those feelings throughout years: "Alzarsi la mattina e, vedendo che le due case a sinistra non c'erano più, ringraziare il Signore perché la tua era stata risparmiata" (Tonzig 2011). In 1948/1949, he attended a famous classical high school in Prague, the V-B Masarykovo Státní Reální Gymnázium, where many important personalities of the cultural and artistic Czech avantgarde of the first decades of the XX century studied as well, like the most important writer of the Czech expressionism Vladislav Vančura, and the art critic Karel Teige, the main writer who theorized the Czech avantgarde and the constructivism and a protagonist of the surrealist movement (Tonzig, 2011).

The political Czech scenario was uncertain during the post-war period and the correlated changes influenced the personal Štěpán's cultural and scholastic education. He was forced to change school after the closure of the high schools, so he was moved to the Jirasek High School first and then to the Neruda High School, where he graduated in 1952. Štěpán's cheerful period of those years ended quite soon because of the strictness of the newborn regime; his parents were catholic and that was considered an aggravating factor for the ideology of the regime since they were part of the middle class, his father was an owner of a tailor shop and he was considered as an entrepreneur. This fact had an impact on his cultural formation since he was not allowed to be regularly admitted to any university or artistic institute because his family was not a proletarian. Nevertheless, he attended lectures at the Academy of Fine Arts at the Charles University and School of Arts and Crafts and meanwhile, he went on visiting museums and exhibitions and studying everything he was able to in libraries (Tonzig, 2011).

The propagandistic censorship controlled the cultural and artistic sectors with an iron fist. The political attitude was surprisingly different for the animated movies, since they were considered an



Figure 1 Štěpán Zavřel during his childhood in Prague

important propagandistic instrument, promoting nationalistic content using popular tales, folkloristic music, and traditional iconography. This tool was fundamental for creating the ideal new communist man and was used for children education. Related to this tendency, many legislative and cultural initiatives were promoted between 1945 and 1948, such as the creation of FAMU (the faculty of cinema and television of the academy of arts) or the foundation of animation studios like Bratri v trinku, whose director was the most famous Czech puppeteer Jiri Trnka (Tonzig, 2011). After the graduation in 1952, Zavřel was employed there as an animator and his talent was recognized soon. In that studio, many people worked at different tasks, from the animators and film directors to the set designers and Stepan was able to see Trnka working with puppets and directing movies and that experience resulted very important for his future artistic work as an illustrator (Tonzig, 2011).

From 1953 to 1955 he interrupted his work in Trnka's studio because of the obligation to perform military service. His relationship with this world was quite conflicting, they offered him to work in the artistic complex of the army but he rejected this offer because he was not interested in creating Bolshevik subjects. So, he returned in Trnka's studio in 1955 and worked there until 1959. During that period, he took part into the creation of the first Czech animated feature film, *The creation of the world* directed by one of the most important Czech film directors, Edouard Hofman. This animated movie was filmed between 1956 and 1957, based on the Jean Effel's grotesque illustrations and presented at the Venice Film Festival in 1958, where it reached an enormous success (Tonzig, 2011).

Between 1956 and 1958, Zavřel attended different courses at the Academy, firstly the direction course at the FAMU and then illustration painting and graphic techniques at AVU, focusing his attention mainly on the creation of religious subjects. He lived in a simple way in an attic in Mala Strana and he spent his money on colours and painting tools and travelling in different countries in East Europe (Tonzig, 2011). However, life in Czechoslovakia at that time resulted in being restrictive and suffocating. The political situation and the ideology of the new government in Czechoslovakia resulted invalidating for cultural ideas and artistic development. The oppressive censorship of the media and the inability to travel to Western countries contributed to isolate more Czech artists, wishful to discover and explore new concepts and find inspiration. In that context, travelling to the most important and vibrant artistic centres like Paris was impossible so more than one young generation of Czech artists was not able to know the most recent historical avantgardes. Such a situation was the main cause that made many artists escape from the country and Zavřel was one of those (Tonzig, 2011).

During one of his travels to Albania, he decided to try to escape from that strict and oppressive situation in 1959: "Ho lasciato la Cecoslovacchia nel 1959, non potevo vivere accettando certi compromessi, a Praga. Non riuscivo a vivere in un paese che m'impediva di esprimermi, di viaggiare, di conoscere altre realtà, fu così che decisi di fuggire durante un viaggio studio in Albania" (Tonzig, 2011). His cousin Vaclav Plisek was a priest who lived in Italy and his influence was crucial for his decision to leave his country. His escape and the experience in prison camps marked him for the rest of his life.

His arrival in Italy is certified on 5th September 1959 and he spent the first period in Rome where he attended the Accademia di Belle Arti and became a friend of Corrado Pirzio – Biroli and Hèlène de Franchis. He graduated on 26th June 1962 but he already had the possibility to show his artworks in some exhibitions in Salerno, Oslo (Gallery Grafikk) and Stuttgart (Schloss Rosenstein) before, in 1960. Then he exhibited in Rome (Galleria Stagni) where the xylographic drawing series *Dies Irae* was exposed, a tormented testimony of his experience in prison camps and the cruelties of war. The drawings are characterized by the presence of suffering characters, with angular shapes and grotesque deformations which reminds the design of the German Expressionism (Tonzig, 2011). He went on experimenting with xylography and other graphic techniques and during those years, in particular between 1962 and 1964, he started to work with Hèlène de Franchis in the most important Italian animation studio directed by Giulio Gianini and Emanuele Luzzati. He knew how an animation studio works after his first job in Trnka's studio in Prague but in Rome he discovered new animation techniques so he started to experiment with the decoupage or the cut-out techniques which would have been important for his future career as a book illustrator. Meanwhile, he worked on different projects, like the creation of a series of sketches of costumes for a Molière's pièce or as a drawer for two feature films, *La Storia di Ali Reza* and *La gazza ladra* (Tonzig, 2011).



Figure 2 Illustration from the book *Il pesce magico*, watercolour

Luzzati was not only a great illustrator but also a set designer and the years Zavřel spent working in his studio influenced his formation so much that he decided to attend the courses on set design and



Figure 3 Štěpán Zavřel with two guests in the garden of his house in Rugolo di Sarmède

theatrical costumes of the Kunstakademie in München until 1966. There he went on to work for other studios that created animated advertisements (Tonzig, 2011). There, Zavřel met the person who would have been changed his future artistic career and allowed him to achieve his idea to make illustration an art of its own, in 1964. Mafra Gagliardi was a critic and an expert in childhood literature and she wrote the story of the very first children book illustrated by Zavřel, *Il pesce magico* (*Der Zauberfisch*). In this series of illustration, all the

influences that Zavřel received during his experience until that time were used and combined in an originally: for the colour palette and the subject he was inspired by Paul Klee, he worked with the decoupage techniques, transparencies, and overlapping the backgrounds like he did with animations and he chose the watercolour technique, innovative for book illustrations (Figure 2). It was written in German, published in 1966, and it was translated into other languages: Japanese, English, and Italian in many editions throughout years (Tonzig, 2011).

In 1968, Zavřel chose a place to live, even if he went on spending many years travelling in many countries around the world meeting artists, illustrators, editors and new friends; he bought a country house made of stone in Rugolo di Sarmède, a village located in the hills near Vittorio Veneto, in the province of Treviso, in Italy (Figure 3). That place soon became a vibrant artistic centre, where many artists from all over the world met each other and share ideas and their artworks would have constituted the very first artworks of the first exhibition of the international illustration festival, the *Rassegna Internazionale dell'Illustrazione* later, in 1983 (bohempres.it).

That illustrated book, *Il pesce magico* was the first of many others since he considered the childhood publishing an interesting field to experiment with different techniques and iconography, using the experiences he learned in different countries. In 1966, Zavřel started a collaboration with the Patmos publishing house from Düsseldorf and to frequent the event *Fiera del Libro* in Bologna. During that decade he illustrated some books for that publishing: *Il Sale vale più dell'Oro* (1967), *Pioggia di Stelle* (1969), *La nostra meravigliosa Terra* (1971). He worked also on the book *Vodník* (1970), published by Nord-Süd Publishing, whose story was based on a myth of Prague. He travelled to different countries and in Japan he started to collaborate with Gakken Publishing, illustrating the book *I colori rubati* (1972) written by Mafra Gagliardi. With the Nord-Süd from Monchaltrof, he published *Il sole perduto* (1973) whose texts were written by Štěpán Zavřel on his own and it won a prize in the same year (Tonzig, 2011).

He started a new adventure with a friend, the editor Otakar Bozejivsky von Rawenhoff, founding a new publishing house in 1971, the Bohem Press in Zürich, whose he was the artistic director until he died in 1999 (bohempres.it).

In 1974 he met another person who would have been important for his career and became a friend and collaborator, the publisher Mario Vigiak, whose publishing house, Quadrangolo Libri from Conegliano (Treviso), curated illustrated books for children and adults. He published the Zavřel's book *Il ritorno di Ario. Da Ciro il Grande a Ciro il Piccolo* (1974) and in 1975 they founded together an art gallery in Verona, Galleria QuadrangoloArte. This book was characterized by a colour palette and decorations that remind the Persian textiles from the XVI century and is considered by many people as one of the best books illustrated by Zavřel. In the same year, the book *Venezia domani* (later *Un sogno a Venezia* in 1976) was published, whose story faces a contemporary problem, that is the degradation of Venice and was an attempt to focus the attention of the readers to such an alarming situation (Tonzig, 2011).

In 1976, he created the illustrations for the book *L'ultimo albero* and he was inspired by the artworks by Marc Chagall and the iconography of East Europe, whose main message is related to another contemporary problem, that is the preservation of forests. In 1977 and 1978, two other books are published *Il ponte dei bambini* and *La pentola magica*, respectively. The stories of both were focused



Figure 4 Štěpán Zavřel in 1992

on important values for the education of children, such as generosity and being against divisions and hate (Tonzig, 2011).



Figure 5 Štěpán Zavřel in 1990's

In 1978, he published the first book which focused on a religious subject, a theme that Zavřel faced more than one time during the last part of his production, *Il flauto del pastore*. For those illustrations, Zavřel took inspiration from Gustave Klimt's paintings and the Vienna Secession's palette and design. In 1980 he published *La farfalle* and *Natale* in 1981 and *Nonno Tommaso* in 1983. Then he published in Japanese *Il segreto delle erbe magiche* for Gakken Publishing in 1984 and *Nani e Giganti* for the Bohem Press publishing from Zürich in 1985, whose texts were written by the German author Max Bollinger who collaborated many times with Štěpán Zavřel (Tonzig, 2011). In 1987, another book that was inspired by Klimt's art was published by the Bohem Press, *La città dei fiori*. In the same year, he created the illustrations with two of his pupils (Donata Dal Molin and Flavio Cortella) for the book *Sotto la laguna di Venezia*, where they used the decoupage and the watercolour techniques which contribute to recreate the lights and shades of water. In 1988, the book *Gesù Bambino Rubato* was published and, during the last years, he published *Jacopo il giullare* (1991) and *In cammino con Dio* (1996). All of those last artworks are linked to religious subjects and are like a vehicle for transmitting universal messages to children, not only related to faith. The illustrated Bible was the very last Zavřel's work related to the field of illustrated books and again he introduced references to other artists and artistic movements, like Gustave Klimt, Henri Rousseau or Pieter Bruegel (Tonzig, 2011).

Meanwhile, in addition to his rich creation of artworks, an important event started to take place every year from 1983, the already mentioned *Mostra Internazionale dell'Illustrazione per l'Infanzia* that had a great success and it was set up also in other cities and European capitals (bohempres.it). Later, in 1988, Štěpán Zavřel organized his first illustration courses that was the first step for the foundation of the *Scuola Internazionale d'Illustrazione Š. Zavřel* which allowed to discover and educate many important illustrators and artists (bohempres.it).

During the 90's, an evident physical decline started, especially after his mother's death and his personality get worse throughout years. Some of his friends thought that was due to a sort of fatalism after the fall of the Berlin Wall, an awareness of the cultural poverty of his country after all those years of the regime and a sadness due to the age and his mother's death. His friend Loris Follador said: "Mi sono interrogato a lungo [...] su cosa lo avesse portato verso l'autodistruzione, ma ho concluso che in lui era intervenuta una sorta di fatalismo, se non di appagamento. Ne ho avuto sentore la prima volta nel 1989. [...] Mi fece una lunghissima telefonata e mi spiegò che, quando un uomo ha superato i sessant'anni, ha fatto una guerra e ha lasciato i segni tangibili del suo passaggio, può anche morire senza rimpianti. La seconda

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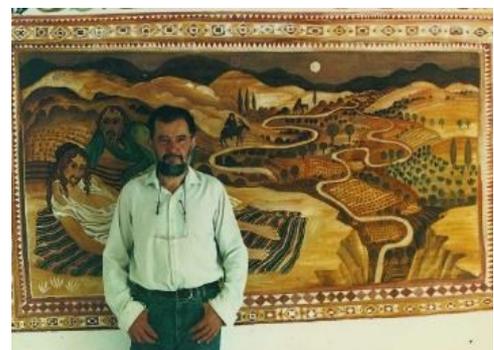


Figure 6 Štěpán Zavřel in 1990's

volta fu nel 1998, quando mancò sua madre” (Vigiak, 2019). Štěpán Zavřel died in his house in Rugolo di Sarmède on 25th February 1999.

1.2 Topics and inspirations of Zavřel’s books: “educare con l’arte”

1.2.1 Artistic influences and the use of colours

Ferruccio Giromini, journalist and art critic who met Štěpán Zavřel, defined him as a real European artist without evident dividing lines, a multifaceted personality that created an original imaginary that resulted to be revolutionary for the illustration field. “Un autore realmente europeo, [...] tutt’altro che semplicemente boemo, o italiano, o svizzero [...] un artista multiforme, che nella sua opera ha saputo dapprima fare confluire e indi ricomporre una serie non piccola di suggestioni provenienti da direzioni disparate, da culture diverse. Una personalità ricca che [...] ha saputo produrre una cucina visuale solo e pervicacemente sua, lasciando una traccia del tutto riconoscibile nella storia della nostra figurazione continentale di fine Novecento” (Vigiak, 2019). Considering the very first artistic artworks created with xylographic technique, the angular shapes and grotesque deformations of the subjects remind the German Expressionism and his future artworks kept the signs of that first technique employed by Zavřel many times, with simple severe lines without excessive decorations (Vigiak, 2019; Tonzig, 2011).



Figure 7 Detail of the characters of drawing 04

Another important inspiration came from his experience with some famous puppeteers like Jiri Trnka and the world of puppet theatre, an art that is a pillar of the traditional Czech folklore and that was changing its way of representation from the small theatres to the cinematographic show during the 50’s. As an assistant, the young Zavřel worked with some of the greatest masters of puppets and animators, such as the already mentioned Jiri Trnka, Bretislav Pojar, Jiri Brdecka, Eduard Hofman, and he learned the animation technique of *stop motion*, that

is filming each single frame in order to reconstruct the idea of motions during the quick projection of a sequence. In that field, he also learned how to use and experiment with such making of technologies and so how to combine them with evocative fantasy, acquiring the ability to abstract the representation of subjects that result not to be realistic (Vigiak, 2019). The Czech artist followed a sort of natural completion working with other important Italian animators, Emanuele Luzzati and Giulio Gianini, in Rome, who taught him how to create motion not with real puppets, but with characters made of paper. Zavřel appreciated more and more the inner poetry of those rigid motions and acting of the delicate paper characters; he learned new artistic techniques like decoupage and the cut-out, how to assemble those paper sheets to make them alive with those basic movements of their arms and legs. And so how to make them assume the basic four canonical positions: frontal, the left and right profiles and the “Romanesque” one, when the character’s face

is rotated upwards and appears not to have in the right perspective. The already acquired ability of abstracting was improved by another one, that is simplifying the graphic traits of the characters, representing them with two big eyes similar to the ones of the Byzantine saints, vertical lines for noses and a soft horizontal line for mouths. He went on improving and consolidating this type of drawing (*Figure 7*) collaborating with other people from the animation field, like Secondo Bignardi and Richard Williams, from who he learned other techniques for the creation that resulted to be fundamental for his career (Vigiak, 2019).

His collaboration with Emanuele Luzzati, who was also a set-designer, instilled him the interest in set-design and he decided to study it at the Kunst Akademie in München. That lesson would have been very important for his artistic production, in combination with the previous experience in the world of animation. In his illustrations, Zavřel gives life to a series of architectural inventions and constructions that remind a theatre setting, often similar to an imaginative Oriental world (*Figure 8*). The backgrounds appear flat and the actors lie on them, “figure compatte e coese per meglio muoverveli sopra” (Vigiak, 2019). The buildings and cities are represented with orthogonal structures, whose details are depicted with a regular and rhythmic sequence or also all the other possible elements in the background like trees, columns or pillars. On the other hand, natural elements like landscapes, hills or forests have softer, freer, and more curvilinear shapes (*Figure 9*) (Vigiak, 2019).

About the composition of the scenes of his drawings, other artistic inspirations influenced on determining his vision and style, not only his experience in the animation field but also his studies at the Academy of Fine Arts, his origin and culture played an important role. One of the main characteristics of his illustrations is the no-perspective construction, whose evident reference is the tradition of medieval art, in particular the Romanesque miniatures of the manuscripts and the vertical lines of Byzantine art. Horizontal illustrations – in general constituted by two pages - are usually used for representing an ambience (*Figure 9*); on the other hand, the single pages has a narrative function and appear to be totally flat and spatial depth is almost absent, similar to pre-gothic depictions. Pictures in single pages show sort of a division into two parts where in the upper part there is every distant detail, while in the lower part, everything that is closer is depicted; one part is dominated by the representation of characters, then in the other one there is the background and the ambience. This last one would give the impression of catching the eye to the horizon away or guiding it closer and closer to the point where the action of the scene is taking place (Vigiak, 2019). However, the characters are surprised in their most intimate and introspective moments, they are observed from a defiladed perspective, never too close, they are generally showed entirely, and smaller in relation to the rest of the scene (*Figure 9*). The point of view appears to be a little upper, so the scenes result having a flattened perspective, giving the impression of having characters and ambience, primary and secondary actors on the same



Figure 8 Illustration from the book *L'ultimo albero* (1976), watercolours

level, “una democrazia assoluta, quasi totalitaria, dove ogni elemento vorrebbe avere lo stesso peso di tutti gli altri” (Vigiak, 2019). To avoid an excessive flattening of the scenes, Zavřel combine other zones of wide and empty spaces but enriched with decorations and accessor details that give a perfect equilibrium. His taste for decorations can be the result of many previous influences: the Indian and Persian miniatures; the traditional Slavic textiles; the Vienna Secession movement and Gustave Klimt, in particular; the mosaics from the Byzantine tradition; Paul Klee and Kveta Pacovská. All of those influences contribute to the creation of the personal and innovative artistic style of the Czech artist, where



Figure 9 Horizontal illustration of a landscape of drawing 02 from the book *Sterntaler* (1969)

the taste for the decorations, light and brightness of gold and gemstones, colours and enriched details and the combination of straight and curvilinear lines in a bidimensional space are the main characterizing elements. The simplified shapes of characters and background details, the distribution of empty and full spaces and the sign of the drawings itself are then the result of Zavřel’s origins and his personal love for the early medieval Christian iconography, in particular the solemn mistic austerity of the orthodox religious icons from the East Europe (Vigiak, 2019).

His typical colour palette, the experimentation with different colours and, thus, the choice in using certain colours, instead of other ones, derived from other artistic inspiration but is principally due to his collaboration with Emanuele Luzzati. The Italian animator made him discovered the Mediterranean colourism with its bright shades and light games and he added another element that contributed to create those poetic and delicate illustrations. Luzzati said: “Credo che proprio a Roma sia nato l’estroso illustratore che ha saputo coniugare la grande tradizione grafica mitteleuropea con la solarità e la... faciloneria latina. E così sono nati quei libri pieni di poesia e di luce” (AA.VV., 1991). However, Ferruccio Giromini observed that lesson was not so incisive and deep, the Mitteleuropean influence remained preponderant with a darker light shade, high horizons and perspectives, dark skies and material colour palette. Sometimes, the most evident inspiration could be the artworks by Marc Chagall with a more fable and oriental trait, while in other illustrations, Emil Nolde could have inspired a Central European taste for a more delicate and lower Luminism, with a great attention to light effects. Zavřel did not tend to use bright colour mixtures for their own sake but to choose them accurately in accordance with the subjects he wanted to depict, characterized by a dominant colour shade. So, his choice to employ different artistic techniques, from the watercolour to the acrylic paint, were in function to the general atmosphere of a story, in such a way as to create the final result, nothing appears to be in a random thought: “L’artista andrà a scegliere di volta in volta le trasparenti leggerezze dell’acquerello per ambientazioni estive e gli acrilici più densi per gli scenari invernali. Solo di tanto in tanto ricorre all’uso del pastello ad olio per rinforzo” (Vigiak, 2019). That particular use of colours and their precise function in Zavřel’s art, combined with the influence of the already mentioned early-medieval art and the orthodox religious iconography, contributed to give life to his recognisable style. In his illustrations, the eyes of the

observer look at a single visual level where the depth is almost absent and the scenes give the impression of being suspended in time, the action and movements are like frozen in a moment. On this way, every single element of the composition results to be chromatically isolated from all the others, or if it is part of a group, the colour makes it perceivable as a shared element (Vigiak, 2019). At this point, the various inspirations in Zavřel's art are evident, the typical stylistic elements of East European folklore combined with the refinement of the traits of graphic design's field and the 20th century painting characterize his artworks. The main goal in book's illustrations for Zavřel was to make illustration an independent art form, especially after the stimulating collaboration with Emanuele Luzzati and his first step on that direction was the publishing of the book *Il pesce magico* in 1966, the result of his meeting with Mafra Gagliardi. The story itself underlies that idea: it is about a gold fish depicted on a painting in a museum, its adventures and the children's love for it and how it considers children its best friends and giving them joy in the museum as its main most important task. The story focuses on the relationship between children and the gold fish which symbolises art world, how it needs to be loved by children, and how they need pictures that allow them to dream and fuel their imagination. That was what Zavřel really wanted, creating a bridge between art world and childhood. With this purpose in mind, he founded the publishing house Bohem Press, specialised in books for children, with Otakar Bozejivsky von Rawennhoff in Zürich in 1971. His philosophy was that an illustrated book is like a museum or an art gallery, a collection of artistic pictures. Štěpán Zavřel started a new chapter in the story of illustration for children with that book, not only in Italy but at an international level since *Il pesce magico* embodied the very first idea of thinking about illustrations as a real art form (Tonzig, 2011). The aesthetic plays a fundamental role from the educational point of view and the Czech artist insisted on that point, the need of the "illustrated book's aesthetic": "Sostiene l'importanza e l'urgenza di portare l'arte al linguaggio del bambino, innescando la sua fantasia attraverso l'uso di tecniche molto diverse" (Tonzig, 2011). The main goal of artistic illustration is to be able to talk to children and stimulate their imagination. In this case, art is not only for its own sake but has a specific role, that is a channel for transmitting specific messages to children: "Con Zavřel l'illustrazione per l'infanzia si innalza ad opera d'arte e l'arte, attraverso il libro illustrato, si muove verso il bambino" (Tonzig, 2011).

1.2.2 The pedagogical and educational message of illustrations

The pedagogical valence of Zavřel's illustrations is evident not only on a formal level but also from a content point of view. The recurring themes are brotherhood, friendship, and love and respect for nature before the great attention to ecology and environment, he tries to represent contemporary fears in a solemn and sometimes mystic style. Another aspect of his stories is a sort of diffuse celebration of material poverty as a synonym of spiritual wealth and that is the reason why his drawings seem to be dominated by a soft melancholy and not by a real cheerfulness despite the bright colours (Vigiak, 2019). The contents are fascinating both for children and adults since they recall universal messages, drawings and colours can transmit mature feelings and concepts. The colour shades are different according to what Zavřel wants to underline, from the brighter ones like

violet yellow blue green mixed with pink and red to the warmer and darker ones like brown black ochre mixed with white (Vigiak, 2019).

Those illustrated books are bearers of extremely current values, such as the respect and safeguard for nature, diversity as a resource, quest for peace and solidarity as the only solution. Childhood is always the real protagonist since children are depicted as the main agents of change (dorature.com). Zavřel's illustrations can talk to children's hearts and minds and in his intentions, they play a fundamental role in children's education and in their development as human beings, helping them become internally richer and so more open-minded (AA.VV., 1991).

Silvia Blezza Picherle observed that it is necessary to let the Zavřel's illustrations "talk" to children and give them the opportunity to be alone in front of those drawings for all the time they need to "listen" to them. Children must have the opportunity to leaf through illustrated book's pages and look at the pictures, taking the time to rest their eyes on them to observe, understand and internalize the messages. They can pause on those details which catch their attention the most for some reasons, according to their personality and this requires time. This is the only way to allow them to elaborate their first wonder and convert it into specific sensate emotions: "Perché le opere d'arte possano comunicare meraviglia e incanto, lo spettatore ha bisogno non già di informazioni razionali, bensì di pazienza e di tranquilla perseveranza; allora ad un bel momento arriverà un autentico confronto con l'oggetto della contemplazione, e quindi a un confronto con sé stesso" (AA.VV., 1991). As it has just underlined, taking time is a fundamental step in children's education process and growth, they need time for looking and time for seeing, that is understanding since "saper vedere significa infatti far parlare l'opera d'arte in tutta la ricchezza dei suoi significati polisemici che si rivelano all'osservatore e diventano per lui carichi di senso solamente se questi avrà avuto il tempo di osservare, di analizzare e di riflettere" (AA.VV., 1991).

Even if understanding what children feel looking at illustrated books is quite hard, Zavřel's drawings can inspire wonder in children's imagination because of colours' explosion, bright shades and their unique mixture and motions (AA. VV., 1991).

1.3 Artistic techniques employed by Štěpán Zavřel

Štěpán Zavřel experimented with many different artistic techniques throughout his career and every time his choice was related to the message he wanted to impress upon his audience and the feelings he wanted to recreate with pictures. He was a multifaceted personality also from the technical point of view, who enriched his experience working in different fields and exploring different techniques that then he also tried to mix to obtain new and unexpected results.

Regarding the techniques, the artist declared to have used different materials and they are also reported in catalogues, but they have not been studied from a chemical point of view before. One of the main purposes of this study is to analyse the materials and so to explore the employed techniques, to confirm or not his indications. A better knowledge of the material will be fundamental for understanding possible future degradation phenomena and planning the best way for conservation.

1.3.1 Xylography

His very first artistic production in Czechoslovakia when he was young, is characterized by the study of the xylographic technique, that is the engraving on a wooden matrix, a technique that he went on working with all along his life. In more than one of his later artworks, the signs of



Figure 10 Illustration from the book *Jacopo il giullare* (1991), xylography and watercolour

his beginning with xylography are evident and also when he does not employ that particular technique, some traits in lines drawing can be seen even if he smooths them with watercolours. Severe, angular, basic signs with no exaggerated decorations (Vigiak, 2019). Following his production, the series *Dies Irae* (1962), the religious drawings for calendars created for the *Calendari Patmos dell'Avvento* (1967-1968) and the *Dědictví Otců 869-1969 (L'eredità dei Padri 869-1969)* which was commissioned by the Istituto Slovacco dei Santi Cirillo e Metodio where Zavřel lived during his first period in Rome, were created with the xylographic technique. He realized also many depictions of the Virgin Mary with Jesus and one Pietà between the 60's and the 80's. In many of his illustrations for children's books, this technique or its mere reminiscence can be found, in particular in *Sterntaler* (1969), *Jacopo il giullare*

(1991) (Figure 10) and some unpublished drawings for the book *In cammino con Dio* (1996) (Tonzig, 2011).

Regarding the technique, xylography is one of the most primitive relief printing techniques and the images are carved into the surface of a block of wood, typically with gouges leaving the printing parts level with the surface while removing the non-printing parts. Those areas that are cut away carry no ink, while the details at the surface level carry the ink to produce the print. To obtain the print, the surface of the created matrix is covered with ink by rolling over it with an ink-covered roller, leaving the ink upon the flat surface but not in the non-printing areas (Wikipedia). Then, the inked matrix is used for printing using a printing press or also by hand printing, depending on the chosen support (stampaedintorni.it). So, this is a technique that requires very good manual skills and abilities and confidence in working such a hard material. Zavřel demonstrated those hand-crafted abilities and the artworks created with that technique characterized the first part of his artistic career, until he arrived in Rome where he improved it by studying with professor Maccari (AA.VV., 1991).

1.3.2 Oil pastels

In Rome, that so defined second period of his artistic career began when he was employed in the animation studio of Gianini and Luzzati. Zavřel got a lesson from Lele Luzzati about the colours and colourism typical of the Mediterranean world and how the artists can play with lights (AA.VV., 1991; Vigiak, 2019). There, he discovered the oil pastels and how they can be diluted with water, another technique which he used for creating his illustrations throughout the years, for example for *Il Sale vale più dell'Oro* (1968), *I colori rubati* (1972) and *Il ritorno di Ario* (1974) (Figure 11). Oil pastels are characterized by vibrant colours which remind oil paintings. They are composed by pure powder pigments mixed with variable quantities of binders, like linseed oil or wax which lends to pastels mellowness that makes them particularly adaptable to different supports and creation of shades' effects. Differently to the hard pastels, generally constituted by powder pigments mixed with minuscule amounts of organic binders like Arabic gum and a pulverized inert white filler like calcium carbonate or kaolin (metmuseum.org; Tenorio et al., 2019_Umberto Boccioni), oil pastels contain an oily binder in major quantity so they do not become dusty and they adhere excellently also on a smooth surface, like a paper sheet and they are employed on supports of different nature. The artworks created with that technique are characterized by bright and pure colours and excellent covering but they can be also used for creating shades diluting them with different solvents, such as water oil or white spirit (staedtler.com; fila.it). Zavřel used to create his drawings diluting oil pastels in order to recreate a result similar to watercolour (the so called *pastelli ad olio acquerellati*).

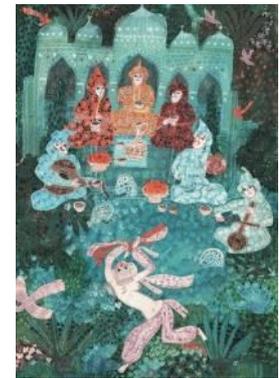


Figure 11 Illustration from the book *Il ritorno di Ario* (1974), oil pastels

1.3.3 Watercolours



Figure 12 The book and one of the illustrations of *Il pesce magico* (1964), watercolours

Related to this, the third phase of Zavřel's artistic career is defined as the *watercolour phase*. The Czech artist was the first one to employ this artistic technique for creating illustrations for children's books. In fact, before his experimentations, illustrators used to employ other techniques, such as pure treated or diluted pastels or tempera (gouache). There was only one previous

case of a book illustrated using the watercolour technique which probably inspired Zavřel, that is *Il fagiolo Gaetano* written by Guido Rocca and illustrated by two young animators, Giulio Cingoli and Giancarlo Carloni, edited by Mursia publishing in 1961 (AA.VV., 1991; Tonzig, 2011). Livio Sossi, one of Zavřel's friends, said: "L'opera di Cingoli e Carloni [...] ha ispirato senz'altro Zavřel. Me lo ha confidato [...] in uno dei nostri periodici incontri a Rugolo ed ha aggiunto: *Loro per primi hanno usato*

l'acquerello in un libro per bambini... (AA.VV., 1991).” That book was extraordinarily innovative from a compositional and technical point of view for that decade (beginning of the 60's), the use of watercolours and Indian ink diluted with water for drawing birds and their feathers gave the impression of embroidery decorations (AA.VV., 1991).

Zavřel went on discovering the world of colours and all the possible experimentations with watercolours mixing it with all his others knowledges relative to artistic techniques iconography and other artists' influence in design. In particular, he created many of his most famous illustrations employing watercolours, that is *Il pesce magico* (1964) (Figure 12), *Vodnik* (1970), *L'ultimo albero* (1976), *Il ponte dei bambini* (1977), *La pentola magica* (1978), *La farfalla* (1980), *Il segreto delle erbe magiche* (1984), *La città dei fiori* (1987) and *Sotto la laguna di Venezia* (1987). In addition to this, the usage of watercolours in combination with xylography is an interesting solution for *Jacopo il giullare* (1991) and the unpublished illustrations for *In cammino con Dio* (1996), that contribute to render the spatial depth of the drawn scenes.

About the technique, watercolour painting has a rich history and is cherished for its vibrant and translucent qualities. From a compositional point of view, watercolour pigments are finely ground powders that, when mixed with water, create a fluid medium for painting. The pigments used for watercolours can be inorganic, organic or synthetic and their source determines not only the colour and hue, but also other properties, such as transparency, lightfastness and staining. Binders are then present in watercolour formulation, the most common is the Arabic gum but other resins can be employed. Glycerin and honey are sometimes added, for example, to increase moisture retention and so improve the paint's behaviour. Additives are then included to enhance properties like texture and drying time and among the most common, Ox gall or similar synthetic alternatives can be found, a wetting agent that helps to reduce surface tension and improve the flow of the paint across the support. Other additives like phenol and urea can be added in order to prevent the growth of mold or bacteria or also plasticizers and fillers, like kaolin or chalk to bulk up the volume of the paint without adding more pigment (artpracticed.com; artchive.com).

1.3.4 Acrylic paint



Figure 13 Illustrations from the book *Il sole perduto* (1973), acrylic paint

The illustrations by Cingoli and Carloni were only the first step of the new artistic phase, which can be defined as the artistic maturity of Zavřel's production, since 1978. He added other inspirations and conditioning from his education, such as the Italian iconography and colouristic tradition that gave him the possibility to experiment with another technique, that is acrylic colours. Acrylics are composed by pigments suspended in acrylic polymers emulsion and plasticizers, silicone oils, defoamers, stabilizers, or metal soap (Izzo et al., 2014). Acrylic

colours do not need specific thinner but simply water can be added like for watercolours, most of them are water-based but they become water-resistant when dry. Depending on how much the

acrylic paint is diluted with water or modified with other mediums, the finished acrylic painting can resemble a watercolour, a gouache, or an oil painting, or simply show its unique characteristics. The appearance and other properties like flexibility or hardness of this type of painting can be modified using acrylic mediums. In particular, acrylics are able to bond to many different surfaces and mediums can be used to modifying their binding characteristics. Acrylic paint can be applied in thin layer or washes to create effects that remind watercolours and other water-based mediums, or use for building thick layers of paint. Differently to watercolours, even if also acrylic paints can be thinned with water, it cannot be rehydrated once dry but it can be applied in layers, sometimes diluted with water or acrylic medium to allow to the layers underneath to partially show through (Izzo et al., 2014) (Fardi et al., 2018). Acrylic paint, then, tends to be very bright and that is one of the most appreciated characteristics of this technique.

Zavřel showed his appreciation for acrylic paints by creating many illustrations for different books, such as *Il sole perduto* (1973) (Figure 13), *Il flauto del pastore* (1978), *Gesù Bambino Rubato* (1988) and some paintings on canvas which he realized for the contemporary art gallery *Studio La Città* that he founded in collaboration with Hèlène De Franchis in Verona during the 70's. He realized also some portraits of his friends and many sketches of landscapes and ideas for his books.

1.3.5 *Tempera coprente*

Another artistic technique particularly appreciated by the Czech artist was the tempera technique, that is often mentioned as *tempera coprente*. This definition sounds a little ambiguous since it could probably refer to the gouache technique. The result appears to be similar to the one obtained with tempera since they are both water-based techniques but their formulations are different: gouache paint contains pigments mixed with lead white or calcium carbonate-based white pigment and Arabic gum or glue. On the other hand, tempera paint is composed by pigments mixed with organic binders like egg-yolk, egg-white, oil, casein or milk. During the 20th century, the definition of *tempera* changed its original meaning. It is important to highlight that during the 19th and 20th centuries there were many complex mixtures of different binders that were generically called *tempera*, especially regarding the composition of colour tubes. They may have been contained egg mixed with fig milk, resins, gums or wax treated with basic additives. Other mixtures containing milk, alone or with egg, oil and chalk, and casein, that may have been mixed with gelatine, glycerine and wax or with chalk. In some cases, tempera was also a mixture of animal glue, glycerine and water, like for the Italian painter Francesco Michetti (Bensi, 2015). During the second half of the 19th century, there was a revival concerning the use of



Figure 14 Illustration from the book *La nostra meravigliosa Terra* (1971), *tempera coprente*

tempera technique but the main goal was to introduce tempera colour tubes like they did for oil colours. One of the most vibrant environments at that time was München, in Germany, and there, many scientific researches were done in order to formulate the best artistic materials using an industrial approach. The tempera colours formulated by the baron Adolf von Pereira in 1891 and other industrial formulations proposed by Richard Wurm, Hermann Neish, Franz Schonfeld and Hermann Schmincke were displayed during a conference in München in 1893 and they are some of the most famous attempts (Rinaldi, 2016) (Bensi, 2015). The numerous formulations for tempera colours were proposed as a water-soluble alternative to oil colours and they seemed to be particularly appreciated by artists because they tended to deteriorate less, even if the quality of some of them, such as tempera Wurm, became worse throughout time and they showed their main conservation problems like yellowing phenomena and the drying time. Some Italian painters, like Cesare Laurenti and Pietro Fragiaco noticed those problems and they tried to solve them looking for a better tempera formulation by themselves. In particular, Laurenti tried to patent his formulation containing animal glue and Arabic gum. That was a common tendency, so many other artists had their own tempera recipes containing different ingredients like egg, Arabic gum, alcohol, vinegar, sugar. The painter Giorgio De Chirico had his own formula and so Mariano Fortuny y Mandrazo, who had his factory specialized in producing tempera colour tubes and also in those cases, tempera contained a mixture of oils, wax, resins and glycerin (Rinaldi, 2016). Considering all of those facts, it is evident that the definition of tempera from a chemical point of view during the 19th and 20th centuries is quite complex and ambiguous.

Gouache technique substituted in many cases tempera, in particular during the second half of the 19th century for creating sketches for oil paintings and billboards. Even if gouache paint becomes less bright after it dries, one of its most appreciated properties is that it could be work easily and that was the reason why it was used in particular for creating drawings for printing like posters. The easy workability and the characteristic opacity are particularly appreciated for printing reproducibility and how they allow to realize artworks quickly (Pierozzi, 2011). Those peculiar properties could have been appreciated by Zavřel as well and he employed the so-called *tempera coprente* technique for creating illustrations for some of his books: *Sterntaler* (1969), *La nostra meravigliosa Terra* (1971) (Figure 14), *I colori rubati* (1972), *Gesù Bambino Rubato* (1988) and *In cammino con Dio* (1996).

1.3.6 Indian ink and ecoline

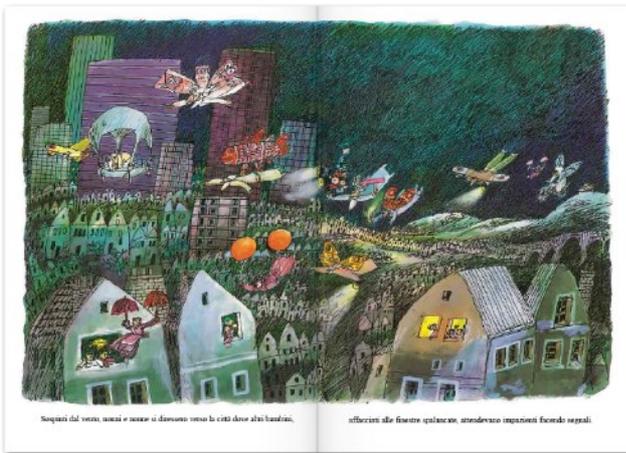


Figure 15 Illustration from the book *Nonno Tommaso* (1983)

Other two artistic techniques that Zavřel experimented with were Indian ink and ecoline, often diluted and treated like watercolours in order to obtain a similar result. Inks were traditionally composed of black pigments, like carbon black or a ferric-tannate charge-transfer complex formed between iron (III) and catechol groups of tannins for Iron-Gall inks, but in modern times, the formulation of inks is extremely various as for pigments as for binders. Other dyes are often added in order to change the shades and so the organic binders

are various, such as Arabic gum or animal glue (Smith, 2009; Wikipedia). Fine soot also can be mixed with water to form a suspension and gelatin or resins like shellac can be added to make ink more durable once dried. Zavřel used it for creating the illustrations for *Nonno Tommaso* (1983) (Figure 15), *Nani e Giganti* (1985) and the sketches for both of those books and for the storyboard of *L'ultimo albero* (1976).

On the other hand, Zavřel created the sketches of the illustrations for the book *Seguendo la stella* (1967) using the ecoline that lend to the drawings a particular elegance. The ecoline are specific liquid inks, also called liquid watercolours, but dyes and not pigments are present in their formulation, mixed with Arabic gum as binder. Their colours are vivid and bright and they can be reworked with water also after they dried to obtain effects that are not comparable with watercolours and they dry quite quickly. For those characteristics, those inks are employed for illustrations and comics, as well as in the architecture and design fields and the most common technique is the *velatura*, from the lighter shades to the darker ones, the same employed for watercolours. A paper support with a thick grammage is required and with specific characteristics that allow to use the ecoline since they tend to corrode paper support easily (pennarellicopic.it; momarte.com).

To conclude, Štěpán Zavřel demonstrated to have strong artistic abilities since his youth and the ability to combine what he technically learnt from different experiences to create new unexpected results. He was then aware of the characteristics and properties of the materials he used and he wanted to experiment with new techniques, that is watercolour to trace a new perspective in the world of illustration and his influence had a big impact on the younger illustrators from this point of view as well.

2. Case studies

In this study, seven drawings taken from different books and two paintings on canvas were selected and analysed.

In particular, the drawings were called:

- **01:** a snowy landscape with mauve shades is represented and the only characters, a little girl and a couple of red birds, are not located in the centre of the drawing but they have quite small dimensions respectively to the natural elements.
- **02:** the natural snowy landscape is the real protagonist of this drawing and the only character is a little girl in red. She is the only element in a different colour that could be well distinguishable to the background.
- **03:** a blue hill is drawn in the centre of the paper sheet and a blue castle is located on the top. The lines of the castle are in a bright reddish orange colour and a cloud is depicted as a single brush in bright magenta. No characters are present in the scene.
- **04:** this drawing is characterised by a dark palette, in particular green colour is mixed with black. The scene is illuminated by white areas and the orange beard of one of the characters is the main bright element which captured the observer's eyes. Three characters are depicted on close-up.
- **05:** the interior of a house is depicted and a woman is the only and main character of the scene. A bright light ray divides the drawing in two parts and illuminates the dark colours of which characterise the house.
- **M1:** this drawing is an overview of St. Mark's basilica in Venice from an upper point of view, like it is a bird's point of view. The colour palette is characterised by blue and green shades and the scene is delimited by algae, reminding sort of a landscape underwater.
- **M2:** San Marco basilica is the main character of this drawing and dominates the entire scene, even if a group of small characters is present, as well. Algae enriched this scene as well, reminding an underwater landscape also in this case. The colour palette is characterised by green shades.

Since, the paintings were called:

- **D1:** this painting is characterised by round and rectangular geometrical forms, smaller and bigger, depicted with white, brown and ochre colours.
- **D2:** geometrical forms are the main elements of this painting and the artist experimented with rectangular and round forms in this case, as well. The colour palette is characterised by white, brown and ochre colours.

The selection of the different drawings was based on:

- different conservative conditions. In fact, the drawings 01, 02, 03, 04, 05 and the paintings D1 and D2 are conserved in the archive and in the storage of the Museum Stěpán Zavřel, since the drawings M1 and M2 are exposed in the main room of the museum;
- the variability of the colour palette employed by the artist;
- different artistic techniques as declared by the artist or reported in the label or catalogues. In fact, the drawings 01, 02, 05, M1 and M2 were created by means of *tempera coprente*,

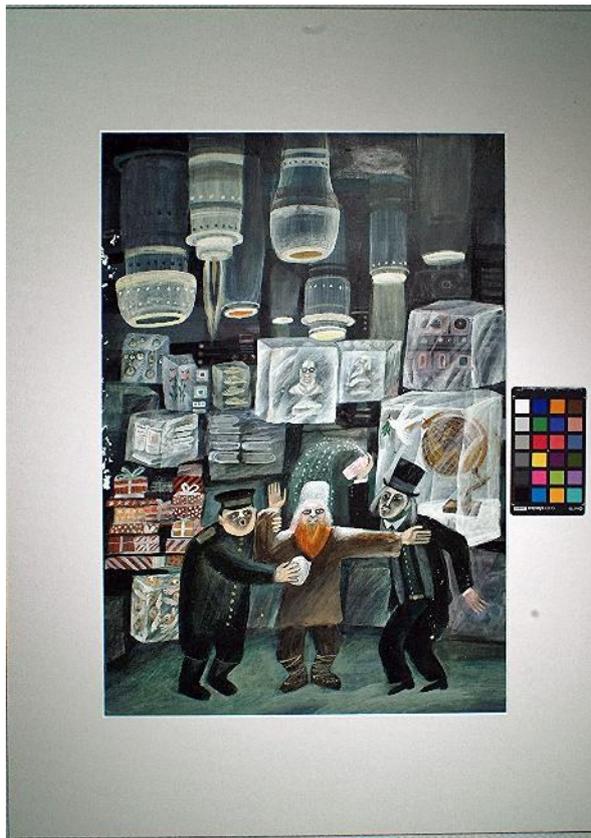
probably gouache; the drawing 03 by oil pastels diluted with water and the two paintings D1 and D2 by acrylic paint.

Finally, the intention was also to retrace the compositional and stylistic path of the Czech artist choosing drawings and paints from different periods of his artistic career and connecting them with the different techniques he experimented with.

2.1 Original drawings of illustrated books for children

Regarding the main purposes of this study, some drawings from different books illustrated by Zavřel were selected. This section focuses on presenting an overview of those books in order to understand the main topics of them. As already underlined previously, Zavřel's books have always a precise educational message and understanding it is fundamental for contextualizing the use of some colour palette and the chosen technique for obtaining particular effects.

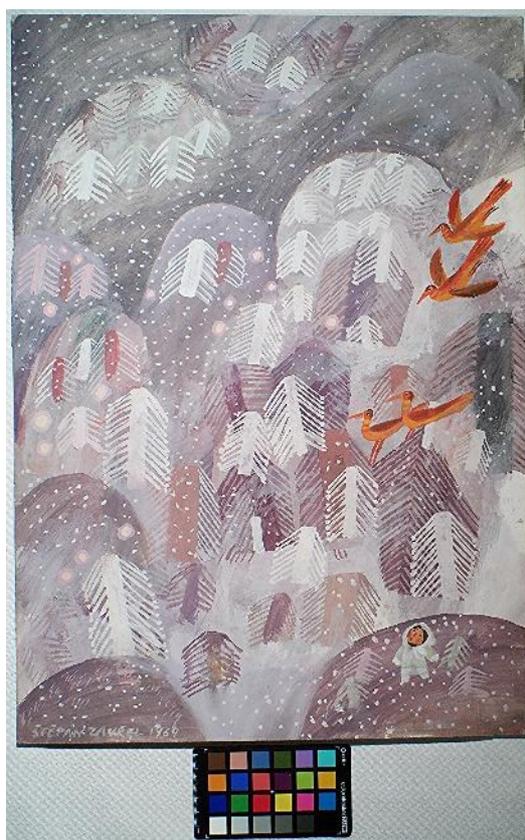
All the case studies come from a specific series of illustrations. The only drawing for which it was not possible to understand from which book it comes from, was drawing 04.



Measure: 35,00 x 50,00 cm

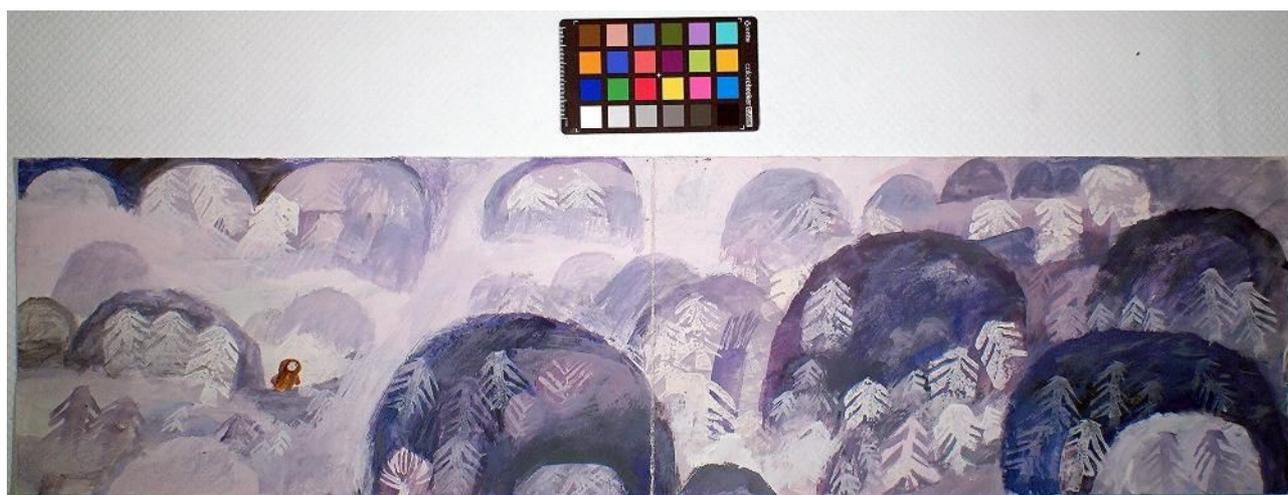
Drawing 04 is conserved in the archive of Štěpán Zavřel Museum

2.1.1 Drawing 01 and drawing 02 from *Sterntaler* (1969)



Measure: 34,70 x 49,50 cm

Drawing 01 is conserved in the archive of Štěpán Zavřel Museum



Measure: 69,50 x 19,00 cm

Drawing 02 is conserved in the archive of Štěpán Zavřel Museum

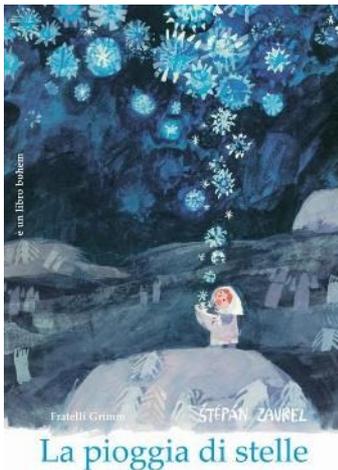


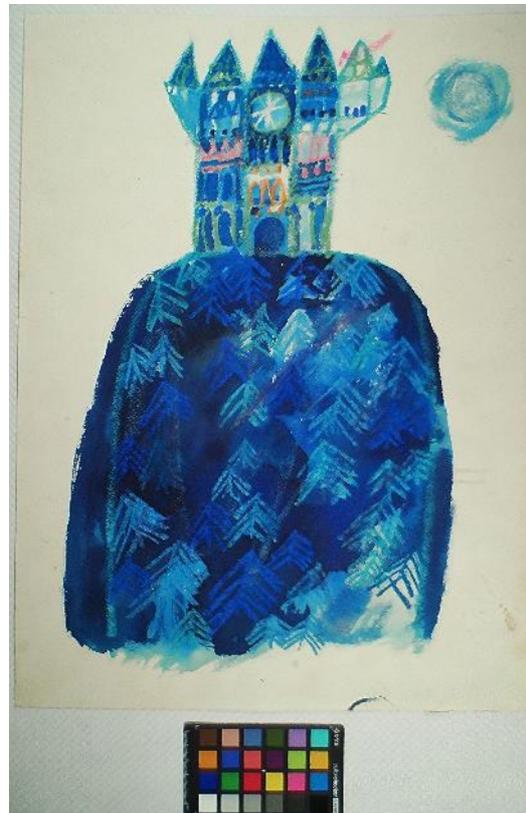
Figure 16 Cover of the book *Sterntaler* (1969)

Sterntaler (*Pioggia di Stelle*) (Figure 16) is the last book of the 60's edited by the Patmos publisher from Düsseldorf. The story is based on the original tale written by Grimm brothers and it is about a poor little girl, an orphan without a house, who decided to give everything she had to other people poorer than her until she had nothing more. At that moment, suddenly a star rain covered her with light, a symbol of the divine Providence that will protect her for the rest of her life. The main topic of the story is the importance of giving to the others and be able to give themselves to the others, a particularly important message for the artist.

Zavřel decided to set the tale during a perpetual winter and he used the *tempera coprente* (probably gouache) technique and the xilographic effects for the illustrations in order to recreate successfully the idea of winter landscapes and the consistency of snow with all the shades and shadows (Tonzig, 2011) (fondazionezavrel.it). The tempera allowed him to pull the snowy ambience and the sky and stars perfectly together, so the final effect results to be harmonic and functional for the topic.

Drawings 01 and 02 were part of the illustrations from this book.

2.1.2 Drawing 03 from *Il Sale vale più dell'Oro* (1968)



Measure: 34,50 x 47,00 cm

Drawing 03 is conserved in the archive of Štěpán Zavřel Museum

Il Sale vale più dell'Oro (*Sale is better than Gold*) (Figure 17) was published in 1968 by the Nord-Sud Veriag publisher from Mönchaltorf. The book is based on a popular Czech fairy tale and Zavřel did not create only the illustrations but he also wrote the text. The main topic of this story is the importance of love, the purer simpler and sincerer form of love that is most precious than all the possible materialistic treasures in the earth. This message, related to the intimate feelings and affection, is highlighted also by the choice to change the name of the princess who was the main character from Maruška to Liduška, the name of Zavřel's younger sister, Ludmila, making her the real protagonist of his book.

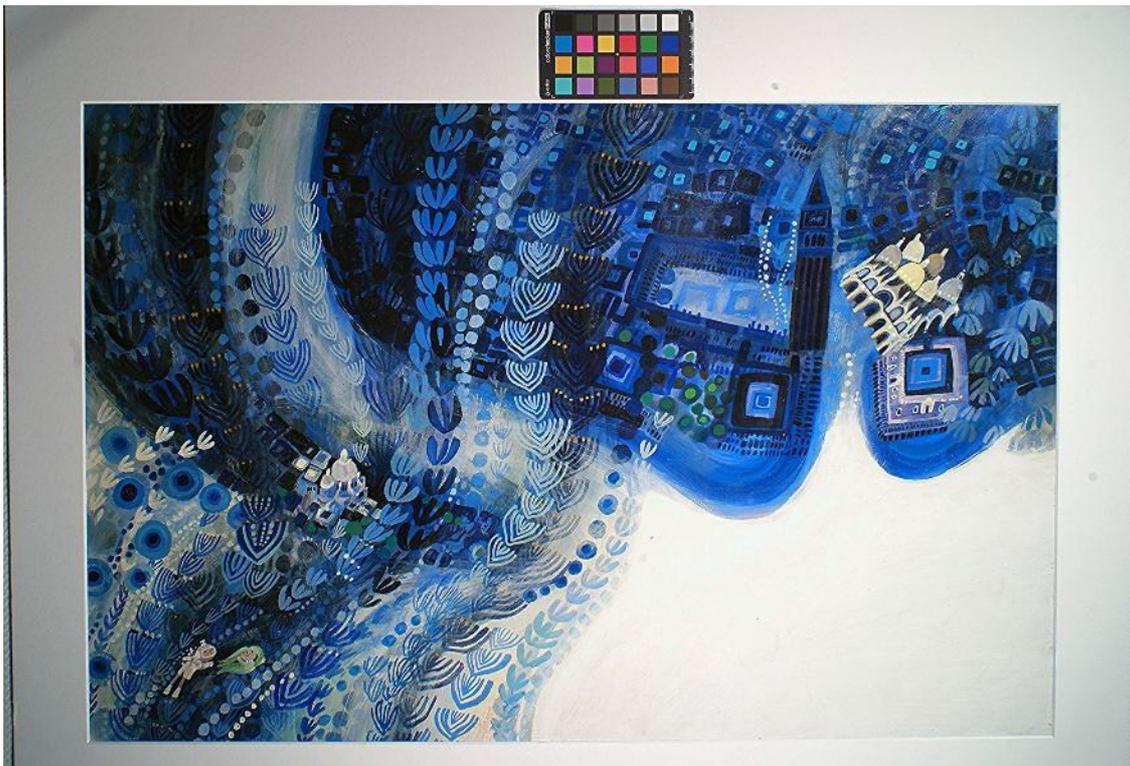
The artist chose to create the illustrations with oil pastels technique that allowed him to play with vibrant and vivid colours, a clear result that he learnt the lessons of his Italian Master Lele Luzzati (Tonzig, 2011) (mangialibri.com).

Drawing 03 was selected from the series of illustrations of this book.

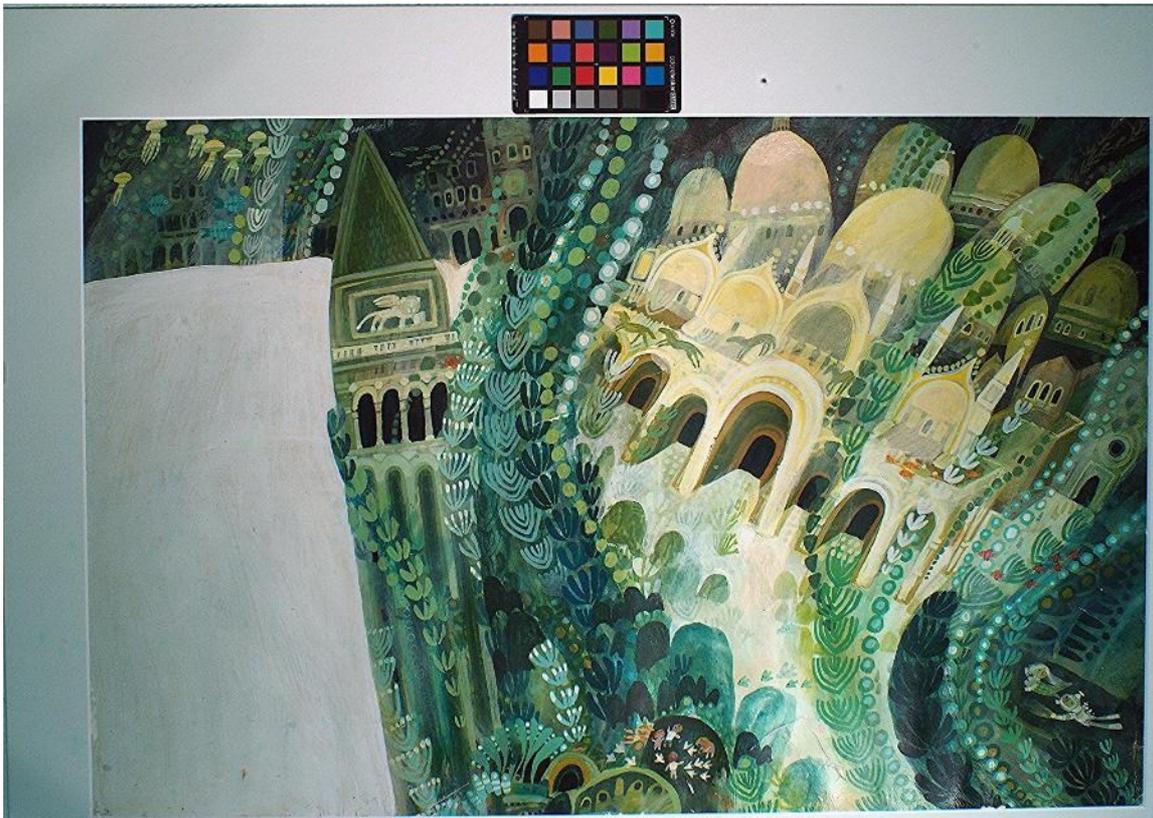


Figure 17 Cover of the book
Il Sale vale più dell'Oro
(1968)

2.1.3 Drawing M1 and drawing M2 from *Un sogno a Venezia* (1974)



Drawing M1 is exposed in Štěpán Zavřel Museum



Drawing M2 is exposed in Štěpán Zavřel Museum

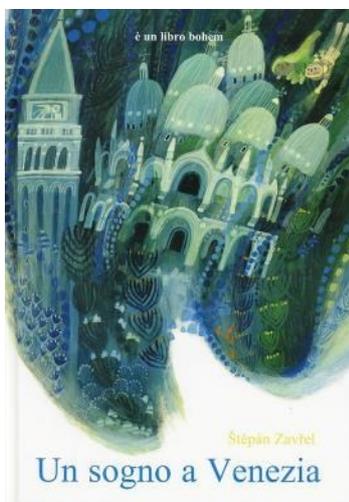


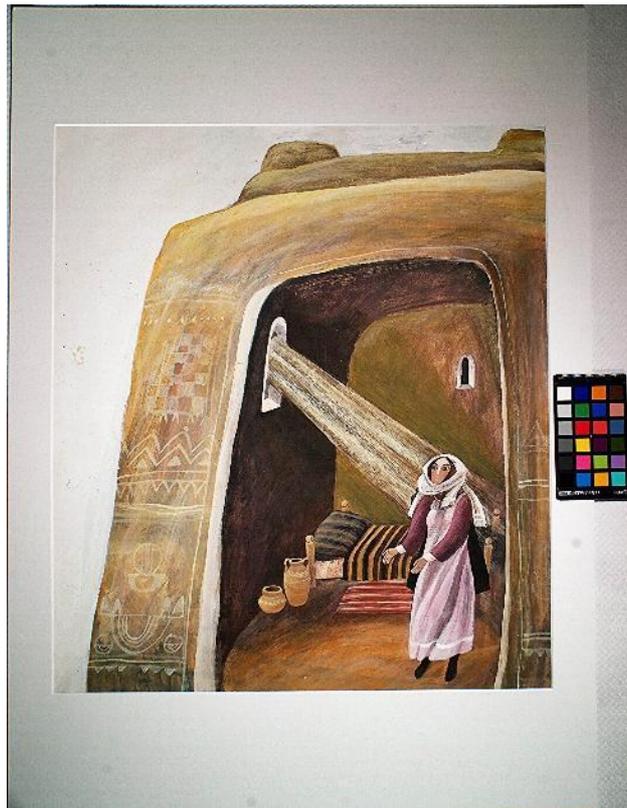
Figure 18 Cover of the book *Un sogno a Venezia* (1974)

The first edition of the book *Un sogno a Venezia* (*Venedig Morgen*) (Figure 18) was published in German by the Bohem Press publisher from Zürich and then in Italian by the Grafiche AZ publisher from Verona, both in 1974. The project, including illustrations and text, was totally thought and invented by Zavřel and the drawings were also exposed at the Metropolitan Museum in New York. The artist received the prize “Primo Premio Europeo di Letteratura Giovanile Pier Paolo Vergerio” for the book in 1989. The story takes place in Venice and is suspended in a dimension between the real world and a dreamlike one. The main intention of the artist is to focus the attention of the readers on the conservation of the cultural heritage of Venice and to consider it also from an ecological point of view (Tonzig, 2011).

The artist chose to create the illustrations by means of acrylic technique, in order to recreate the feelings given by water and by such a unique city like Venice. The vibrant colours of acrylic paint allowed him to reproduce the bright shades and the transparency of a water ambience and also the idea of a suspended world.

Drawing M1 and M2 were part of the illustrations from this book.

2.1.4 Drawing 05 from *In cammino con Dio* (1996)



Measure: 50 x 70 cm

Drawing 05 is conserved in the archive of Štěpán Zavřel Museum

The main topic of the book *In cammino con Dio* (Figure 19), edited by the Bohem Press publisher from Zürich in 1996, is the religious theme that Zavřel took into consideration in more than one of his stories. This book focuses on the most important episodes from the Old and New Testament in an original way thanks also to the text written by Regine Schindler, a famous Protestant theologian.

Zavřel chose two different techniques to create the illustrations, that is xylographic engravings coloured with watercolours (mostly not edited) and tempera technique, which allowed him to play with washes of different colours and create an effective colourful result. It is possible to recognize different references to other artistic artworks by famous painters, such as Henri Rousseau, Gustave Klimt and the Babel Tower by Pieter Bruegel and the composition of the scenes reminds the Zavřel's experience as a set designer and the legacy with Lele Luzzati (Tonzig, 2011).

Drawing 05 was selected from the illustrations created for this book.

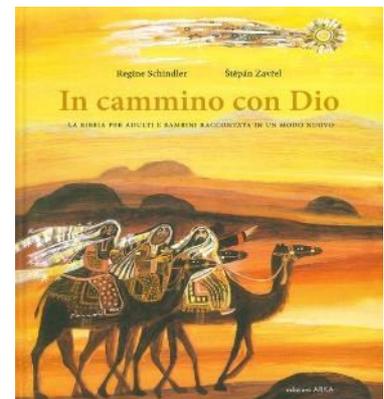
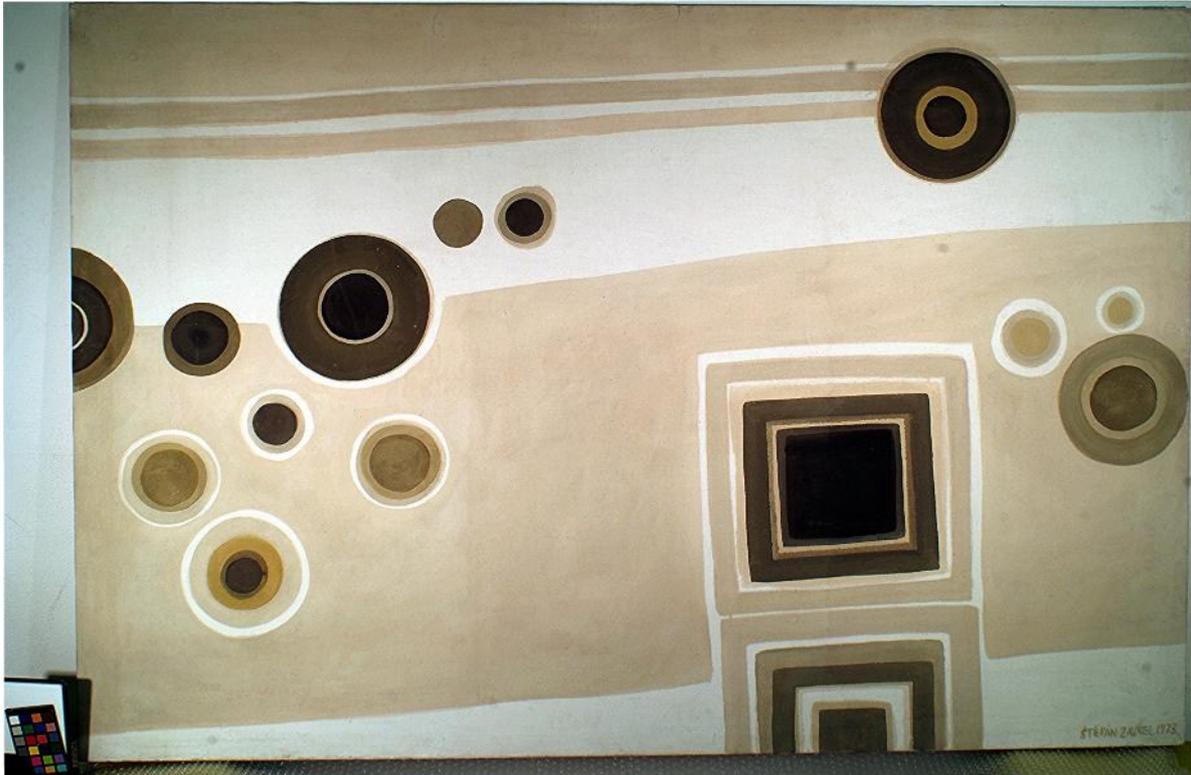


Figure 19 Cover of the book *In cammino con Dio* (1996)

2.2 Paintings on canvas D1 and D2



Painting D1 is conserved in the archive of Štěpán Zavřel Museum



Painting D2 is conserved in the archive of Štěpán Zavřel Museum

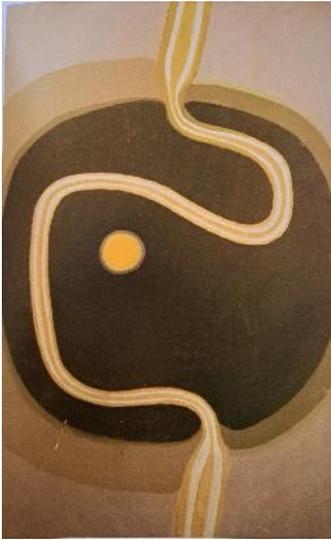


Figure 20 Painting *L'incontro*, acrylic paint on canvas

Stěpán Zavřel experimented with different techniques and supports along his artistic career and he created also some paintings on canvas, in particular during the 60's and 70's (Figure 20). That period corresponds to the opening of the art gallery *Studio La Città*, which he decided to found together with his friend and colleague Hèlène De Franchis in Verona in 1968. Zavřel directed personally the gallery for a very short period of time, until the spring 1969 when he decided to leave the direction only to his colleague, in order to focus his attention on the creation of his new house in Rugolo di Sàrmede. At the beginning, the gallery treated with exhibitions of artworks by Lucio Fontana, Piero Dorazio, Mario Schifano and Gianni Colombo and focusing on the Minimalism and the *Pittura Analitica* later, during the 70's, paying attention to the international artistic horizon (Tonzig, 2011).

Zavřel created a series of acrylic paintings on canvas with abstract subjects in that period (like the painting *L'incontro*) and he painted also the poster in the same style for an exhibition at the gallery in 1971 (Tonzig, 2011).

Paintings D1 and D2 were the only two paintings on canvas which were taken into consideration and that could have been created in such a context.

2.3 Painted mock-ups

In order to obtain clearer information about the binders contained into the artistic materials used by Zavřel, a series of mock-up painted films were prepared in laboratory considering the declared artistic technique employed by the artist. Taking into consideration the colour palette of the selected artworks as well, tempera/gouache and watercolours paint mock-ups were painted on different paper support, with a preparatory layer of acrylic chalk and without it, in order to understand if the probable presence of a preparation could have an influence on the analysis.

The paper sheets, branded Winsor & Newton, used as support were specific for watercolours, with A3 size and a cold press, acid free and containing 25% cotton in composition (Figure 21a). The acrylic chalk employed for the preparatory layer, branded Lefranc & Bourgeois, was a matt non-yellowing universal primer that could be applied directly on all porous substrates such as canvas and paper (Figure 21b). It dries in 30 minutes and can be sanded after drying, it is ready to use and cannot be diluted or mixed with turpentine or oil paint.

a



b



Figure 21 a: paper sheets used as support for creating the painting coats; b: the acrylic chalk used for the preparatory layer.

The chosen tempera/gouache paints were made by different brands, from the non-professional to more professional ones: Giotto (Italy), Carioca (Italy), Maimeri (Italy), Talens (Netherlands) and Ferrario (Italy). On the other hand, the watercolour paints were by only one brand, that is Winsor & Newton (UK). The colour palette included green, blue, yellow, red, magenta, brown, black and white shades, which pigment composition was declared only for Maimeri, Talens and Winsor & Newton. A complete list of the employed paints is presented in *Table 1* and the paint coats on paper support are presented in *Figure 22*. All of those paints are recent, the only exception is the gold colour *Oro 038* by Ferrario Color, which could be dated back to 1970's/1980's.

Technique	Brand	Name and Colour	Color Index (if known)
Tempera	Carioca	Verde Brillante 12	-
Tempera	Carioca	Verde Veronese 13	-
Tempera	Giotto	Verde Cinabro 11	-
Tempera	Giotto	Verde 12	-
Tempera	Giotto	Verde Paolo Veronese 13	-
Gouache	Maimeri	Verde Oliva 331	PG17, PY42
Gouache	Maimeri	Verde Vescica 338	PG8
Tempera	Giotto	Verde Smeraldo 14	-
Gouache	Talens	Verde Smeraldo 616	PG7
Tempera	Carioca	Celeste 15	-
Tempera	Giotto	Cyan 15	-
Tempera	Giotto	Blu Oltremare 17	-
Gouache	Maimeri	Blu Oltremare 392 (PB29)	PB29
Gouache	Maimeri	Ceruleo imit. 415	PB15:1
Tempera	Carioca	Giallo Primario 3	-
Tempera	Giotto	Giallo Primario 02	-
Tempera	Giotto	Giallo Limone 03	-
Tempera	Giotto	Ocra Gialla 21	-
Gouache	Talens	Yellow 200	PY74, PO67
Tempera	Maimeri	Ocra Gialla 131	PY42
Tempera	Ferrario Color	Oro 038	-
Tempera	Giotto	Rosso Carminio 09	-
Tempera	Giotto	Rosso Scarlatto 08	-
Tempera	Carioca	Arancione 5	-
Tempera	Maimeri	Ocra Rossa 191	PR101
Tempera	Maimeri	Rosso di Cadmio imit. 223	PR112, PR145
Tempera	Giotto	Rosa 06	-
Tempera	Giotto	Magenta 10	-
Tempera	Giotto	Violetto 19	-
Tempera	Carioca	Magenta 9	-
Tempera	Giotto	Terra di Siena Naturale 20	-
Gouache	Maimeri	Terra di Siena Naturale 161	PY42, PY83
Gouache	Maimeri	Terra di Siena Bruciata 278	PR101, PBk11
Tempera	Ferrario	Ocra Naturale 09	-
Gouache	Maimeri	Terra d'Ombra Naturale 493	PY42, PR101, PBk11, PBk7
Gouache	Talens	Raw Umber 408	PBk6, PY42, PO67
Tempera	Giotto	Bianco 01	-
Gouache	Maimeri	Bianco di Titanio 018	PW6
Tempera	Giotto	Ivory Black 24	-
Tempera	Carioca	Nero 24	-
Gouache	Maimeri	Nero 530	PBk1
Watercolour	Winsor & Newton	Terra Verde 637	PG23, PG18, PB28
Watercolour	Winsor & Newton	Chromium Oxide 459	PG17
Watercolour	Winsor & Newton	Cobalt Blue 178	PB28
Watercolour	Winsor & Newton	Cerulean Blue 137	PB35
Watercolour	Winsor & Newton	Ultramarine Blue – Green shade 667	PB29
Watercolour	Winsor & Newton	Cadmium Yellow 108	PY35, PO20
Watercolour	Winsor & Newton	Indian Yellow 319	PO62, PY139
Watercolour	Winsor & Newton	Naples Yellow 422	PW6, PBr24
Watercolour	Winsor & Newton	Yellow Ochre 744	PY43
Watercolour	Winsor & Newton	Alizarin Crimson 004	PR83
Watercolour	Winsor & Newton	Cadmium Red 094	PR108
Watercolour	Winsor & Newton	Indian Red 317	PR101
Watercolour	Winsor & Newton	Permanent Carmine 479 (Quinacridone Pyrrolidone)	-
Watercolour	Winsor & Newton	Raw Umber 554	PBr7
Watercolour	Winsor & Newton	Vandyke Brown 676	PR101, PBk6
Watercolour	Winsor & Newton	Venetian Red 678	PR101
Watercolour	Winsor & Newton	Sepia 609	PBk6, PR101
Watercolour	Winsor & Newton	Lamp Black 337	PBk6/7
Watercolour	Winsor & Newton	Ivory Black 331	PBk9
Watercolour	Winsor & Newton	Mars Black 386	PBk11

Table 1 Tempera/gouache and watercolour paint mock-ups



Figure 22 a Tempera/gouache painted mock-ups on paper support without chalk preparation layer.

Another series contained Arabic gum as binder (*Figure 23a*) and in the last series, different replicas were done with different combinations with acrylic, oil, vinylic, gum Arabic binders with different dyes (*Figure 23b*). In *Table 2*, a complete list of paint coats and binders is presented. Those paints are quite recent as well, but the precise years were not known. The paint replicas containing gum Arabic were painted on a paper support; on the other hand, the other series containing different binders was painted on canvas.

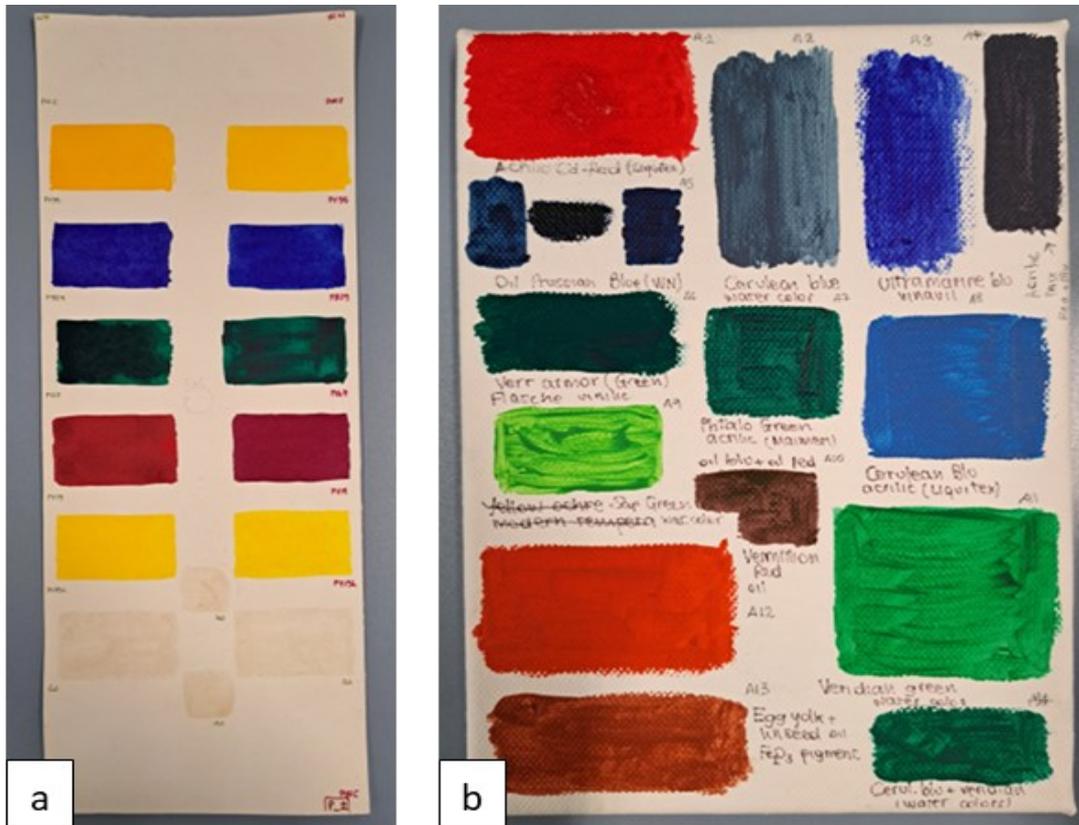


Figure 23 Painted mock-ups containing Arabic gum (a) and different combinations with acrylic, oil, vinylic, Arabic gum (b) as binders.

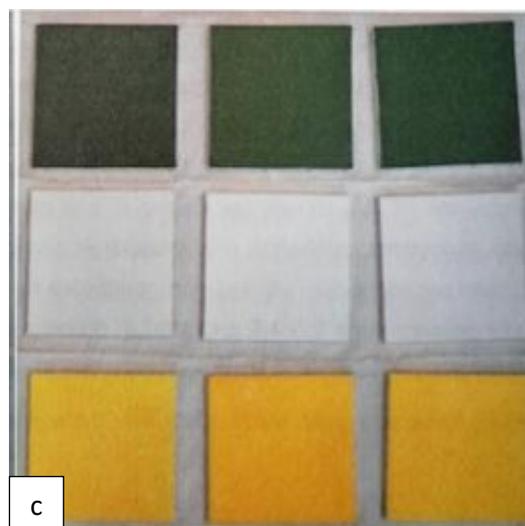


Figure 23 c Painted mock-ups containing acrylic, oil and vinylic binders.

Binder	Brand	Colour	Color Index (if known)
Acrylic	Liquitex (Heavy Body)	Verde ossido di cromo 166	PG17
Acrylic	Liquitex (Heavy Body)	Bianco di Titanio 432	PW6
Acrylic	Liquitex (Heavy Body)	Giallo medio azo 412	PY74 LF
Vinylic	Lefranc & Bourgeois (Flasche)	Verde ossido di cromo 542	PG17
Vinylic	Lefranc & Bourgeois (Flasche)	Bianco 001	PW5-PW6
Vinylic	Lefranc & Bourgeois (Flasche)	Giallo Senegal (primario) 195	PY74
Oil	Winsor & Newton (Winton)	Ossido di cromo 31	PG17
Oil	Winsor & Newton (Winton)	Giallo di cadmio Limone (imitazione) 7	PY3-PY4
Gum Arabic	Kremer	White	PW6
Gum Arabic	Kremer	Yellow	PY35
Gum Arabic	Kremer	Blue	PB29
Gum Arabic	Kremer	Green	PG7
Gum Arabic	Kremer	Red	PV19
Gum Arabic	Kremer	Yellow	PY154
Acrylic	Liquitex	Cadmium Red	-
Watercolour	-	Cerulean Blue	-
Vinylic	-	Ultramarine Blue	-
Acrylic	-	Red + Blue	-
Oil	Winsor & Newton	Prussian Blue	-
Acrylic	Liquitex	Cerulean Blue	-
Vinylic	Lefranc & Bourgeois (Flasche)	Verramor Green	-
Acrylic	Maimeri	Phthalo Green	-
Watercolour	-	Sap Green	-
Watercolour	-	Veridian Green	-
Watercolour	-	Cerulean Blue + Veridian Green	-
Oil	-	Vermillion Red	-
Oil	-	Blue + Red	-
Egg yolk + linseed oil	-	Fe ₂ O ₃	-

Table 2 Mock-ups containing acryli, vinylic, oil, Arabic gum as binders

II. Diagnostic Survey

3. Materials and Methods

This study started with the selection of representative measure points of the artworks and then an analytical analysis was conducted by means of different methods, that is digital imaging, microscopy, Raman Spectroscopy and FORS. Some samples were also taken and analysed with microscopy and Micro-Raman Spectroscopy. The main goal was to identify the materials, pigments as well as binders, employed by Stěpán Zavřel and trying to understand if the declared materials corresponded to the effective colours from a compositional point of view. In order to do that, a series of paint coats, whose composition was known, was selected and analysed with FORS and compared with the analytical results of measure points.

3.1 Diagnostic techniques

In this section, the employed diagnostic techniques are going to be presented. The chosen approach was adopted thinking mainly to a non-invasive or at least micro invasive analysis since the artworks weren't movable and the pictorial surfaces weren't particularly rich.

3.1.1 Technical photography

Imaging technology has emerged as a crucial tool in the realm of art conservation and restoration, since it allows to delve deep into the intricacies of artworks and so safeguard them for future generations. High-resolution scanning and imaging systems provide conservators with a non-invasive means to study and document an artwork's condition. Such a documentation is useful as a baseline to monitor changes over time, enabling early detection of deterioration or damage. In fact, "as well as recording the condition of an artwork, visible light [...] can be used to provide further information with a general view of the artwork. [...] Careful positioning of light sources also allows for the recording of surface details such as texture and cracking; this process referred to as tangential or raking light photography" (Carlin and Grimaldi, 2024). Infrared imaging can provide information regarding underdrawings or *pentimenti*, hidden layers or alterations; on the other hand, UV fluorescence photography "can generally inform regarding the surface coatings, varnishes that have been applied over the years, as well as indicate the presence of in-painting" (Carlin and Grimaldi, 2024). Additionally, it allows an overview on artistic materials like specific pigments or binders (de la Rie, 1982). In conclusion, technical photography reveals to be a significant tool to empower conservators with detailed insights into artworks' condition and history and useful to track's an artist's evolution and even attribute artworks to particular artists or period.

Digital imaging of the studied drawings and the paintings was carried out in raking and normal light and then examined using a stereomicroscope. The images of two paintings were then carried out in transmitted light as well. Images were taken using a digital camera Samsung NX500 28.2Mpx 1:2.8/28. Visible images were captured with the Visible filter Hoya 390-700 nm; on the other hand, infrared images were captured with the IR filters at 720 nm, 850 nm and 950 nm and UV images were captured using UV filters. A standard colourchecker X-rite Pantone classic mini was employed as well. Images in UV light were also taken in specific dark conditions.

The images were tortured using PhotoPad[®] software.

3.1.2 Microscopy

The surface and microscopic details and features of the artworks were observed and visually characterized using a DINO-LITE AM4113T portable microscope, as in normal light as in UV light. The five samples collected from only the drawings M1 and M2 were observed using a stereomicroscope at 10x, 20x and 40x magnifications.

The microscopic images were tortured using PhotoPad[®] software.

3.1.3 Hyperspectral imaging

"The past few years have seen a tremendous rise in the development of hyperspectral imaging techniques, which are imaging techniques with a sufficient number of channels to provide a complete spectrum for each pixel. In the visible range, the reflectance spectrum can be used to identify pigments and colorants, particularly when they are used pure in thick layers as is the case

in illuminated manuscripts” (de Viguerie et al., 2020). In case of other manufactures like easel paintings, the analysis results to be more complex. In fact, “different pigments are dispersed in a binder, superimposed on other layers and overlaid by a varnish” (de Viguerie et al., 2020). Regarding the near-infrared range, the element of great interest is the possibility to identify the binder, since “vibrations of carbonyl or amide groups, associated with organic matter are visible in the 800 – 2500 nm range” (de Viguerie et al., 2020). The hyperspectral imaging allows to acquire simultaneously high-resolution images and reflectance spectra that are characteristics of the analysed materials.

The images were acquired throughout a contactless scan. The hyperspectral imaging, applied in the range between 400 nm and 1000 nm, allows to analyse pigments and materials from a spectroradiometric point of view and so to acquire information about artistic materials and layers or drawings under the surface. The spectra for each pixel of the drawings and the two paintings were acquired in normal and UV light using a portable push-broom Camera Specim IQ. This camera can acquire images in the range between 400 nm and 1000 nm (Vis-NIR, sensor 512x512px, 204 spectral bands, with spectral resolution FWHM 3 nm) The push-broom technology assures the alignment between acquired pixels and spectral data.

The acquired spectra were processed using Predictera[®] software.

3.1.4 Fiber Optics Reflectance Spectroscopy (FORS)

Reflectance Spectroscopy is a well-established technique used for the characterization of paints and pigments. This is a non-invasive technique which provides useful data for the identification of pigments – by correlating a sample spectrum to a suitable data-base - and for the analysis of colour changes on paintings and provides information that permits recognition of the spectral features of pigments (spectradb.ifac.cnr.it). Additionally, it is useful for “monitoring the presence of alteration products and the status-of-health of objects” (Picollo et al., 2002). “Reflectance spectroscopy in the visible region was applied to the study of paintings for the first time the decade from 1930 to 1940” and “from the beginning of the Eighties, portable spectrophotometers equipped with optical fibers that operate in the visible and near infrared regions have been extensively used” (spectradb.ifac.cnr.it). FORS apparatus can be transported and used for collecting spectra *in situ* and “a large number of spectra can be recorded, offering the possibility of a statistical treatment of the data, which is useful for the identification of different compounds” (Picollo et al., 2002)

The reflectance spectra of the surface of the artworks were acquired by means of the portable spectroradiometer FieldSpec 4 SR. This instrument is composed with a bundle of fiber optics (non-removable, 1,5 m length, field of view 25°) and different accessories that allow contactless analysis as well. The reflectance spectra were collected in the spectral region between 350 nm and 2500 nm with a spectral resolution of 3 nm at 700 nm and 10 nm at 1400/2100 nm. It is provided with detector VNIR: Photodiode Array.

The acquired spectra were processed using Origin95[®] (2018) software. The identification of pigments as well as binders was achieved through a comparison with FORS spectra from published and online databases.

3.1.5 Raman Spectroscopy

Raman Spectroscopy was employed for the identification of dyes and pigments. It has been proposed that it is the ideal technique for the identification of materials used on works of art because it is very reliable, sensitive, specific, non-destructive and can be applied in situ, therefore avoiding any sampling and any damage to the object under examination (Burgio and Clark, 2001). Raman spectroscopy is an excellent for the characterisation of paintings and it has been used to examine easel, panel and wall paintings, as reported by Burgio and Clark []. Even if the study of synthetic organic pigments is more problematic, since a large number of 20th century organic pigments produce strong fluorescence and weaker spectra, there are suitable databases for their identification (Burgio and Clark, 2001; Caggiani et al., 2016; Scherrer et al., 2009). This technique was used also for identifying pigments and dyes on illuminated manuscripts and to study inks on documents (Stuart, 2007).

The analysis was carried out using a portable Raman handheld spectrometer BRAVO Bruker, which has double laser (at 758 nm and 852 nm) that work simultaneously. Specifically, the first laser allows to acquire Raman spectra in the *fingerprint* region, since the second one focuses on the CH region. The laser power is over 100 mW for both. This instrument has small dimensions, is manageable and lightweight and can work in contactless mode, so it allows to perform analysis without damaging the surfaces. The laser power can be reduced, so it does not damage the material as well. The Raman spectra were collected in the spectral region from 170 cm⁻¹ to 3200 cm⁻¹ with a spectral resolution of 3 cm⁻¹. The acquisition time was between 1s and 40s.

The data were processed using Omnic8[®] software. The identification of pigments was achieved through a comparison with Raman spectra from published and online databases.

3.1.6 Fourier Transform Infrared spectroscopy – Attenuated Total Reflectance (FTIR – ATR)

Infrared spectroscopy utilises infrared radiation to cause excitation of vibrations of bonds in molecules. This type of spectroscopy is widely used and can be applied to a range of material types in conservation (Stuart, 2007). Moreover, “reflectance techniques may be used for samples where destruction of the sample needs to be avoided or when the surface properties are of interest. Attenuated Total Reflectance (ATR) spectroscopy utilises the phenomenon of total internal reflection” (Stuart, 2007). FTIR – ATR is employed for the characterization of both organic and inorganic paint components, that is the binder, pigments and inorganic fillers and extenders in paintings and it reveals to be particularly useful for studying modern and contemporary art and materials (Fardi et al., 2018) (Papliaka et al., 2010).

FTIR – ATR was performed on five samples collected from two of the selected drawings (M1 and M2) and another one from an unknown drawing. The analysis was carried out using a FTIR – ATR Alpha II Bruker instrument equipped with Diamond ATR crystal. The spectra were acquired by 48 scans with a resolution of 4 cm⁻¹. The spectra were collected in the spectral region from 350 cm⁻¹ to 4000 cm⁻¹. The measurement time was > 60s.

The data were acquired using Omnic8[®] software. Published and online databases and information from previous publications were used for the interpretation of the spectra.

3.1.7 Statistical Methods

The results obtained from FORS analysis were subjected to multivariate statistical analysis, that is principal component analysis (PCA). That was a useful tool to discriminate between different supposed binders and colourants and so to confirm or not the composition of artistic materials employed by Stěpán Zavřel in the selected drawings.

Principal Component Analysis (PCA) is the most widespread technique used to reduce the dimensionality of multivariate datasets. Specifically, PCA technique is used “for reducing the amount of information in the data while preserving as much of the original variance as feasible” (Gupta et al., 2023). In fact, “PCA generates new uncorrelated variable called *principal components* through a process of linear transformations of original data structure. These new variables are orthogonal and comes out of eigenvectors and eigenvalues of the covariance matrix of the data. Eigenvectors represent the direction of largest variation whereas”; on the other hand, “eigenvalues are measure of variance by each eigenvector in the dataset” (Gupta et al., 2023). The main aim of PCA is to describe the data variance by constructing a set of new orthogonal features, called principal components (PCs), that are a linear combination of the data variables. “Every new PC describes a part of the data variance not explained by the previous ones” (Daszykowski et la., 2007). The original data matrix X is firstly decomposed by PCA and then is replaced by the so-called covariance matrix, that is composed with score vectors T and loadings vectors P . Mathematically, the covariance can be expressed as:

$$X = TP^T$$

T has as many rows as the original data matrix, then P have as many columns as the original data matrix. The number of columns in the matrix T equals the number of rows in the matrix P (Gupta et al, 2023) (Bro and Smilde, 2014).

The FORS spectra of the measure points and painted mock-ups were processed using CAT[®] software.

4. Results and Discussion

The results of the non-invasive diagnostic campaign are discussed in this section. Seven original drawings and two paintings on canvas were taken into consideration and analysed by means of technical photography (Vis – IR – UV ranges), hyperspectral imaging, FORS and Raman Spectroscopy. In addition, five samples from two drawings (M1 and M2) were collected and studied using microscopy, micro – Raman Spectroscopy and FTIR – ATR in order to obtain more specific information about the materials. Finally, FORS analysis was performed on a series of different paint replica and the results were compared to the ones obtained for the case studies, in order to investigate the binder composition, in particular, and implement the online and published databases. A statistical analysis of the data was performed as well, for obtaining clearer information about the binders and so the artistic technique employed by the artist.

4.1 Technical photography

In this section the visual analysis of the selected artworks is presented. Different imaging techniques were used in order to collect information about the morphology and the general conservation state. In particular, IR-UV-Vis ranges were used to investigate the painted surfaces keeping in mind that different wavelength ranges can help into the investigation of an artwork in depth at different levels and to gain information also on the materials employed by an artist, for example on the chemical composition and so the presence of a particular pigment or dye. In particular, investigations with UV imaging were performed in order to verify possible presence of retouching or *pentimenti*, having an idea about the nature of the pigments and understanding if there is a varnish or protective layer on the surface. Regarding IR images, they were taken applying different lenses to the camera in order to change the wavelength and performing the imaging in the IR region. The lenses cut the wavelength at the NIR region of spectrum, in particular at 720 nm, 850 nm and 950 nm. This type of image acquisition was useful to evaluate the possible presence of underdrawings or underpaintings. However, not all pigments can be penetrated effectively.

The inspection of the pictorial surface was done thanks to a portable digital microscope considering two different ranges of the spectrum, that is Vis and UV. This type of observation was useful for studying the conservation state of the surface and identifying any possible superficial degradation phenomena, acquiring more specific information about the morphology and the general conservation state.

On the other hand, raking light and transmitted light were useful to study the morphology and the different layers composing the artworks. Raking light was useful also to individuate the presence of any defects and it was useful to observe and differentiate the areas where the painted layer was thicker than other areas and so studying the homogeneity of the pictorial superficial layer. Transmitted light analysis was performed only for the two painting on canvas since it was supposed to be more informative and useful for the investigation of the canvas potential defects and the information about the preparation and pictorial layers. To acquire the pictures, a light source was positioned behind the paintings.

The results obtained by means of hyperspectral camera are presented. Hyperspectral imaging allows to record simultaneously spectral and spatial information of an artwork's surface. The camera used for that measurement acquires a high-resolution image in which each pixel contains spectral information. It is possible to select a pixel, visualize reflectance spectra and compare it and group it with similar spectra that are acquired. In this way, it is possible to compare a single selected spot with a group of comparable spectra acquired, highlighting areas where there are similarities. Regarding the artworks, this analysis is useful to visualise the similarities of reflectance spectra related to the nature of the employed pigments or dyes. The similarity could be probably due to the presence of the same pigment or a mixture of pigments.

4.1.1 Drawing 01 and drawing 02 from the book *Sternaler* (1969)

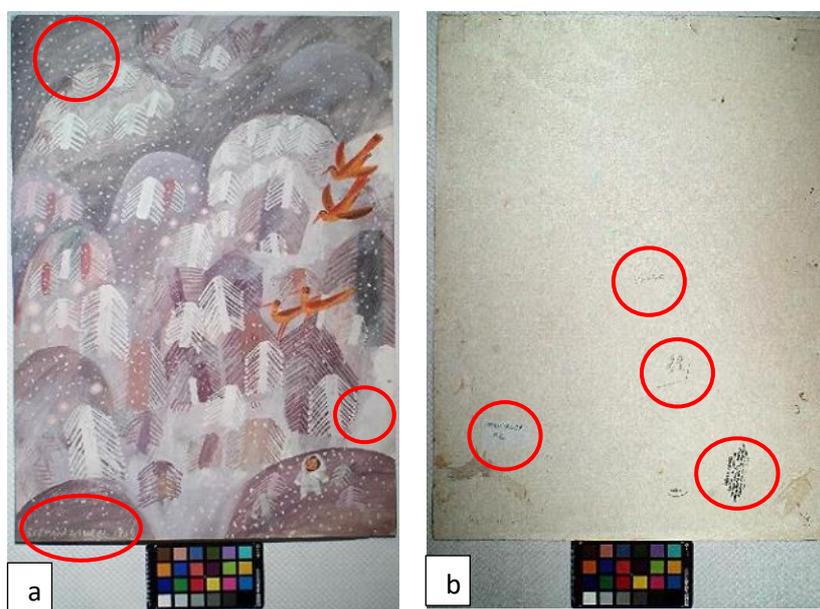


Figure 24 a: Front of drawing 01; b: Back of drawing 01

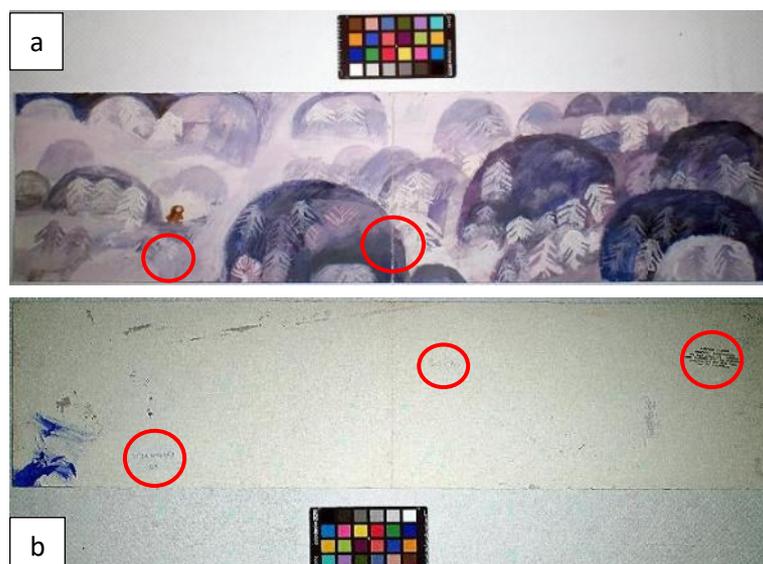


Figure 25 a: Front of drawing 02; b: Back of drawing 02

The drawings 01 (*Figure 24a*) and 02 (*Figure 25a*) from the same series, created for the book *Sternataler* (1969), showed a good state of conservation and there are no evident signs of degradation. Generally, there are differences regarding the thickness of the pictorial layer. In fact, drawing 02 results to be more consistent than drawing 01, which is generally depicted employing less material and some details appear a little more transparent such as the grey colours in the upper zone where not homogeneous brush strokes are noticeable. On the other hand, the white colour and the pink shades seem to be more material. Nonetheless, in drawing 02, the lighter details seem to have been realized with not homogeneous brush-strokes than the darker ones. The orientation of the two drawing is different, since drawing 01 has a vertical one and drawing 02 has a horizontal one, so it was probably bent and the fold is visible in the middle of paper sheet. The artist's signature and the year of realization of the drawing (*Stepan Zavrel 1969*) are visible only on drawing 01, in the lower left corner.

Regarding the back of the two drawings, both present a label which indicates the name of the book which the illustration was created for (*Sternataler*), a stamp indicating the name of the artist and his address and the measure of the paper sheets (35x50 in 01 and 50x70 in 02, respectively). Only on drawing 01, a number (29) is visible, which is probably related to a past inventory. Evidence of the use of an adhesive tape, traces of paints, brush-strokes and fold are present on both drawings.

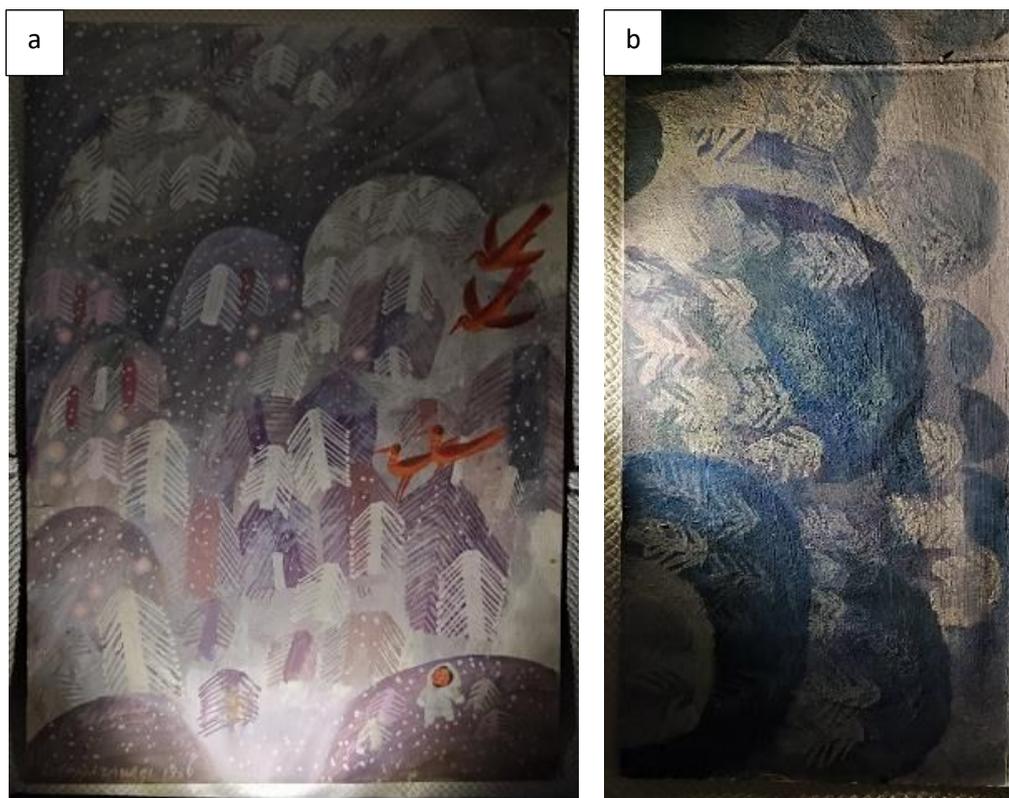


Figure 26 a: Raking light on drawing 01; b: Detail of raking light on drawing 02

The raking light images confirmed that the painted layer of drawing 01 was quite homogeneous (*Figure 26a*). The white and pink shades areas in correspondence to the trees are thicker than the background and the grey areas, which also seems to have been depicted with not homogenous brush strokes. The paper sheet does not show any defects except a little fold on the left side. On the

other hand, drawing 02 (*Figure 26b*), seems to have been depicted with material colours and not homogenous brush strokes are noticeable on the whole pictorial layer. The paper sheet does not show any decay phenomena, it only appears to be a little bent in some parts, near the character in red.

UV imaging showed that drawing 01 (*Figure 27*) exhibits a blueish strong luminescence response, on the right upper and lower sides in correspondence of white coloured details, that could be related more to the pigment's response than to possible retouching. In fact, "under UV examination older ones are often seen as dark purple patches scattered over the surface" (De La Rie, 1986) (Artenet).



Figure 27 UV light on drawing 01



Figure 28 IR light at 850 nm on drawing 01

This type of blueish bright luminescence is known to be exhibited by Lead White pigment (De La Rie, 1986) and Lithopone (Cosentino, 2015) that could be probable since it is present on white zones. Since such a luminescence is present, further analysis are necessary in order to confirm this hypothesis. Except for some details in the right part, all the other white details do not show fluorescence and that suggests that Titanium White could have been employed. In fact, "Titanium White is characterized by the lack of fluorescence in any of the binders – oil, Arabic gum, tempera, fresco -, thanks to its strong absorption band in the UV region" (Cosentino, 2015). Differently, drawings 02 does not show any particular luminescence response and regarding the pigments, probably Titanium White was used in this case.

In drawing 01 (*Figure 28*), IR imaging showed that probable underdrawings are visible on the left side of the composition, since it appears to be darker than the pictorial layer on the surface. That phenomenon could also be due to the nature of the pigments or of the binder, which can affect the

result as well. On the other hand, drawing 02 does not show any particular signs of underdrawings or evident IR response.



Figure 29 a,b,c: Details of pictorial layer of drawing 01 obtained with DINO in Vis



Figure 30 a: Details of pictorial layer of drawing 01; b, c: Details of pictorial layer of drawing 02 obtained with DINO in Vis



Figure 31 a, b: Details of pictorial layer of drawing 02 obtained with DINO in Vis; c: Details of pictorial layer of drawing 02 obtained with DINO in UV

The inspection of drawing 01 by means of portable microscope does not show any degradation pattern. In some points, UV light shows the fibres of the paper support underneath so probably the pictorial layer is not so homogeneous and it was realized using not material colours. In correspondence to one of the pink trees on the left side, there is a hair probably belonging to the brush employed by the artist (*Figure 29b*) and also on drawing 02 hairs of the brush are present. In *Figure 30a*, corresponding to one of the flowers on the left side, a dark fragment is visible, probably related to the materials used during the creation of this drawing.

On the surface of drawing 02, probable drying craquelures are visible on the white coloured details (*Figure 30b, 30c*). The pictorial layer of drawing 02 does not appear homogeneous and on different

zones, signs of bubbles related to the body and quantity of the paints' usage are noticeable (*Figure 31a*). In different areas, UV light shows the fibres of the paper support (*Figure 31b*). About the colour palette, white, blue, red, yellow/orange are distinguishable, alone or as mixture. Paints detachments are also visible, in particular a little sign is present on the lower right corner of drawing 02, in correspondence to the blue coloured zone (*Figure 31c*).

Regarding hyperspectral imaging, the spectra showed that, on drawing 01, there are differences between two spots distinguishable with IR filters and the rest of the white background. These points appear similar to the reddish and mauve areas, so they could have been depicted with a mixture of white and mauve colours. On drawing 02, the blue colour seems to be same as well as the white colour, even if in correspondence of some of the trees appears different. Probably, blue and white were mixed together to obtain different shades, in particular regarding the background.

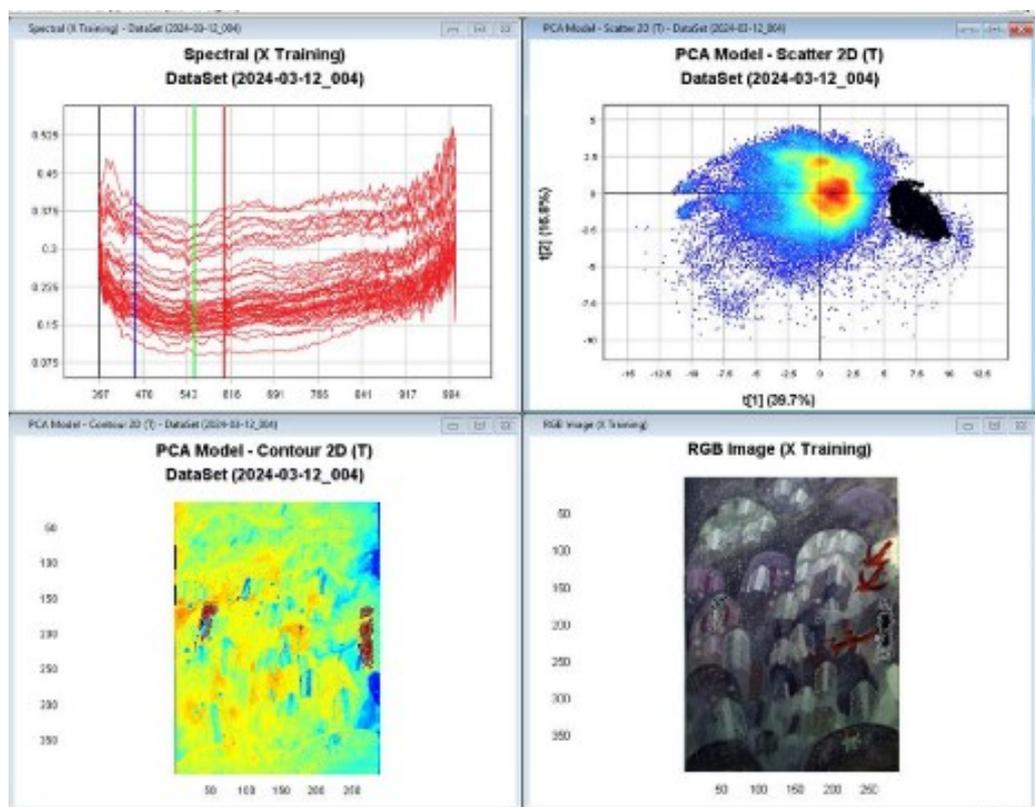


Figure 32 Hyperspectral image of pentimenti on drawing 01

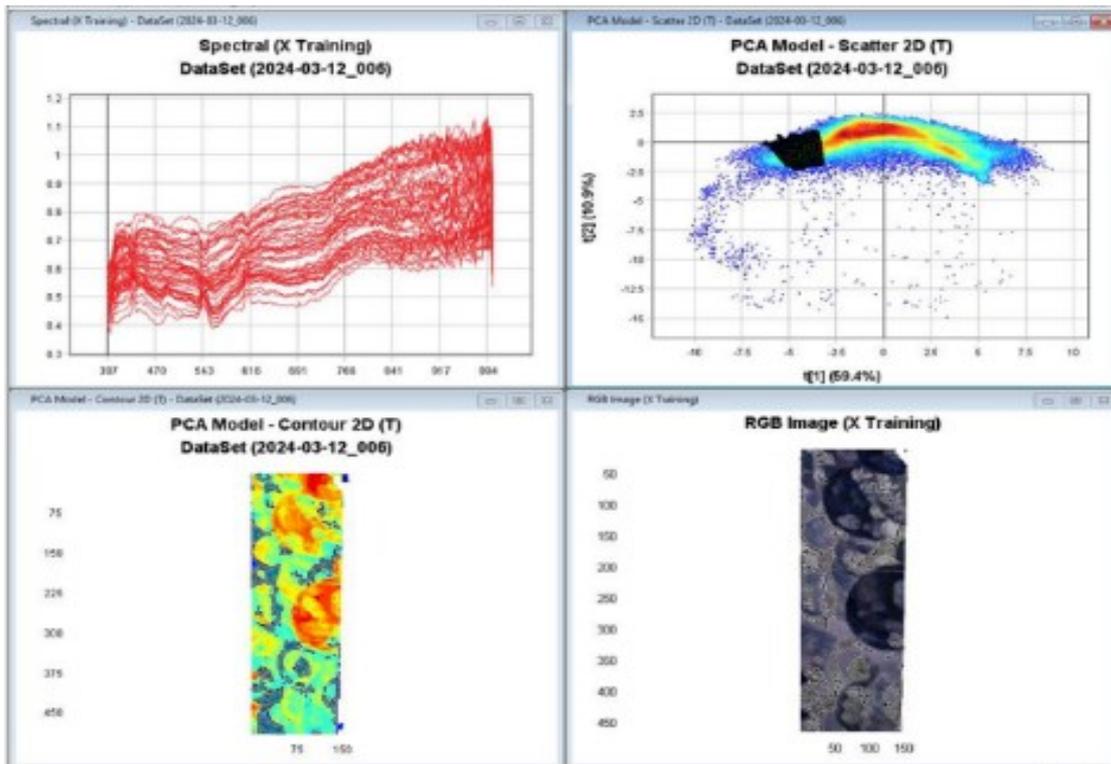


Figure 33 Hyperspectral image of white areas on drawing 02

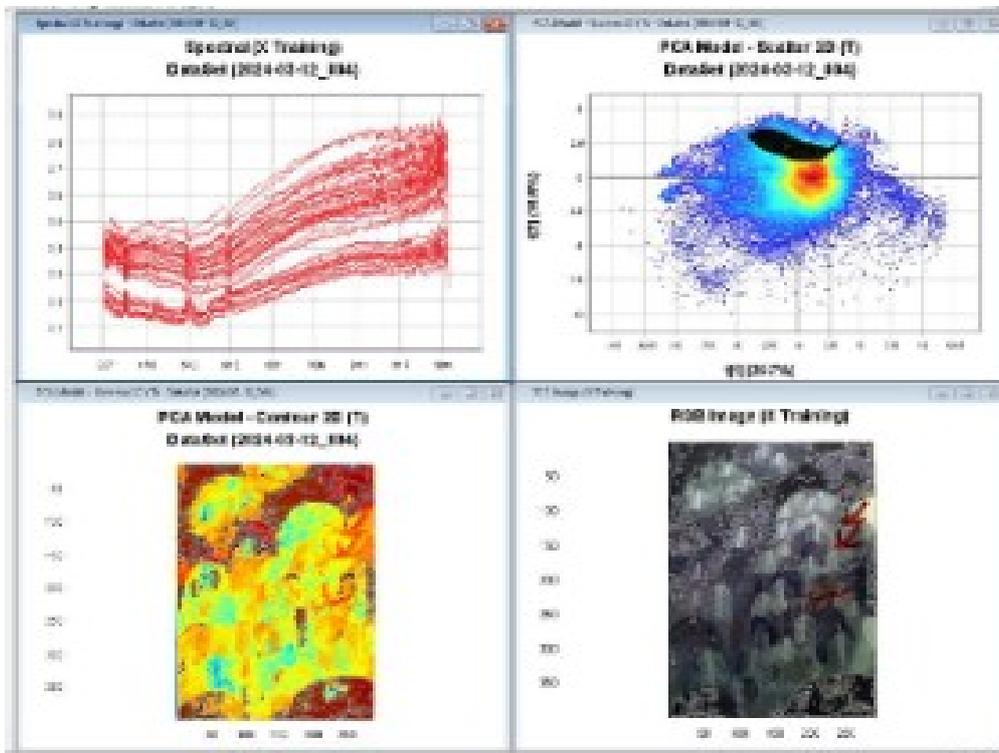


Figure 34 Hyperspectral image of white background on drawing 01

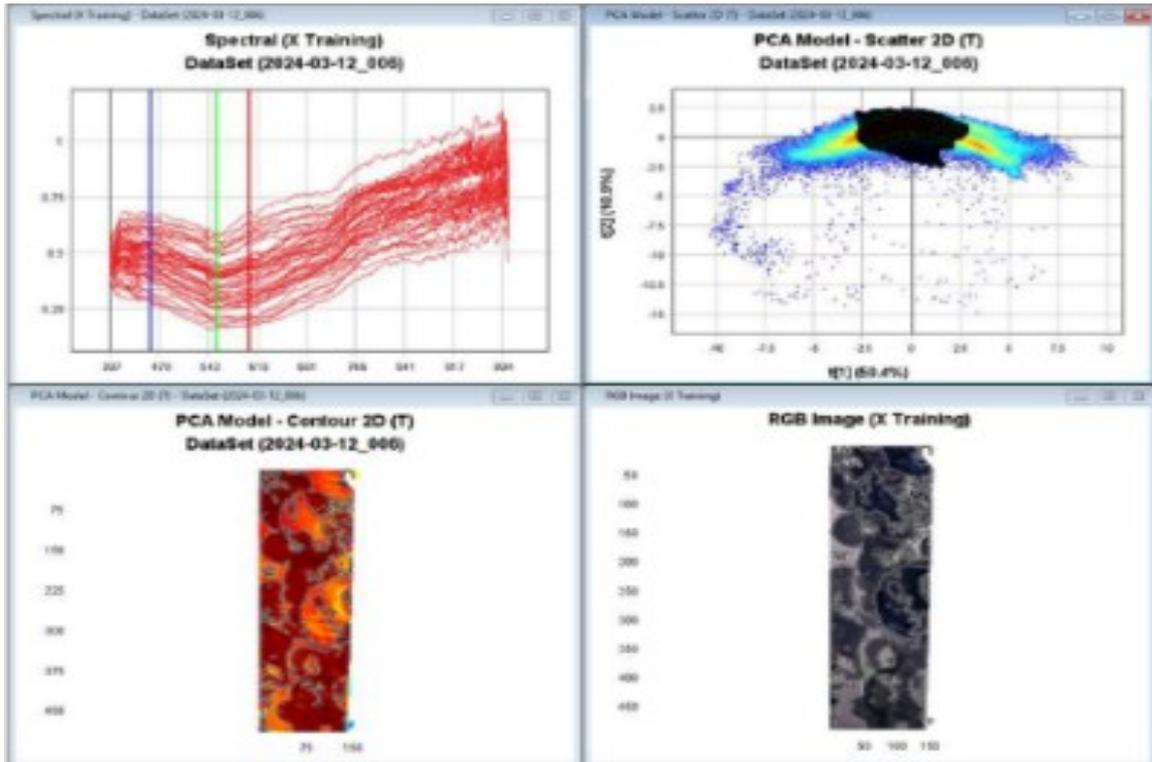


Figure 35 Hyperspectral image of blue areas on drawing 02

4.1.2 Drawing 03 from the book *Il Sale vale più dell'Oro* (1968)

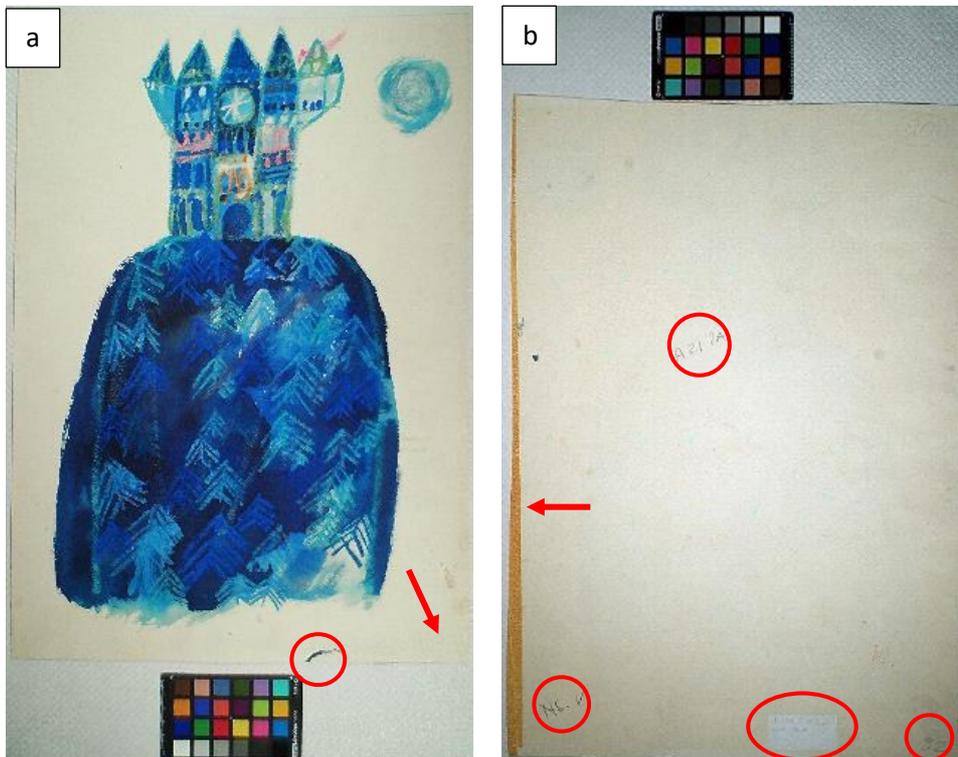


Figure 36 a: Front of drawing 03; b: Back of drawing 03

Drawing 03 (Figure 36) from the book *Il Sale vale più dell'Oro* (1968) shows good state of conservation as well so no evident degradation phenomena can be observed. The painted layer is quite homogeneous and does not seem to be realized with particularly material colours. Unlike the two previous drawings, this one does not occupy the entire surface but only the central zone of the paper sheet. A trace of a blue brush stroke is visible in the lower part and the right side of the sheet appears to be yellow. In the back of the drawing, numbers and letters are visible (A 21 2A – 20 – 32 – NS.V.), probably related to past inventories and a label indicating the title of the book which the illustration was created for (*Il Sale vale più dell'Oro*). Evidence of the use of an adhesive tape along one side are present, in correspondence to the yellow part of the sheet on the front. The raking light images confirmed that the pictorial layer seems to be quite homogenous and it was realized with not particularly material colours. The paper sheets do not show any defects but some signs of bending are visible probably because handling throughout time.



Figure 37 Details of UV light on drawing 03

UV images (Figure 37) show a strong fluorescence response, in particular in correspondence to the bright pink colour and the orange one on castle's details that could be related to the colour's response and it could be a lac dye (Cosentino, 2015).



Figure 38 IR light at 720 nm on drawing 03

IR images (Figure 38) show interesting results. The trees depicted employing lighter blue colour appear darker under NIR region and this phenomenon could probably be related to the pigment or the binder that was used by the artist.

The inspection of pictorial surface of drawing 03 by means of portable microscope showed that craquelures are visible on the blueish details (Figure 39a). UV light evidenced that the paper support is noticeable underneath the pictorial layer. Generally, drawing 03 was depicted using not material colours and probably they were diluted. The pictorial layers of drawing 03 appeared quite homogeneous, even if some details seem to be depicted with more material colour than others and inhomogeneity is visible. White, blue, green, red, yellow/orange colours are distinguishable, alone or as mixture. On drawing 03, fluorescence response is visible with UV light in correspondence to two different colours: the bright pink detail on the castle's roof (Figure 39c) and the orange detail of the castle's door (Figure 39b). Such a response could be related to the pigments' composition.



Figure 39 a: Details of pictorial layer of drawing 03 obtained with DINO in Vis; b, c: Details of pictorial layer of drawing 03 obtained with DINO in UV

Regarding hyperspectral imaging, the spectra showed that some differences in blue areas of drawing 03 were observed, particularly regarding trees, the hill and some castle's details. These differences could be due to the fact that blue colour seems to be diluted in some points or could have been mixed with green colour.

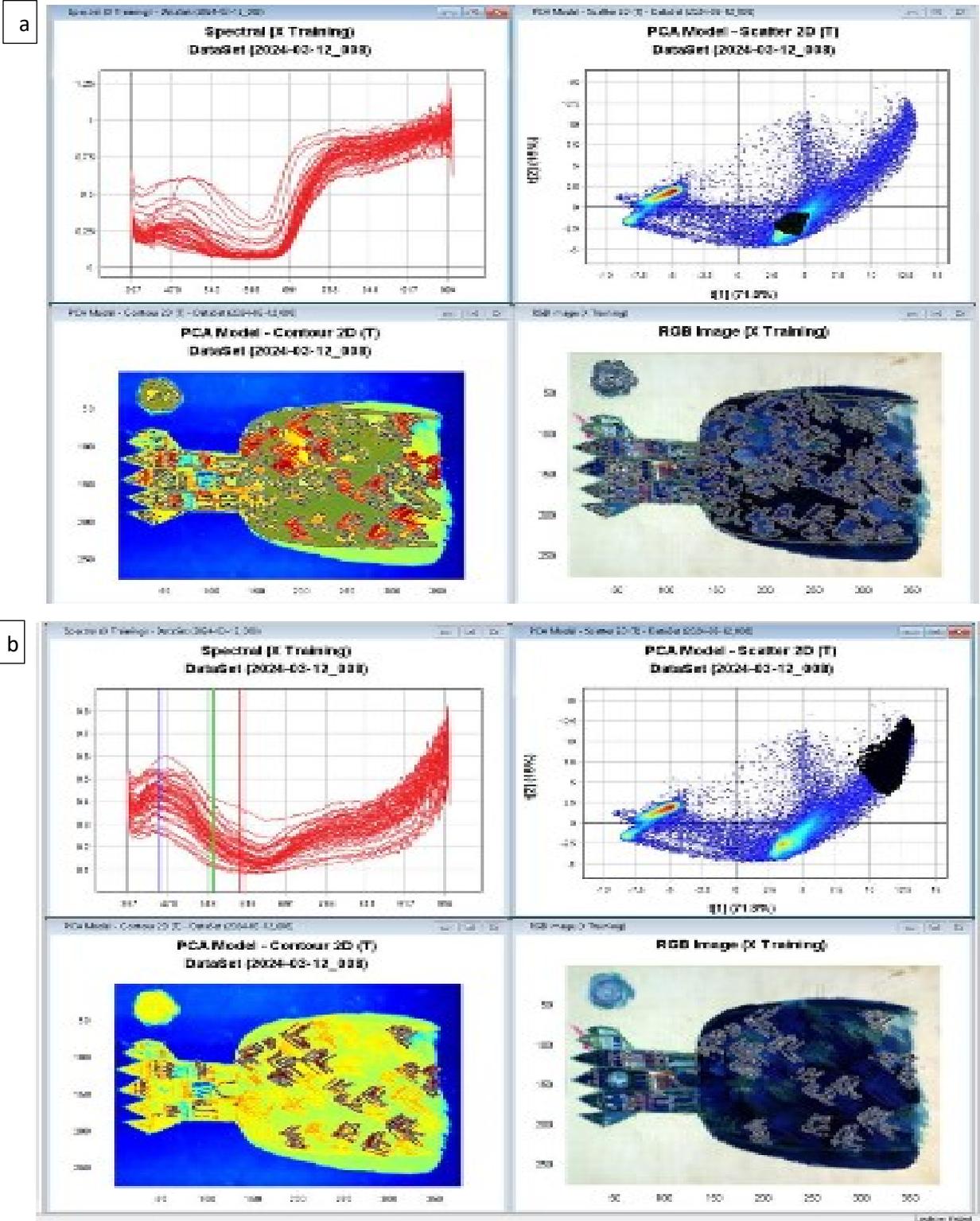


Figure 40 a: Hyperspectral image of blue hills; b: Hyperspectral image of blue trees on drawing 03

4.1.3 Drawing 04



Figure 41 a: Front of drawing 04; b: Back of drawing 04

Drawing 04 (Figure 41), whose series was not identified, appears to be generally in a good conservative state but some colour detachments are visible on the left side, in correspondence to the black coloured zone. The painted layer seems to be quite homogeneous and realized with no particularly material colours. An additional paper support is present.

In the back of the drawing, the measure of the paper sheet is indicated (35x50) and other numeric annotation are present (20,4 base). Traces of different paints are visible.

The raking light images confirmed that the pictorial layers are quite homogenous and realized with not particularly material colours. The paper sheet does not show any decay but paint detachments in correspondence to the black coloured area are noticeable as already noticed previously.

UV images highlighted that all white coloured details show a blueish slight luminescence response (Figure 42) that could be due to the pigment's response. Also in this case, this type of luminescence could suggest the presence of Lead pigment or Lithopone so further analysis will be performed in order to confirm or not this hypothesis. On the other hand, IR images do not show any underdrawings having evident IR response.



Figure 42 UV light on drawing 04



Figure 43 a, b, c: Details of pictorial layer of drawing 04 obtained with DINO in Vis

In correspondence to orange details, there is a hair probably belonging to the brush employed by the artist hairs of the brush (*Figure 43c*). On the surface, drying craquelures are visible on the white details (*Figure 43a*) (Stoner et al., 2021). Paint detachments are also visible, in particular in correspondence to the black zone on the left side and the paper support of drawing (*Figure 43b*). The microscopic images confirmed that the pictorial layer appears quite homogeneous, even if some details seem to be depicted with more material colour than others and inhomogeneity is visible in *Figure 43c*. In general, the whole pictorial layer of drawing 04 was made with quite thick painted layers and the paper support is not visible underneath. About the colour palette, white, green, black, red yellow/orange are distinguishable, alone or as mixture. A slight fluorescence response is visible with UV light in correspondence of white coloured details, that could be related to the colours' composition.

Regarding hyperspectral imaging, the spectra showed that white coloured details and reddish ones on drawing 04 seem to have been painted with the same colours, respectively. Green could also be the same pigment or dyestuff everywhere.

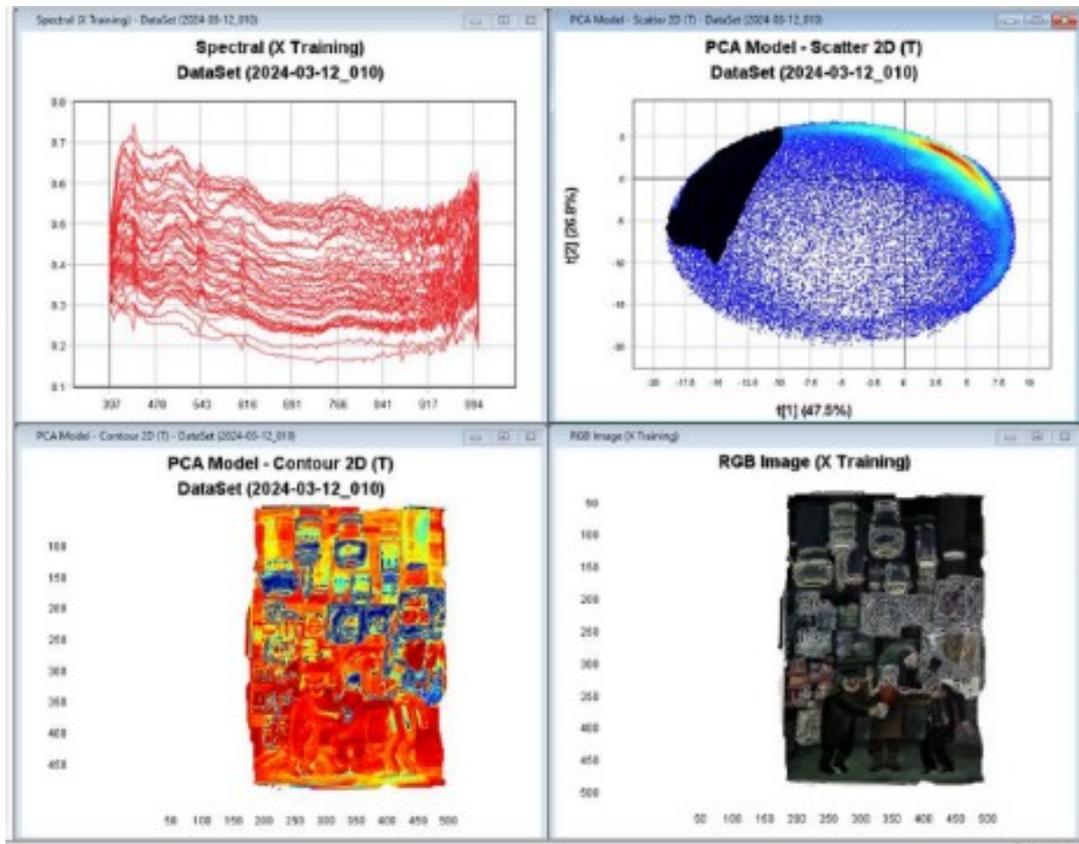


Figure 44 Hyperspectral image of white areas on drawing 04

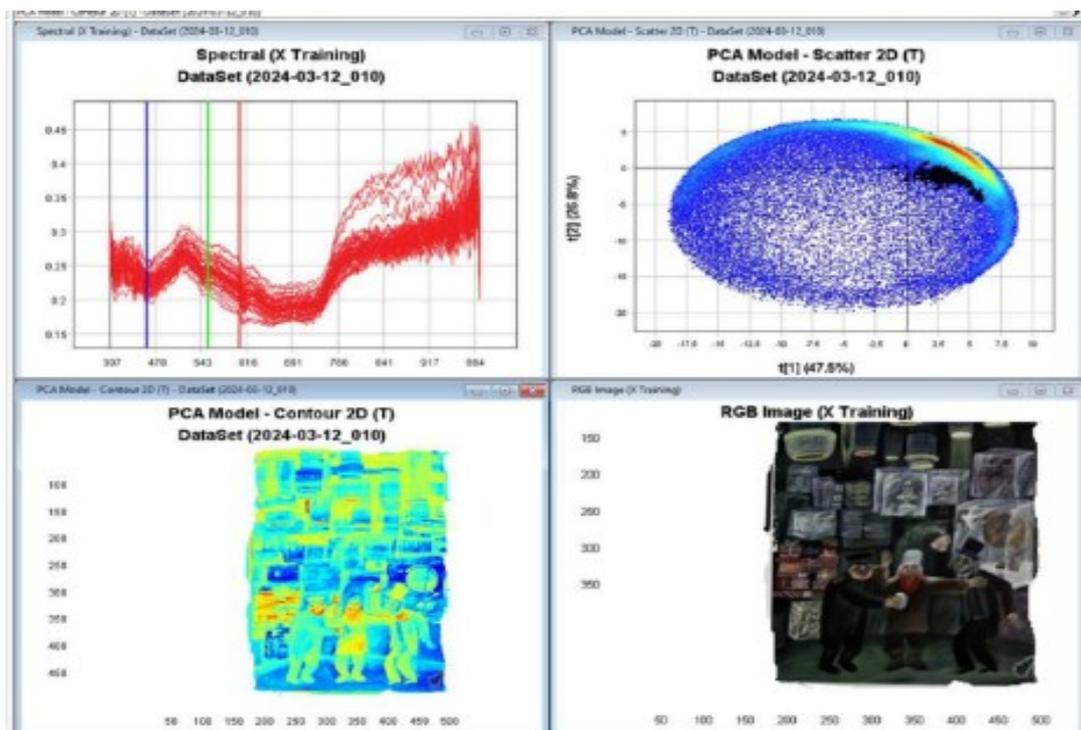


Figure 45 Hyperspectral image of green areas on drawing 04

4.1.4 Drawing 05 from the book *In cammino con Dio* (1996)



Figure 46 a: Front of drawing 05; b: Back of drawing 05

Drawing 05 (Figure 46) from the book *In cammino con Dio* (1996) shows good conservative state and no evidence of degradation processes was observed. Only on the left side, a yellow trace is present in the white zone but it can be a trace related to the use of the brown colour. The painted layer seems to be quite homogeneous and realized with material colours. An additional paper support is present. In the back of the drawing, the measure of the paper sheet is indicated (50x70) and a stamp with the name of the artist and his address is present. Two little printed reproductions of other two drawing for the illustrated book *In cammino con Dio* are stuck on the sheet back and the drawing is anchored on the additional support with adhesive tape along the sides. Paint traces and a vivid pink brush-stroke are visible in the lower part of the drawing back. Raking light images confirmed that the pictorial layer appears homogeneous and it was realized with quite bodied paints, in particular in correspondence to the white coloured zone.



Figure 47 UV light on drawing 05



Figure 48 IR light at 850 nm on drawing 05

It exhibits a blueish luminescence response in correspondence to the white background on UV images. However, it could be related to the use of not so material colours or lack of colour since it is visible only on a small, delimited area of the white coloured zone.

IR images showed that there are a sort of preparatory drawings or guidelines for the walls of the house. In fact, the final drawing appears a little more detailed in the upper part and the wall thicker than in the underpaint.



Figure 49 Detail of pictorial layer of drawing 05 obtained with DINO in UV.

Portable microscope showed that the paper support is noticeable underneath the pictorial layer, in particular UV light shows the fibres of the paper support (Figure 49), in correspondence of the white background and other brownish details. Generally, this technique confirmed that drawing 05 was depicted with quite bodied paints except for white and brown areas. The pictorial layer appears

quite homogeneous, even if some details seem to be depicted with more bodied paints than others and inhomogeneity is visible.

Regarding hyperspectral imaging, the spectra showed that in drawing 05, white areas were depicted with the same pigments, as well as brown and yellow ochre details, which are well distinguished.

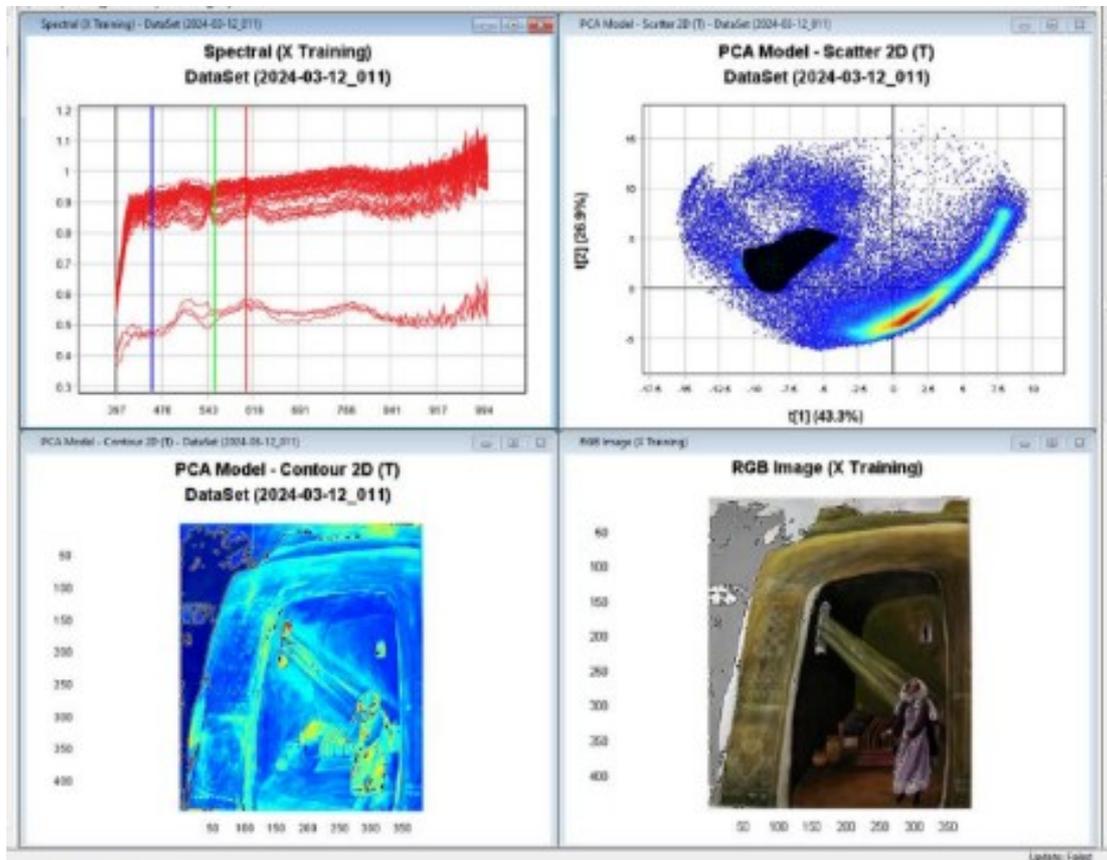


Figure 50 Hyperspectral image of white areas on drawing 05

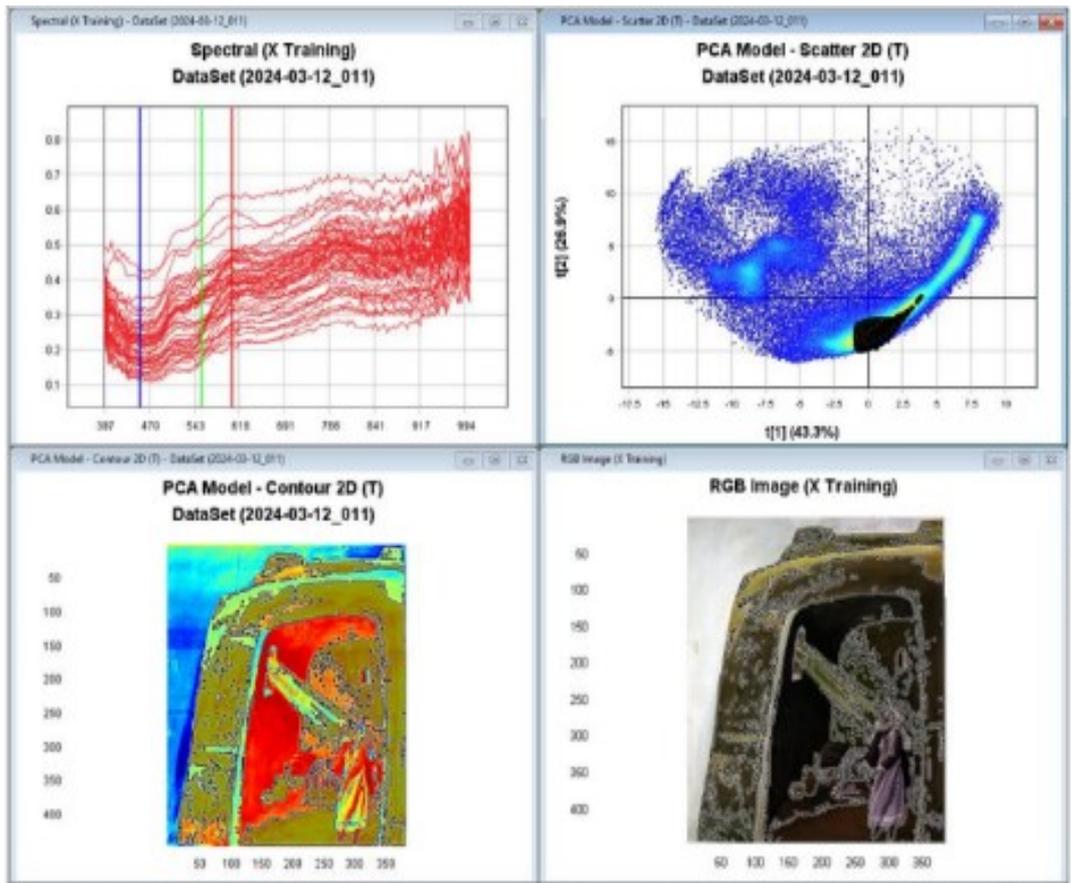


Figure 51 Hyperspectral image of yellow brownish areas on drawing 05

4.1.5 Drawing M1 and drawing M2 from the book *Un sogno a Venezia* (1974)

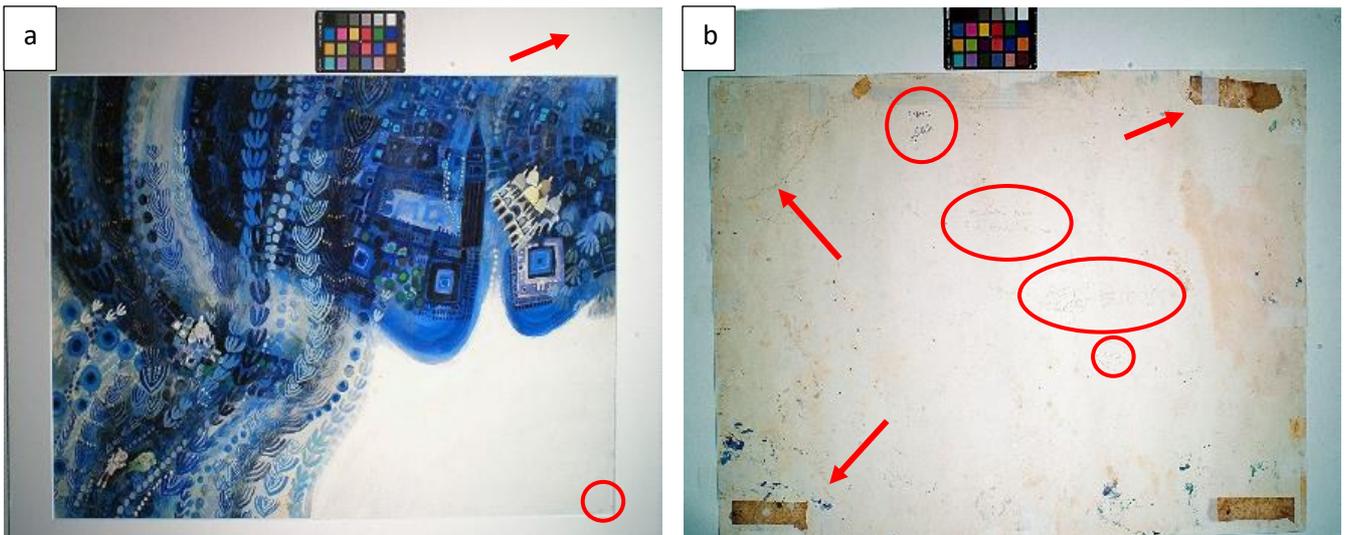


Figure 52 a: Front of drawing M1; b: Back of drawing M1

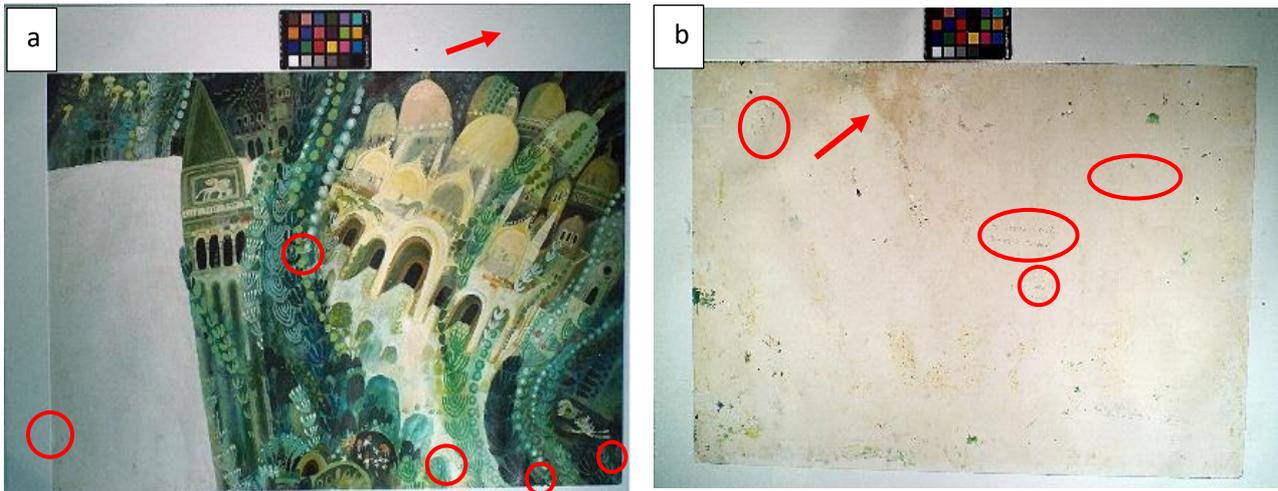


Figure 53 a: Front of drawing M2; b: Back of drawing M2

Drawings M1 (Figure 52) and M2 (Figure 53) from the same series for the book *Un sogno a Venezia* (1974) are both conserved and exposed in the museum and not located in the archive like the six previous ones. Generally, they show a good state of conservation but some paint detachments are visible, in particular, in the lower right corner, in correspondence to the white coloured zone of M1 and in the lower right part and in the middle, in correspondence to the algae near the San Marco bell tower of M2. The pictorial superficial layer appears to be homogeneous and realized with quite bodied paints, in particular in correspondence to the white coloured zones. An additional paper support is present in both drawings.

Regarding the back, on M1 some numeric annotations (*128c – base 9,3 – 29 – XVIII fallo*) and the name of the artist and the title of the book which the illustration was created for (*Stepan Zavrel – Venedig Morgen*) are reported. On the other hand, on M2 a number (28) and the name of the artist and the title of the book are indicated, as well as the title of this particular illustration, the year of the realization and the employed technique (*Stepan Zavrel – Venedig Morgen – Avvistando San Marco – acrilico – 1974*). Evidence of the use of adhesive tape, traces of various diluted paints and probably water are present on both.



Figure 54 Details of raking light on drawing M2

The raking light images confirmed that the pictorial layer appears homogeneous and it was realized with quite bodied paints, in particular in correspondence to the white coloured zone of M1 and M2. Paint detachments are clearly visible in both drawings, specifically in the lower side and in the middle of the artworks, near the San Marco bell tower on M2 (*Figure 54*) and in the white area on M1. The paper sheets do not show any defects, they only appear to be a little bent in the white zones but probably due to the constriction of the additional paper support.



Figure 55 a UV light on drawing M1



Figure 55 b UV light on drawing M2

In drawing M1 (*Figure 55a*), UV images showed a blueish strong luminescence in correspondence to some blue details. This luminescence response could be related to the paint's response since it is visible on some details depicted in light blue and maybe Lead White pigment could have been used to light the blue one. Probably, that luminescence could be due to a mixture between blue and white paints or mainly to the white paint's response. On the other hand, drawing M2 (*Figure 55b*) exhibits a blueish slight luminescence in the lower right corner in correspondence of the dark green details. Also in this case, this type of luminescence could be related to the pigment's response, probably

revealing again a mixture of different s, since generally green pigments result to be “slight affected by the binder or don’t present any fluorescence” (Cosentino, 2015).

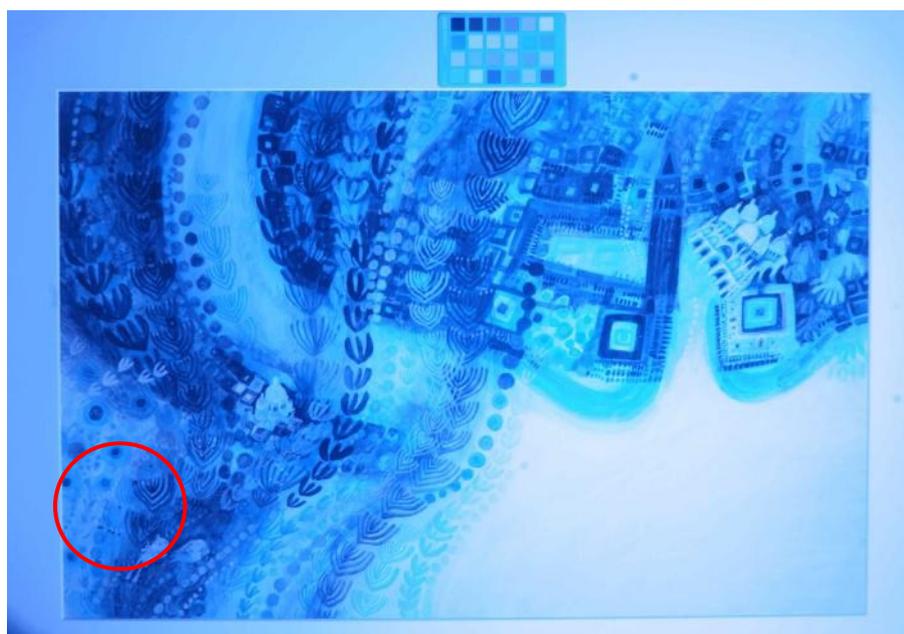


Figure 56 IR light at 720 nm on drawing M1

IR images highlighted the presence of an underpaint on the lower left corner of drawing M1, in correspondence to the blue algae. It seems that there would have been more algae than in the final composition of the pictorial layer. Differently, drawing M2 does not show any particular signs of underdrawings or evident IR response.

Regarding hyperspectral imaging, the spectra showed that in drawings M1 and M2, the white colour is the same everywhere, as well as blue on M1 and green in M2. There are slightly differences probably due to the dilution of the colours for obtaining different shades. Some details on drawing M2 were probably depicted with mixture of green and yellow pigments or dyestuff, since the yellow colour is the same everywhere.

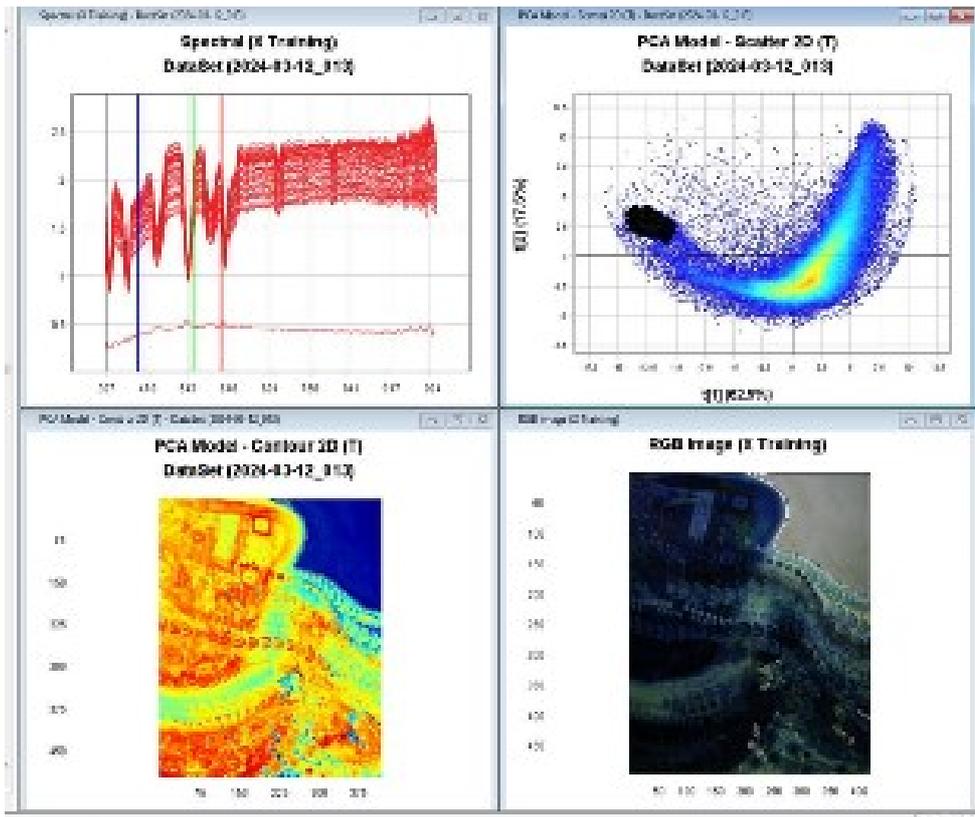


Figure 57 Hyperspectral image of white areas on drawing M1

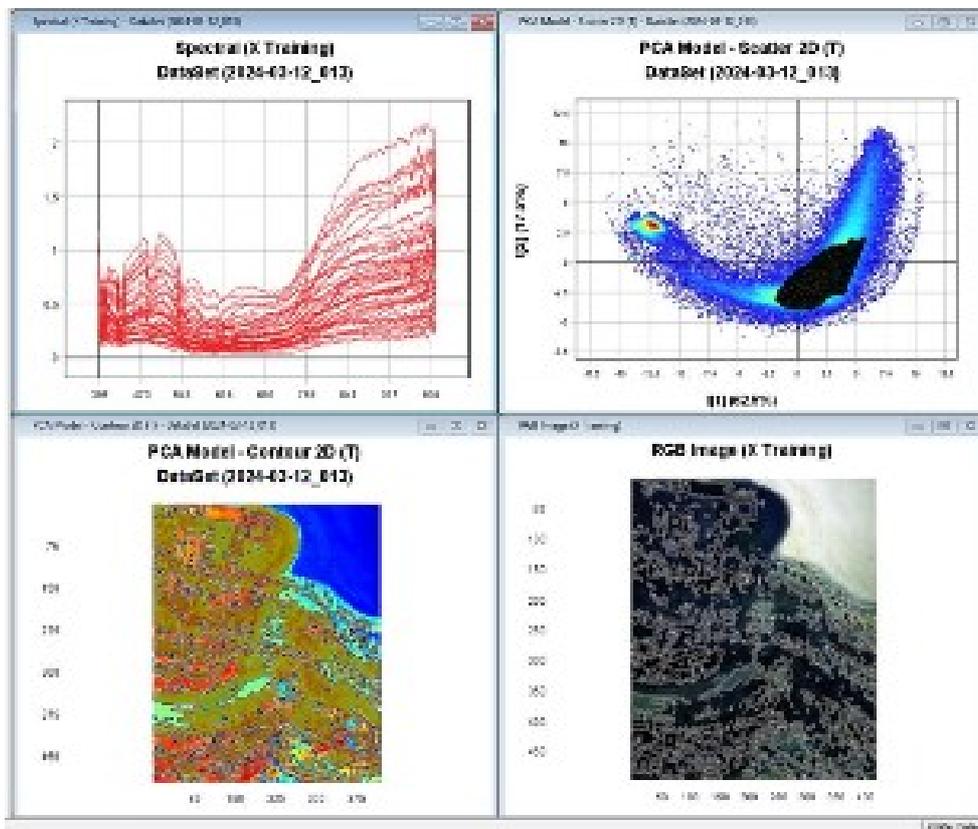


Figure 58 Hyperspectral image of blue areas on drawing M1

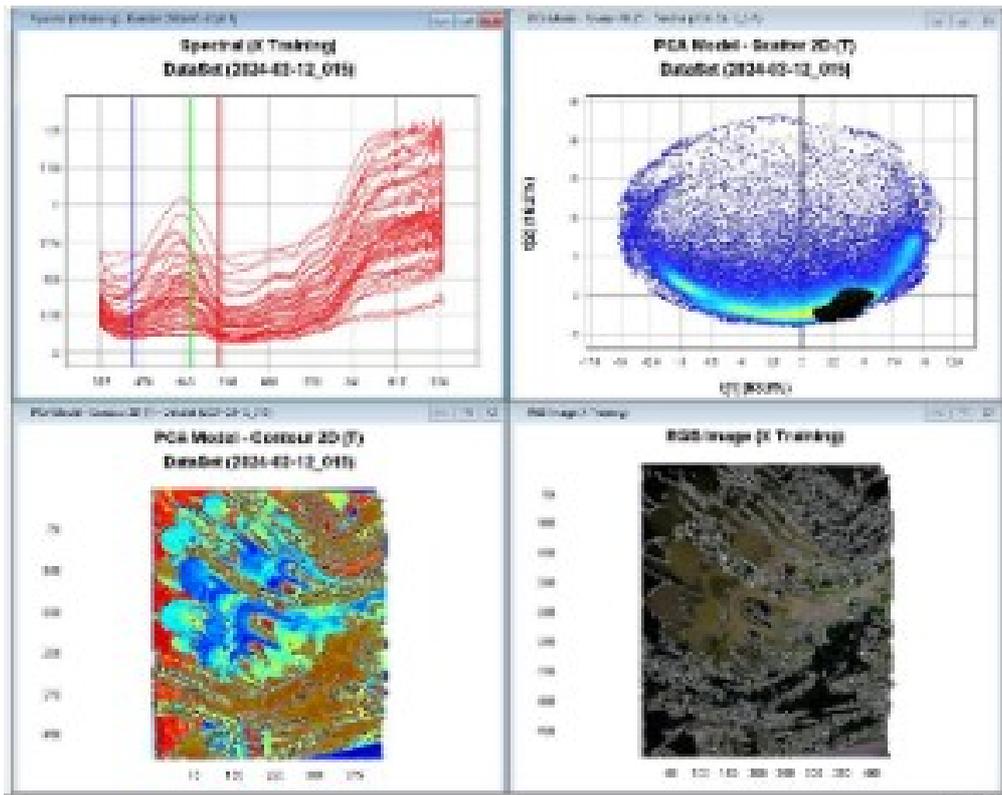


Figure 59 Hyperspectral image of green areas on drawing M2

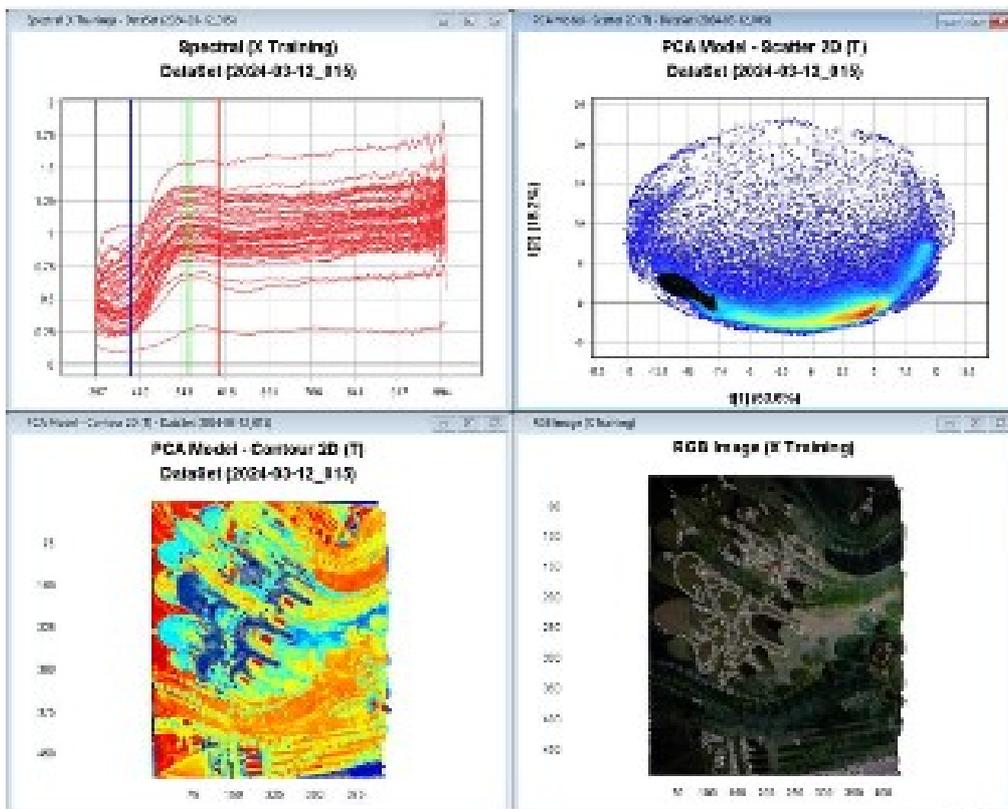


Figure 60 Hyperspectral image of yellow areas on drawing M2

4.1.6 Paintings on canvas D1 and D2

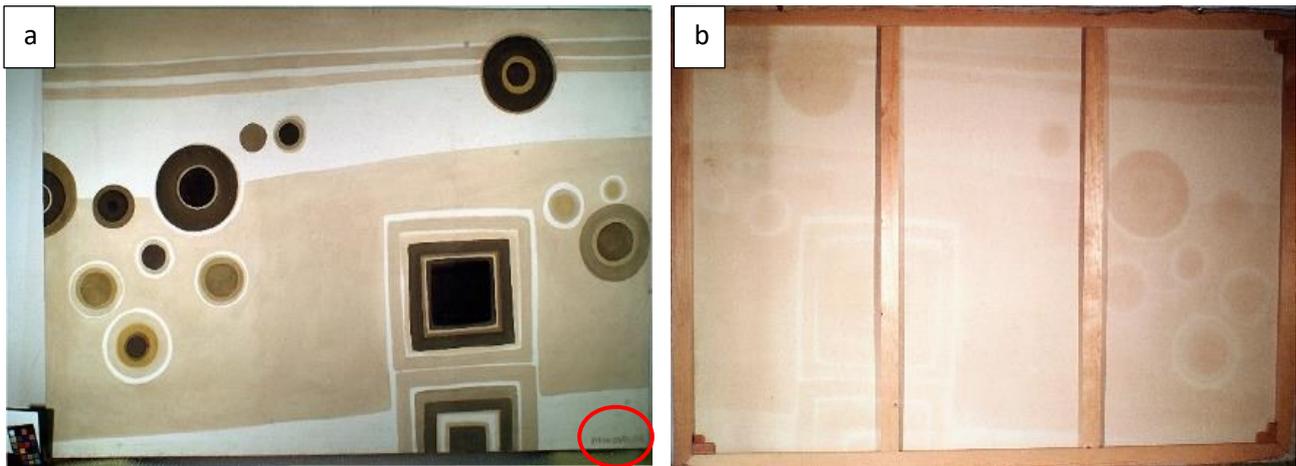


Figure 61 a: Front of painting D1; b: Back of painting D1

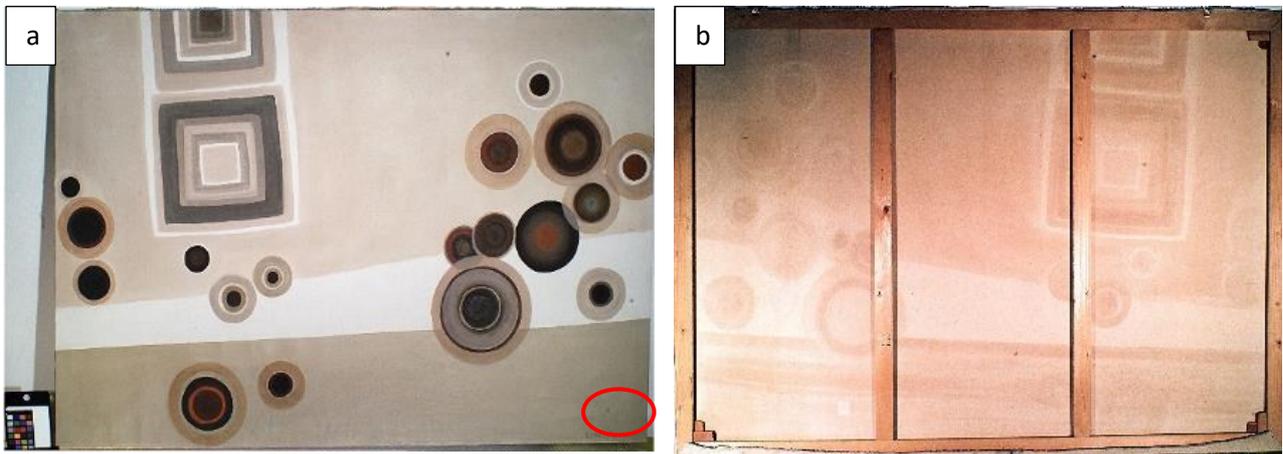


Figure 62 a: Front of painting D2; b: Back of painting D2

Both paintings on canvas (*Figure 61, Figure 62*), exhibit a good state of conservation and the painting design and the colour composition can be distinguished. Only some signs of probable ageing cracks are present, in particular along the upper side of D1 and in the lower left side of D2. The pictorial superficial layer appears to be homogeneous and it was depicted with similar materials. The artist's signature and the year of creation (*Stepan Zavrel 1973*) are indicated in the lower right corner of the two paintings. On the back of both paintings, there is nothing noticeable.

Raking light images evidenced the presence of ageing cracks on the brown coloured zones (*Figure 63a, 63b*), as in the centre as in along the upper and lower sides of both painting. The craquelures visible along the sides are probably due to the stretching caused by the wooden frame, that caused also some canvas deformation. In fact, on D2 (*Figure 63b*), that type of deformations is present probably due to the pictorial layer slightly detaching and the stretching caused by the wooden frame as well. About the pictorial layer, this technique confirmed that it is generally homogeneous and

realized with bodied paints. The previously mentioned deformations and craquelures phenomena apart, the canvases do not show any other defects.

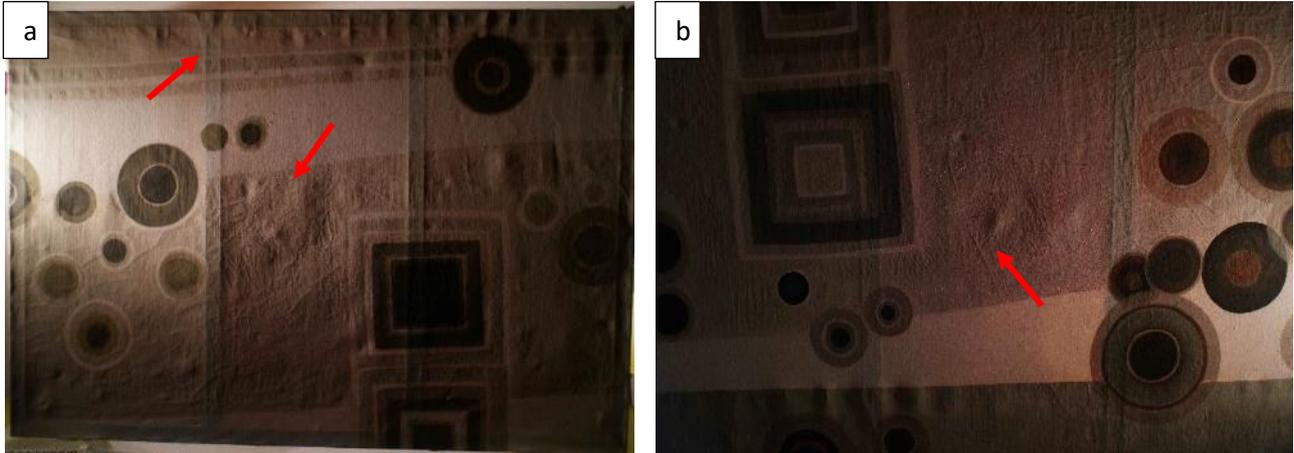


Figure 63 a: Raking light on painting D1; b: Raking light on painting D2

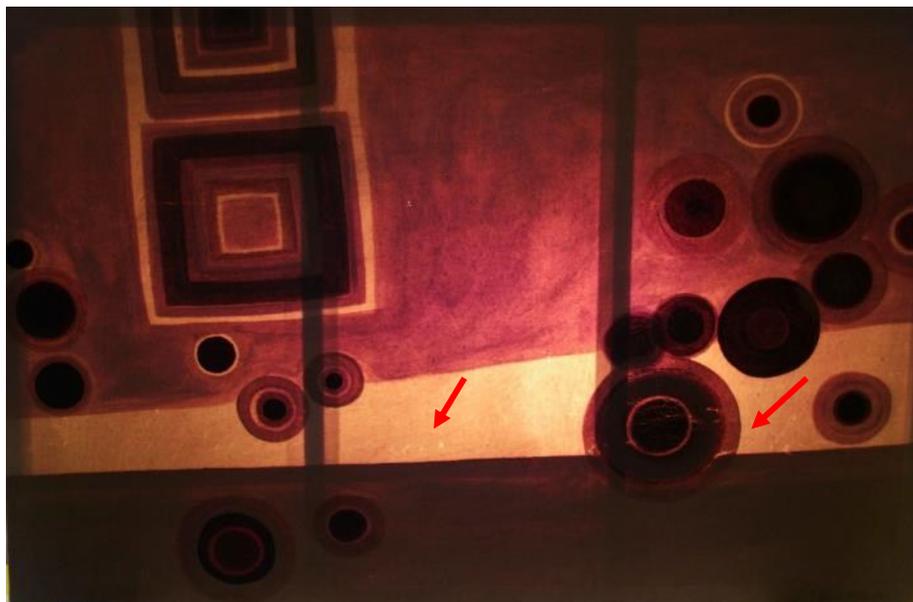


Figure 64 Transmitted light on painting D2

Transmitted light on painting D1 does not show any particular defects except a little stretching near the cube, in the middle of the composition. Additionally, it does not show the craquelure patterns but it evidences a vertical line in the centre of the canvas, probably because it was bent before the frame was assembled. In the brown coloured zones, the brush strokes are visible and they appear to be not really homogeneous. On the other hand, craquelures are noticeable in brown coloured zones and in the lower white zone on painting D2 (Figure 64), as well. Any other particular defects are visible. Like in D1, the brush strokes are evidenced in the brown coloured zones and also in this case, they appear to be not really homogeneous.

UV images do not show any particular luminescence response and probably Titanium White was used in these cases because of that response, as reported by Cosentino (2015). Painting D2 only

exhibits a blueish luminescence response in correspondence to the white coloured zones. However, it could be related to the use of not so bodied paints. On the other hand, paintings D1 and D2 do not show any particular signs of underdrawings or evident IR response.

Regarding hyperspectral imaging, the spectra showed that the colours are well distinguished. White colour seems to be same everywhere, as well as the yellow ochre and brown coloured details and probably those colours are not mixed together.

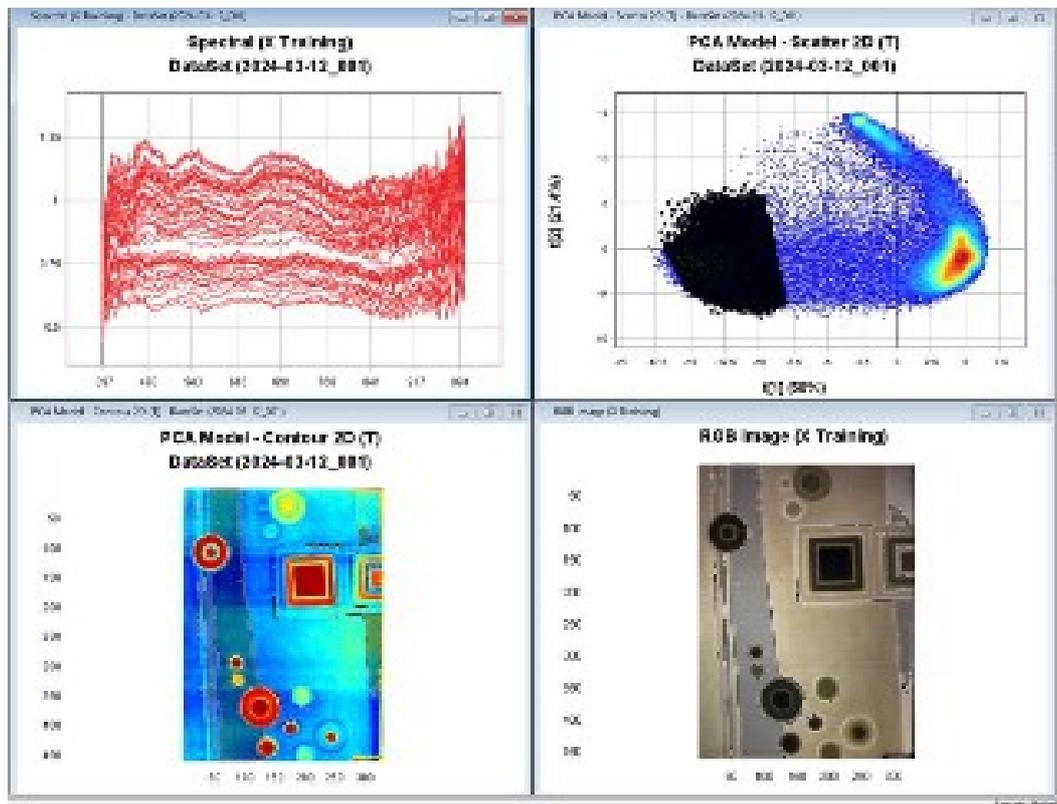


Figure 65 Hyperspectral image of white areas on painting D1

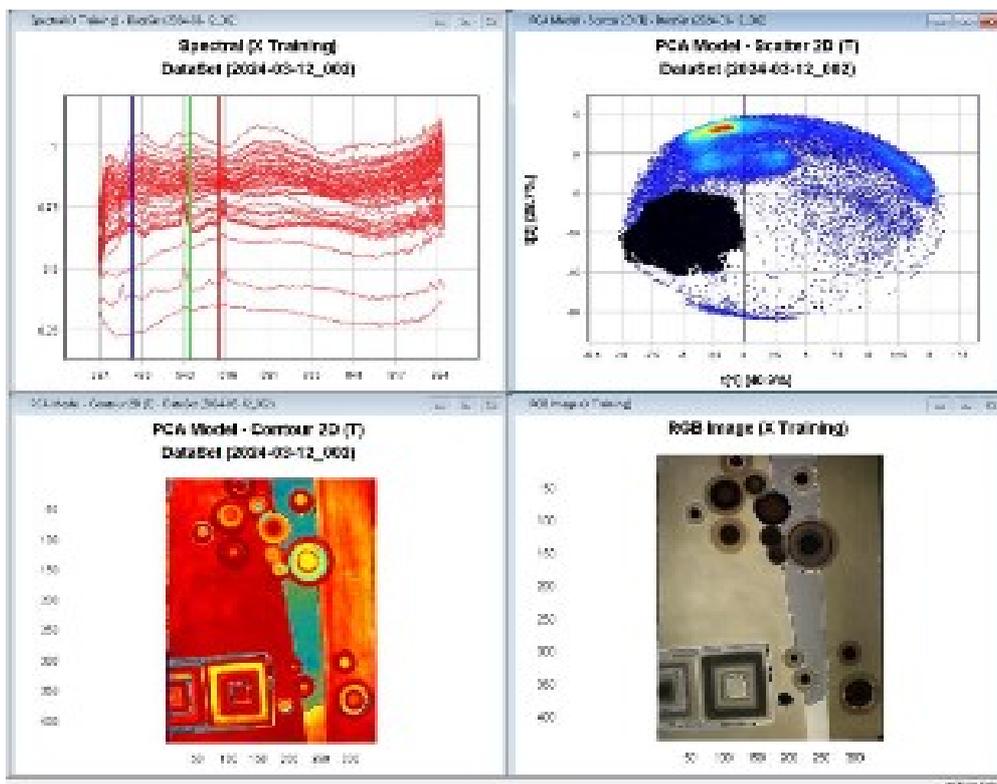


Figure 66 Hyperspectral image of white areas on painting D2

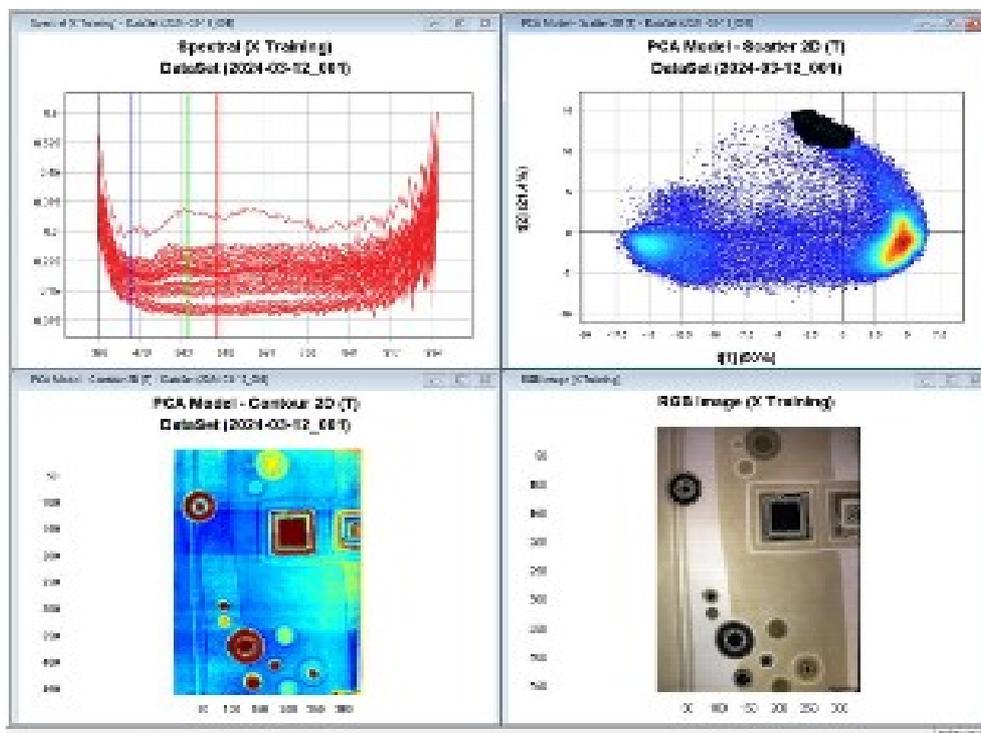


Figure 67 Hyperspectral image of brown areas on painting D1

	01	02	03	04	05	M1	M2	D1	D2
White	X	X		X	X	X	X	X	X
Orange/Red	X	X	X	X	X				
Mauve/Magenta	X		X		X				
Blue		X	X			X			
Green			X	X	X		X		
Brown	X			X	X		X	X	X
Yellow	X					X	X	X	X
Black				X					

Table 3 Colours observed on the artworks

4.2 Fiber Optics Reflectance Spectroscopy (FORS)

The Fiber Optics Reflectance Spectroscopy (FORS) was performed on different points of the considered drawings and paintings in correspondence of different colours. This type of analysis was useful for the identification of the pigments or dyes employed by the artist and possibly, their degradation and variation of the colours. The most relevant spectra are presented and discussed below.



Figure 68 a: FORS measure points of drawing 01; b: FORS measure points of drawing 02; c: FORS measure points of drawing 03

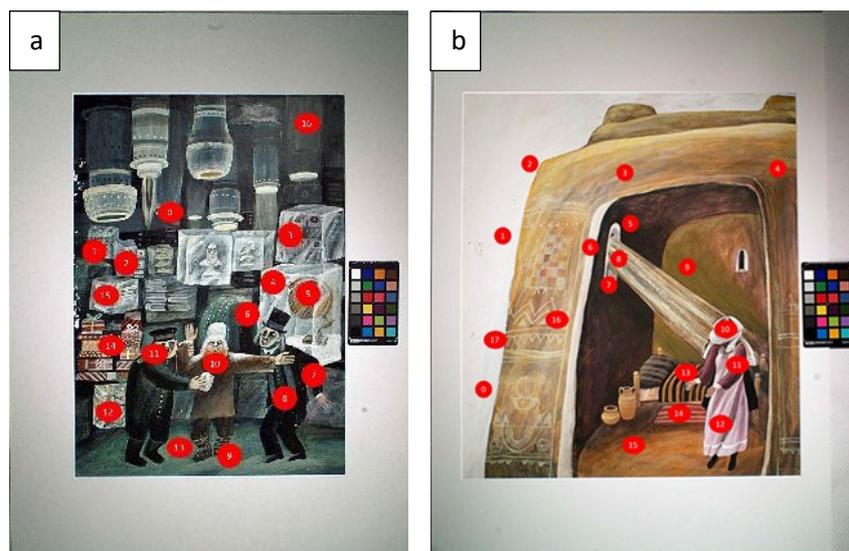


Figure 69 a: FORS measure points of drawing 04; b: FORS measure points of drawing 05

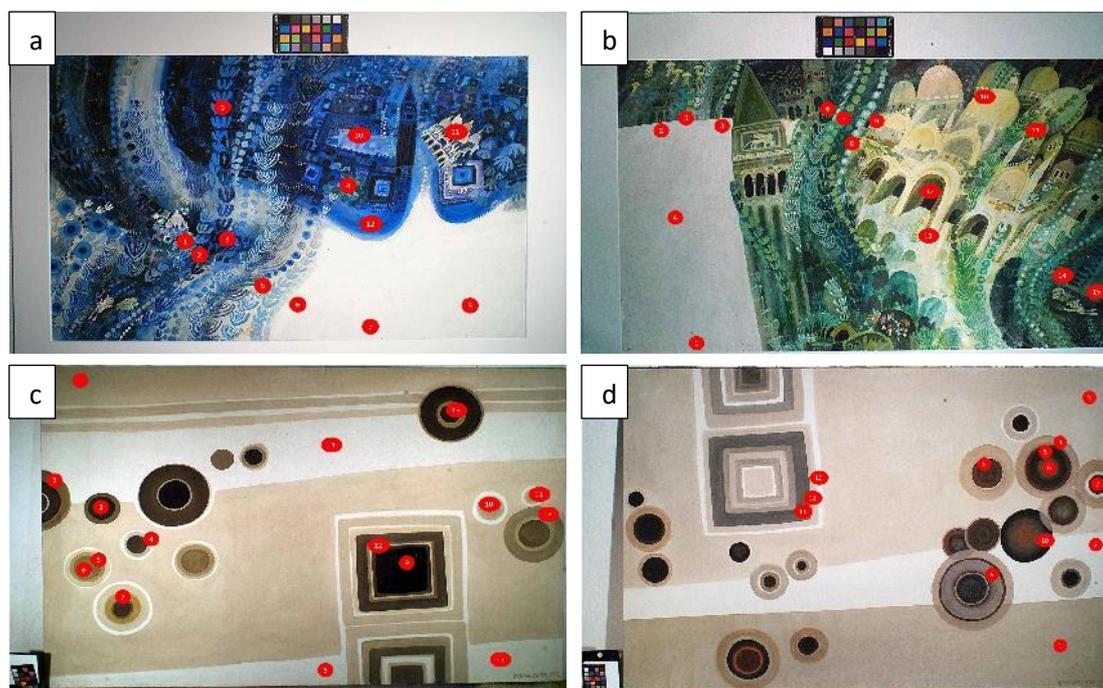


Figure 70 a: FORS measure points of drawing M1; b: FORS measure points of drawing M2; c: FORS measure points of painting D1; d: FORS measure points of painting D2

The orange pigment used for drawings 01 and 02 (Figure 71) could be an azoic-based dye. As reported by Montagner et al., the azo compounds show $n \rightarrow \pi^*$ absorption bands in or near the visible region and the position that absorption band ranges from 300 nm up to 600 nm for a simple azo compound (Montagner et al., 2011). In particular, the FORS spectra of the reddish orange details of the drawings 01 and 02 show two absorption bands at <480 nm and around 540 nm.

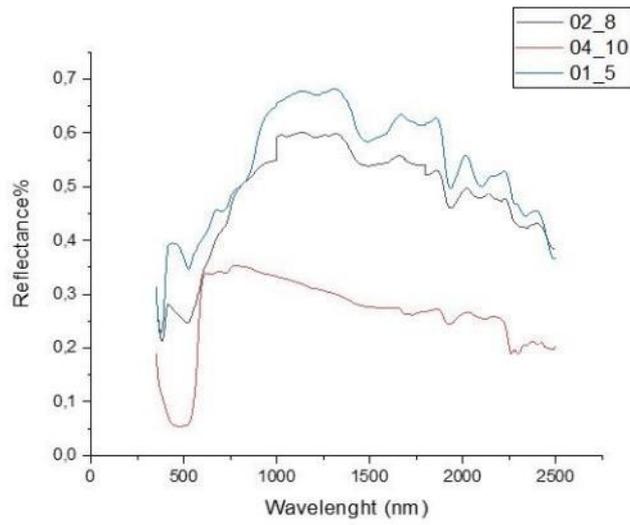


Figure 71 FORS spectra obtained for red/orange details of drawings 01, 02, 04

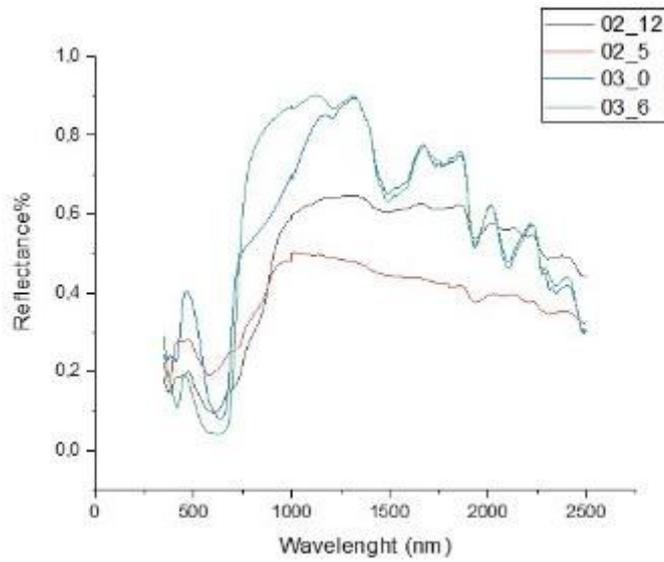


Figure 72 FORS spectra obtained for blue details of drawings 02, 03

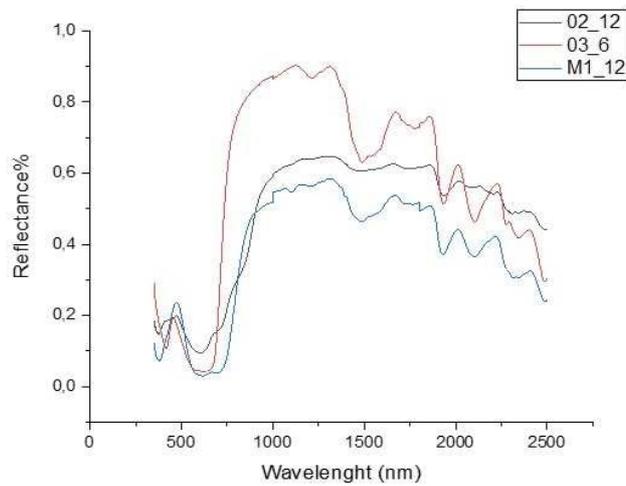


Figure 73 FORS spectra obtained for blue details of drawings 02, 03, M1

The blue pigment used for painting 02 (*Figure 72, 73*) could have been Cobalt Cerulean Blue (PB35 cobalt stannate). Comparing different FORS spectra of different measure points from drawing 02, a strong absorbance peak between 500 nm and 700 nm is noticeable (CHSOS: Cobalt Blue). Blue details of drawing 03 (*Figure 73*) could have been depicted with Prussian Blue (PB27 ferric ferrocyanine), in fact a strong absorbance peak around 450 nm is present (artiscreation.com). On the other hand, the blue colour used for drawing M1 (*Figure 73*) could be Phthalo Blue (copper phthalocyanine). In fact, there is a strong reflectance peak at ~ 460-480 nm and a shoulder at ~ 670 nm and an absorbance band at ~ 345-350 nm and at ~ 580-600 nm (Cosentino, 2014) (Poldi and Caglio, 2013).

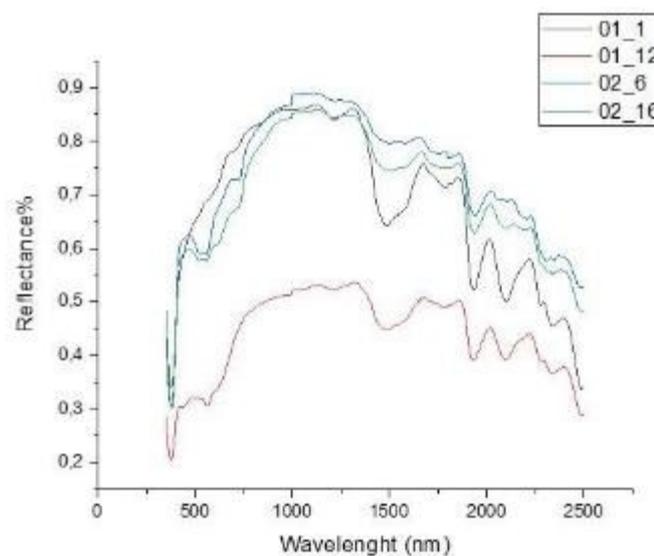


Figure 74 FORS spectra obtained for white details of drawings 01, 02

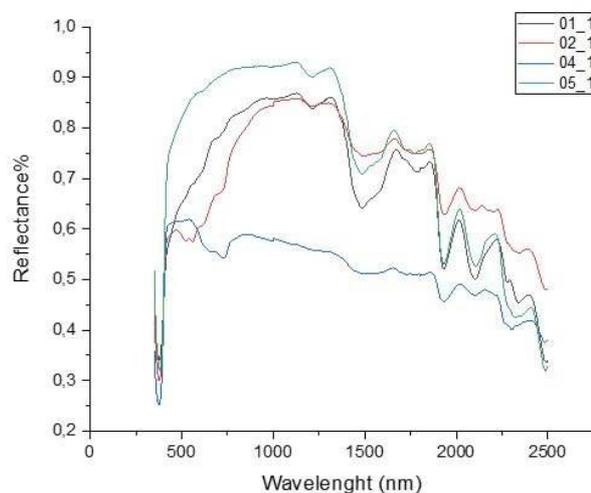


Figure 75 FORS spectra obtained for white details of drawings 01, 02, 04, 05

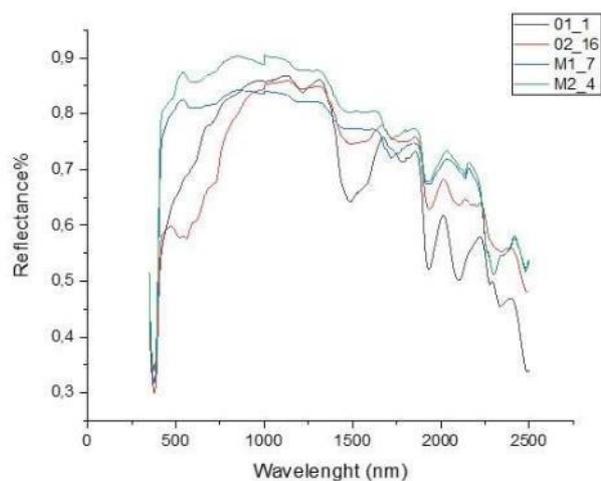


Figure 76 FORS spectra obtained for white details of drawings 01, 02, M1, M2

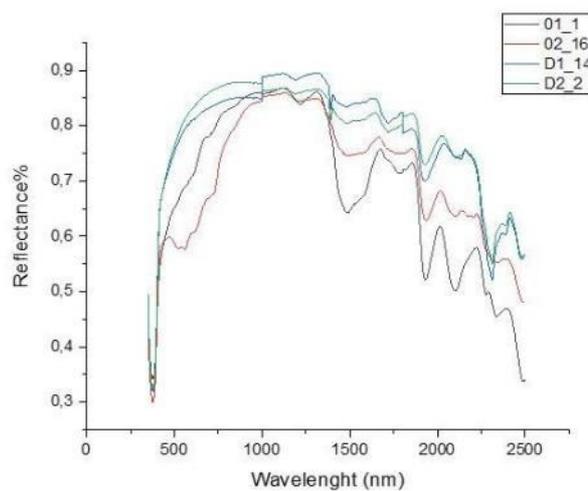


Figure 77 FORS spectra obtained for white details of drawings 01, 02, D1, D2

The white pigment used for drawings 01 and 02 (Figure 74) could be the same and it could be a mixture of Titanium White and Barium sulphate. In fact, an absorbance between 600-700 nm and a reflectance at ~ 450-500 nm are noticeable (CHSOS: Titanium White, Lithopone) (AA. VV., 2006). In all the other analysed artworks (04, 05, M1, M2, D1, D2) (Figure 75, 76, 77) the white colour could be Titanium White (Titanium dioxide) since a strong reflectance at ~ 450-500 nm is visible (CHSOS: Titanium White).

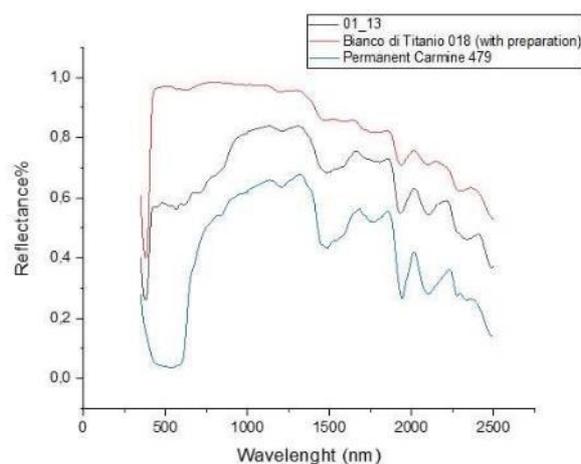


Figure 78 FORS spectra obtained for white mixed with mauve detail of drawing 01

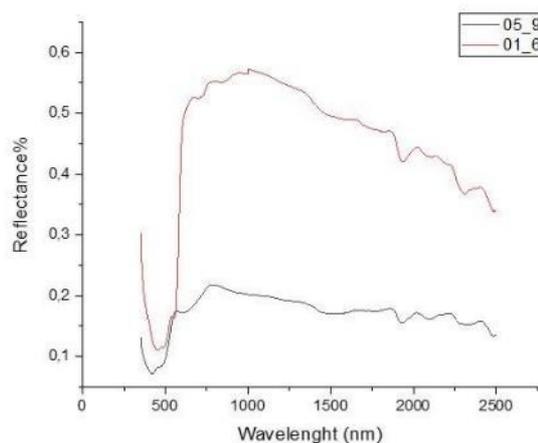


Figure 79 FORS spectra obtained for mauve brownish of drawings 01, 05

The mauve pigment used in drawing 01 could contain a quinacridone-based dye mixed with Titanium White to obtain the snowy effect. The comparison between the spectrum of the paint coats Titanium White 018 and of Permanent Carmine 479 (a quinacridone pyrrolidone dye) and the measure point 01_13 (Figure 78) shows a combination of absorbance and reflectance between 450 and 600 nm; there is then an increasing reflectance between 600 and 1000 nm that can suggest that the mauve colour could be quinacridone based dye.

The mauve brownish colour used in drawing 05 has a very similar spectrum to the mauve colour spectra of drawing 01 (Figure 79), so it could be a quinacridone-based dye as well.

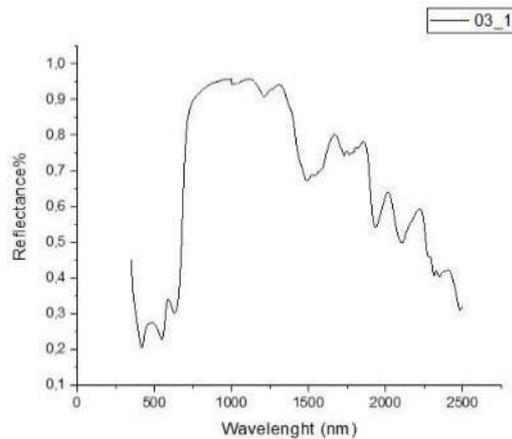


Figure 80 FORS spectra obtained for orange detail of drawing 03

The orange pigment used for drawing 03 (Figure 80) could be probably an azoic dye since there is a strong absorbance between 300-400 nm (Montagner et al., 2011) but it could be a lac dye as well, so an anthraquinone dye (Leona, Winter, 2001) (Bisulca et al., 2008). In fact, as reported by Bisulca et al., the characteristic patterns in the visible region of the studied carminic acid-based lake and alizarin-based lake showed a strong absorption band, structured into two main sub-bands, from 500-560 nm, a shoulder at ~ 480-500 nm, a peak of reflectance at ~ 420 nm and a sharp increase in reflectance at ~ 600 nm. The absorption behaviour in the visible region of the selected anthraquinone based dyes is principally due to $n \rightarrow \pi^*$ transitions of the carbonyl groups (Bisulca et al., 2008).

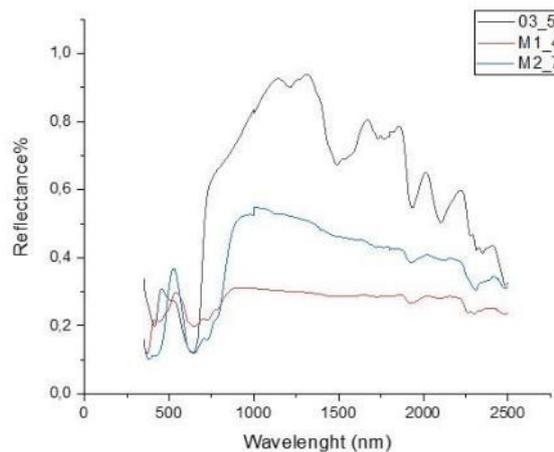


Figure 81 FORS spectra obtained for green details of drawings 03, M1, M2

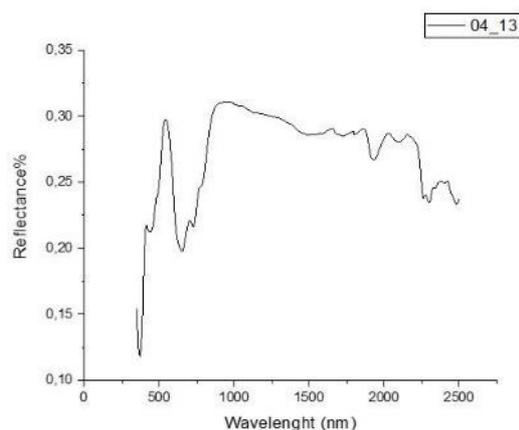


Figure 82 FORS spectra obtained for green details of drawing 04

The green pigment used for some small details in the drawing 03 (Figure 81) could be Phthalo Green (copper phthalocyanine). In fact, according to spectra from databases, there is an evident reflectance peak at ~ 500 nm and in some cases a weak secondary peak at ~ 700 nm (Cosentino, 2015) (Poldi and Caglio, 2013). Phthalo Green is present also in drawing 04 (Figure 82), where an absorbance band is present at ~ 450 nm and 620-650 nm and a strong reflectance peak is present at ~ 500 nm, even if a little shifted and at ~ 710 nm (Cosentino, 2014) (Poldi and Caglio, 2013). In drawing M1 (Figure 81), green details were depicted using Phthalo Green as well. In fact, a strong reflectance peak is present at ~ 500 nm and an absorption band at ~ 700 nm is visible (Cosentino, 2014) (Poldi and Caglio, 2013). Phthalo Green is used also in drawing M2 (Figure 81), in fact a strong reflectance peak is visible at ~ 500 nm and a shoulder is present at ~ 700 nm and an absorbance band at ~ 620-650 nm (Cosentino, 2014) (Poldi and Caglio, 2013).

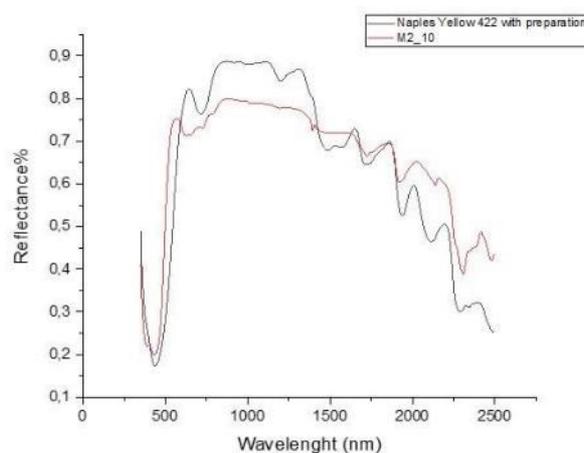


Figure 83 FORS spectra obtained for yellow/ochre details of drawing M2

The yellow/ochre colour used for depicting drawing M2 (Figure 83) could be a Chrome Antimony Titanate, a good non-toxic Naples Yellow substitute mixed with Titanium White

(artiscreation.com/database). The comparison between the spectrum of the paint coat Naples Yellow 422, containing PW6 and PBr24 (Chrome Antimony Titanate dye) and the measure point M2_10 shows a strong absorbance at ~ 500 nm and then a strong reflectance between 500 nm and 650 nm and then another absorbance at ~ 750 nm.

In general, the colour palette results to be homogeneous for a particular shade on the same artwork and on drawings from the same series as well, such as 01-02 and M1-M2, as about pure colours as about mixtures.

There are some differences in pigment's nature throughout drawings from different decades, but their formulation seems to be coherent with the years when Zavřel created those artworks.

4.3 Raman Spectroscopy

In order to have a better and clearer characterization of the pigments or dyes employed in the artworks, Raman Spectroscopy has been performed. The results were then compared to the ones obtained with FORS analysis. The most relevant spectra are presented and discussed below and the main peaks are indicated in *Table 4*.

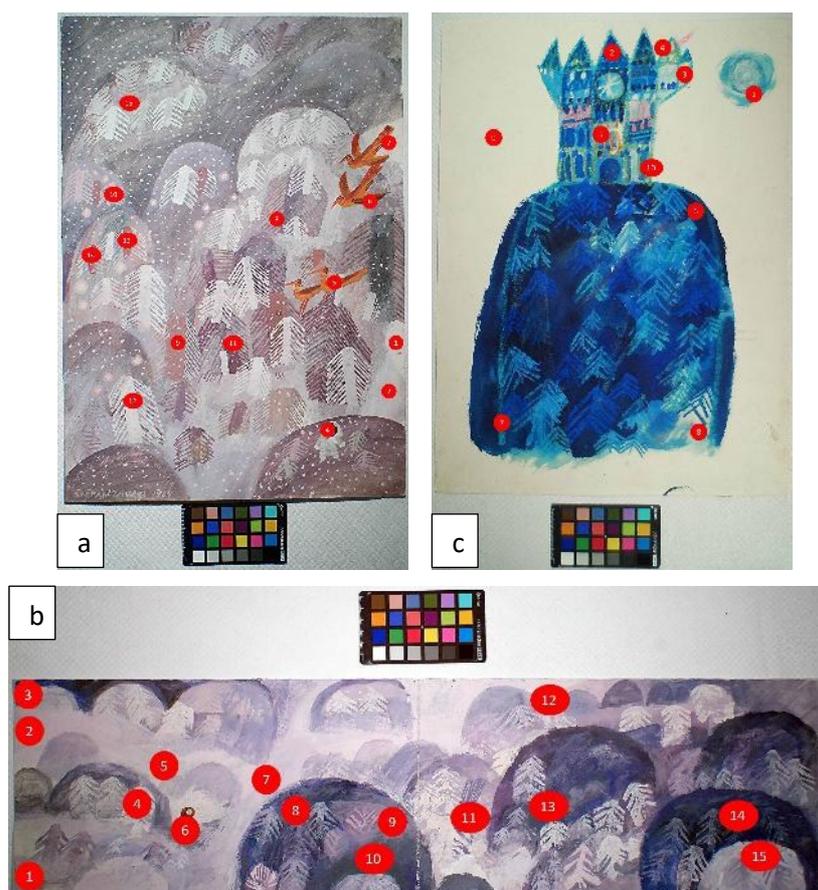


Figure 84 a: Raman measure points of drawing 01; b: Raman measure points of drawing 02; c: Raman measure points of drawing 03

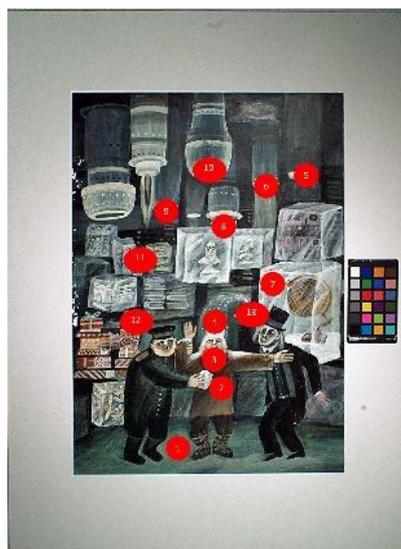


Figure 85 Raman measure points of drawing 04

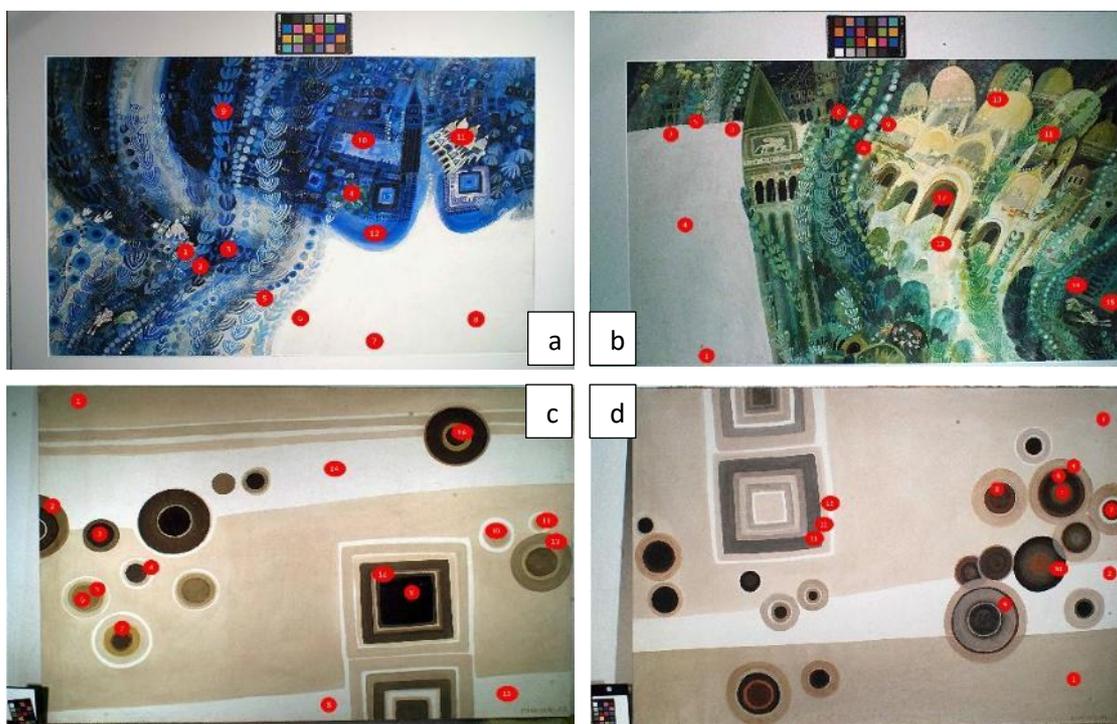


Figure 86 a: Raman measure points of drawing M1; b: Raman measure points of drawing M2; c: Raman measure points of painting D1; d: Raman measure points of painting D2

Regarding the white coloured areas, all spectra from different artworks show common peaks at $\sim 609 - 445 \text{ cm}^{-1}$, which are attributed to Titanium White in the rutile form (Burgio and Clark, 2001), a Titanium dioxide (TiO_2) pigment that has been used since the end of the 19th century (Figure 88). However, there are other peaks that suggest that other white pigments were employed mainly to paint a homogenous preparatory layer on the supports. In Figure 89 the spectra of the measure points from drawing 01 and 02 show peaks at $\sim 989 - 633 \text{ cm}^{-1}$ that suggest the presence of Barium sulphate (BaSO_4) or Lithopone, a pigment containing Zinc sulphide and Barium sulphate (ZnS and

BaSO₄) (Burgio and Clark, 2001). That pigment could have been mixed with Titanium White in order to reduce the opacity and tendency to yellowing of Titanium (pigmenti.net) and obtaining a particular shade to create a snowy effect. In particular, regarding drawing 02, that stronger absorption peak at ~ 989 cm⁻¹ is visible in all spectra so it is probably part of the layer underneath. In Figure spectra from drawing M1 and M2 show a peak at ~ 1089 cm⁻¹ related to CO₃²⁻ stretching, that suggests the presence of a preparatory layer made of chalk, calcium carbonate (CaCO₃), commonly used in ground layers (Burgio and Clark, 2001) (Caggiani et al., 2016). Such a preparation is present also on the two paintings on canvas D1 and D2, whose spectra show a strong peak at ~ 1089 cm⁻¹ and also at ~ 710 cm⁻¹ in some cases (Figure 90).

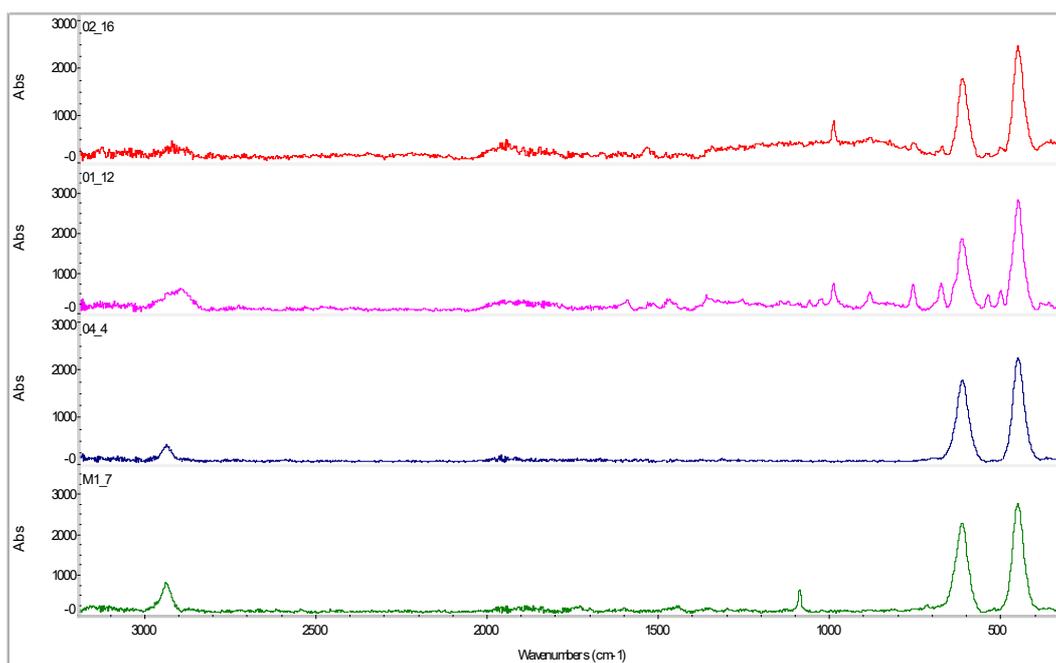


Figure 87 Raman spectra obtained for white details of drawings 01, 02, 04, M1

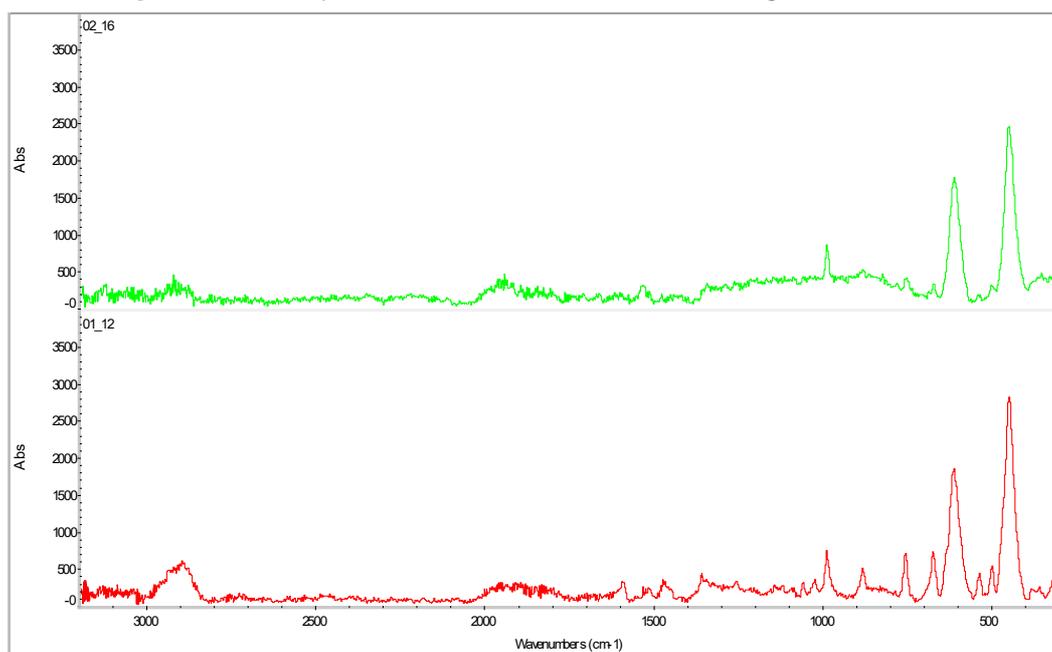


Figure 88 Raman spectra obtained for white details of drawings 01, 02

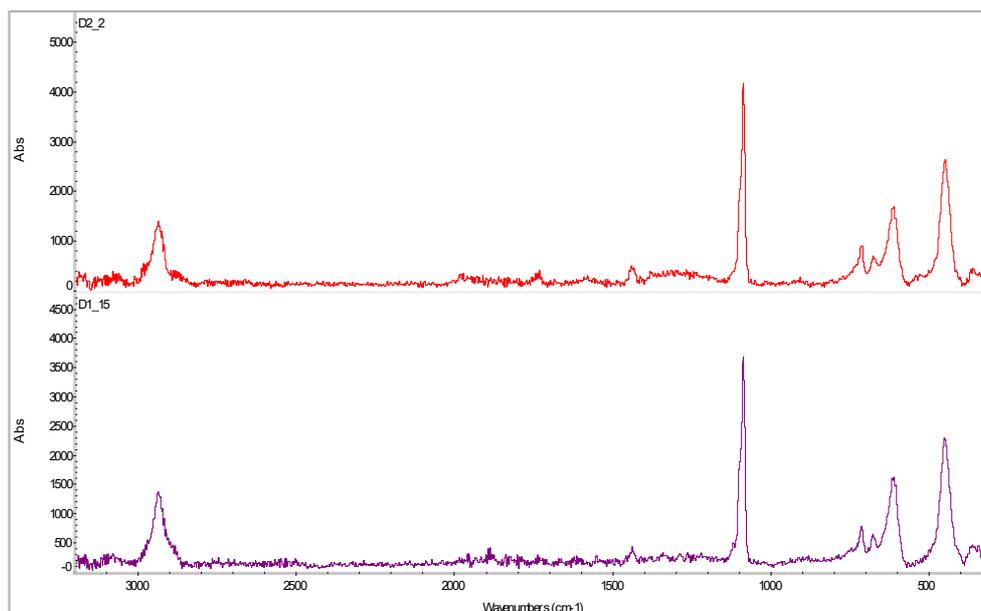


Figure 89 Raman spectra obtained for white details of paintings D1, D2

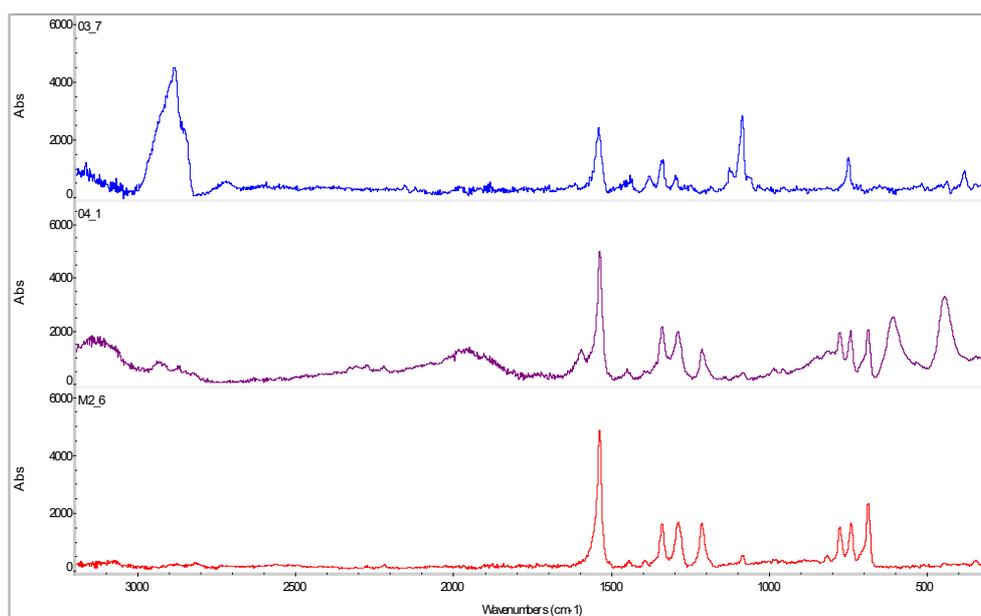


Figure 90 Raman spectra obtained for green details of drawings 03, 04, M2

The green pigments and dyestuff employed in different series dated back to different years results to be same. In fact, all spectra in *Figure 90*, related to drawings 03, 04 and M2, show common peaks at $\sim 1538 - 1339 - 1292 - 1214 - 1080 - 817 - 775 - 738 - 683 \text{ cm}^{-1}$, which are attributed to Phthalocyanine Green, a copper phthalocyanine pigment ($\text{Cu}(\text{C}_{32}\text{Cl}_{16}\text{N}_8)$) (Burgio and Clark, 2001) (Caggiani et al., 2016). “Phthalocyanine derivatives were the first colourants which were launched directly as pigments without having previously been used as dyes, differently from many vat pigments” and nowadays, “Phthalocyanine Blue and Phthalocyanine Green are among the most important organic

pigments in the market” (Herbst and Huger, 2004). In particular, Phthalocyanine Green was prepared commercially for the first time in 1938, in Germany (Herbst and Huger, 2004).

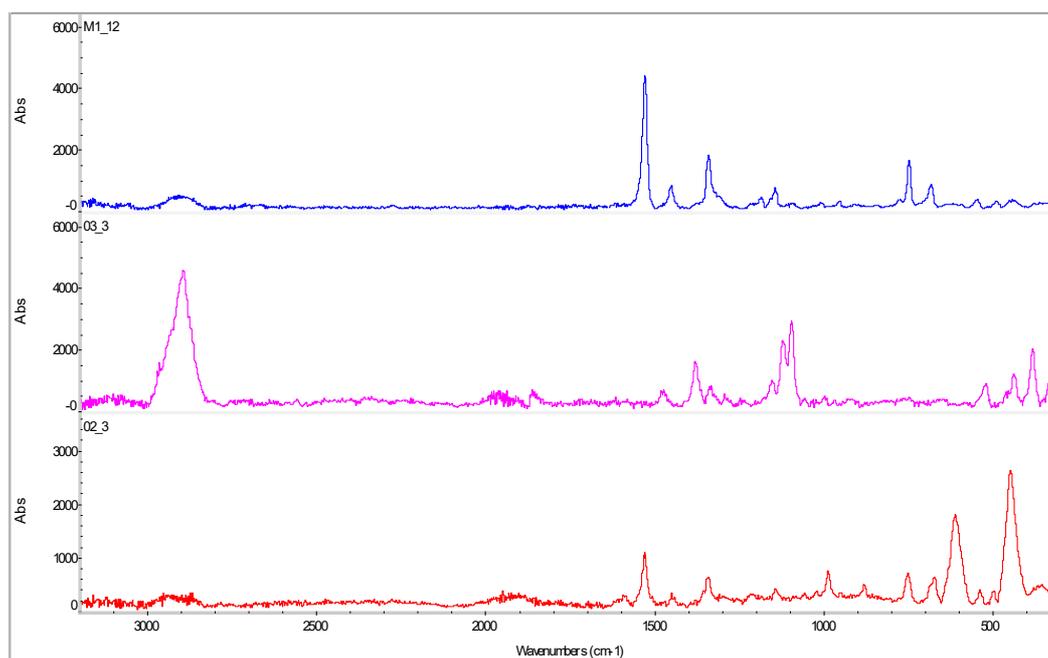


Figure 91 Raman spectra obtained for blue details of drawings 02, 03, M1

Regarding blue coloured details, the *Figure 91* highlights that the pigment's nature is different in the three different drawings where it is present, that is 02, 03 and M1. In fact, in the spectrum of 02_3 measure point, peaks at $\sim 1144 - 670 - 533 - 495 \text{ cm}^{-1}$ suggest the presence of Cobalt Cerulean Blue (PB35), a cobalt stannate pigment ($\text{CoO} \times n\text{SnO}_2$) sold as an artists' pigment in 1860 by Rowney Company under the name of *coeruleum* for the first time (Burgio and Clark, 2001) (artiscreation.com). On drawing 02, that pigment is probably mixed with another blue one, that has been identified as Phthalo Blue, which is present also as the main blue pigment on drawing M1. In *Figure* peaks at $\sim 1534 - 1454 - 1341 - 747 - 686 \text{ cm}^{-1}$ evidence the presence of Phthalo Blue, a copper phthalocyanine pigment (Caggiani et al., 2016) (IRUG: Cu – Phthalocyanine blue PB 15:3) which was introduced to the market as early as 1935 by ICI chemists, followed by a corresponding product by the Ludwigshafen subsidiary of the IG Farben-industrie (Herbst and Huger, 2004). Titanium White and Barium sulphate were also mixed with those blue pigments, since the characteristic peaks at $\sim 609 - 445 \text{ cm}^{-1}$ and $\sim 989 - 633 \text{ cm}^{-1}$, respectively, are noticeable in almost all spectra.

On the other hand, *Figure 91* shows that the blue pigment used on drawing 03 is different from the others and peaks at $\sim 2152 - 2094 - 528 \text{ cm}^{-1}$ are attributed to Prussian Blue (PB27), an iron hexacyanidoferrate ($\text{Fe}_4^{3+}[\text{Fe}_2^{2+}(\text{CN})_6]_3$) pigment (Caggiani et al., 2016), developed in Berlin around 1706 by Diesbach (artiscreation.com). Its presence is particularly noticeable in the two spectra of 03_2 and 03_5 (*Figure 93*) measure points.

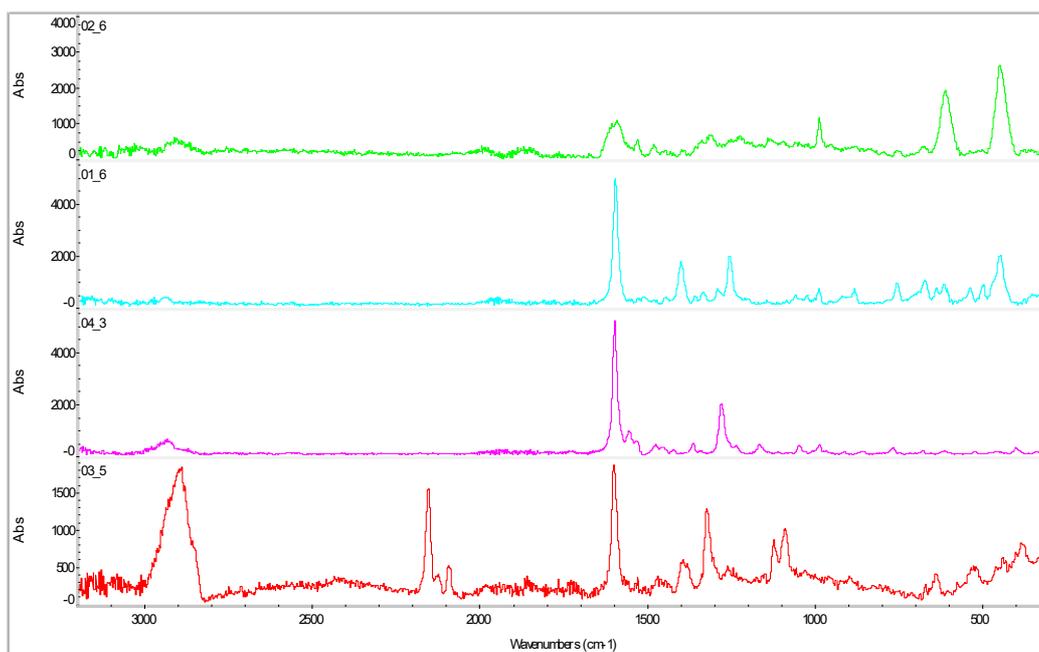


Figure 92 Raman spectra obtained for red details of drawings 01, 02, 03, 04

Red details on drawings 01, 02, 03 and 04, whose spectra are shown in *Figure 92*, could have been depicted with the same pigment since there are some common peaks at $\sim 1601 - 1594 - 987 \text{ cm}^{-1}$. Those peaks could suggest the presence of an azoic-based dye, probably β -naphthol (PR112), a monoazopigment ($\text{C}_{24}\text{H}_{16}\text{Cl}_3\text{N}_3\text{O}_2$) (Burgio and Clark, 2001) but the results appear ambiguous for drawing 02, since the spectra related to the measure point 02_6 (*Figure 92*) suggests the presence of Studio Red pigment ($\text{C}_{17}\text{H}_{13}\text{N}_3\text{O}_3$) because of the peaks at $\sim 1607 - 1527 - 1482 - 1309 - 987 - 678 \text{ cm}^{-1}$ (Burgio and Clark, 2001). Studio Red Hansa pigment is also known as Hansa Scarlet RNC or Pigment Red 3 (PR3), and it is a β -naphthol-based synthetic organic pigment that was made available in 1905 (Raicu et al., 2023), so a clear distinction cannot be made between these two pigments, as they are characterized by similar bands that can be a little shifted in this case because red is mixed with white or blue pigments.

Drawing 03 (*Figure 93*) shows ambiguous results, as well. The orange colour could be an azoic dye, since the peak at 1601 cm^{-1} is related to C=C stretching (Stanislav et al., 2010) but it could be related to a lac dye as well (Leona, Winter, 2001). In fact, the FORS spectrum discussed in the previous section and the fact that it presents a strong luminescence when it is illuminated with UV light could support this hypothesis.

Finally, drawing 04 (*Figure 94*) shows peaks at $\sim 1598 - 1555 - 1532 - 1280 - 1167 - 1048 - 398 \text{ cm}^{-1}$, which could be attributed to Pigment Orange 13 (PO13), a disazopyrazolone pigment ($\text{C}_{32}\text{H}_{24}\text{Cl}_2\text{N}_8\text{O}_2$) (Scherrer et al., 2009) (IRUG: Disazopyrazolone, Azo PO13).

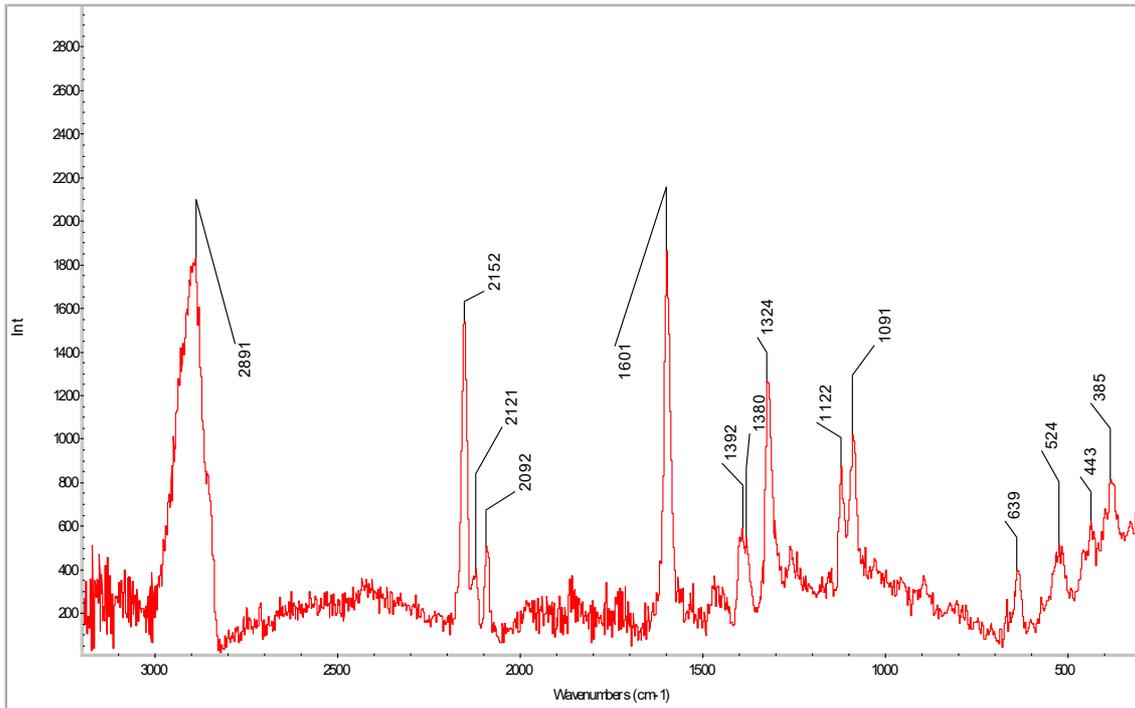


Figure 93 Raman spectra obtained for red details of measure point 03_5 of drawing 03

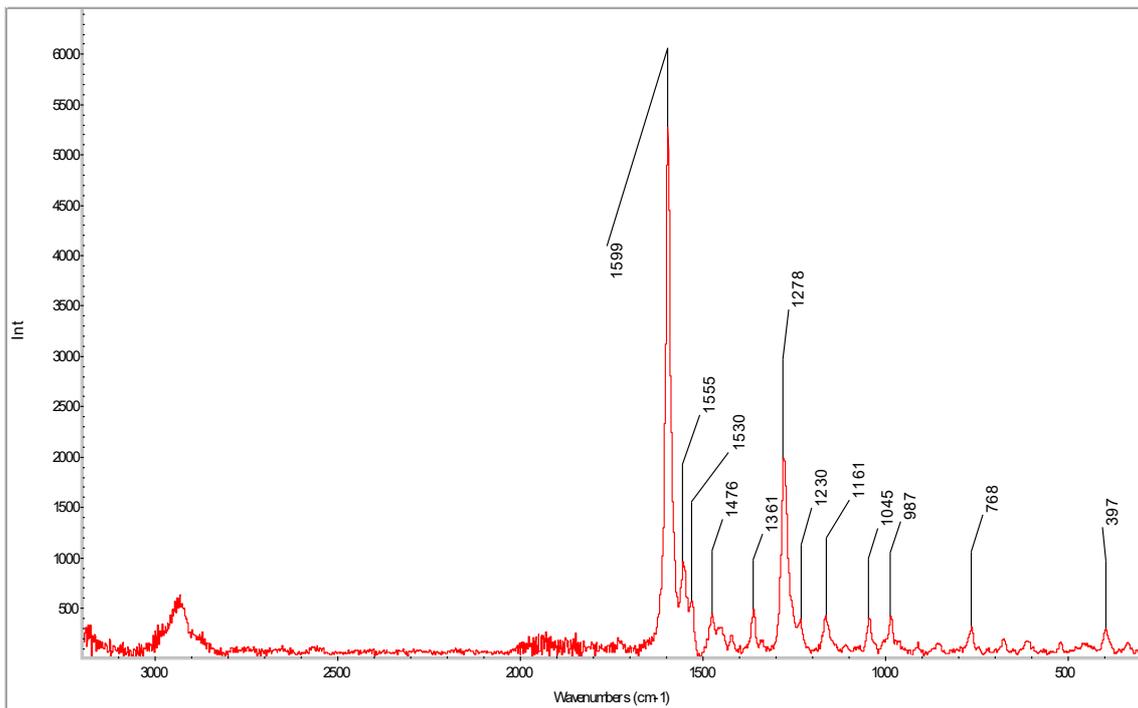


Figure 94 Raman spectra obtained for red detail of measure point 04_3 of drawing 04

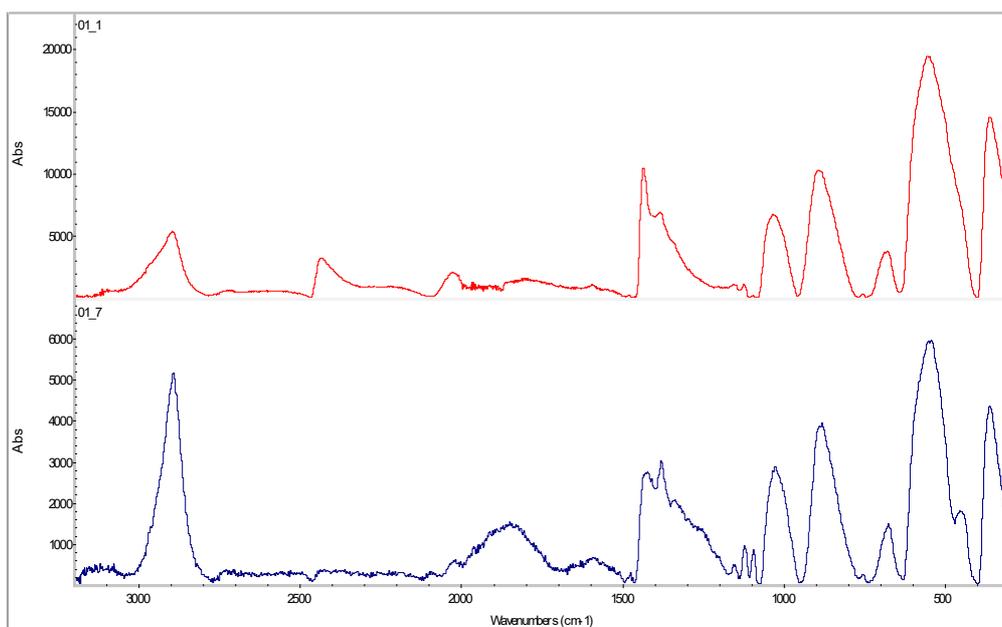


Figure 95 Raman spectra obtained for mauve/magenta details of measure points 01_1 and 01_7 of drawing 01

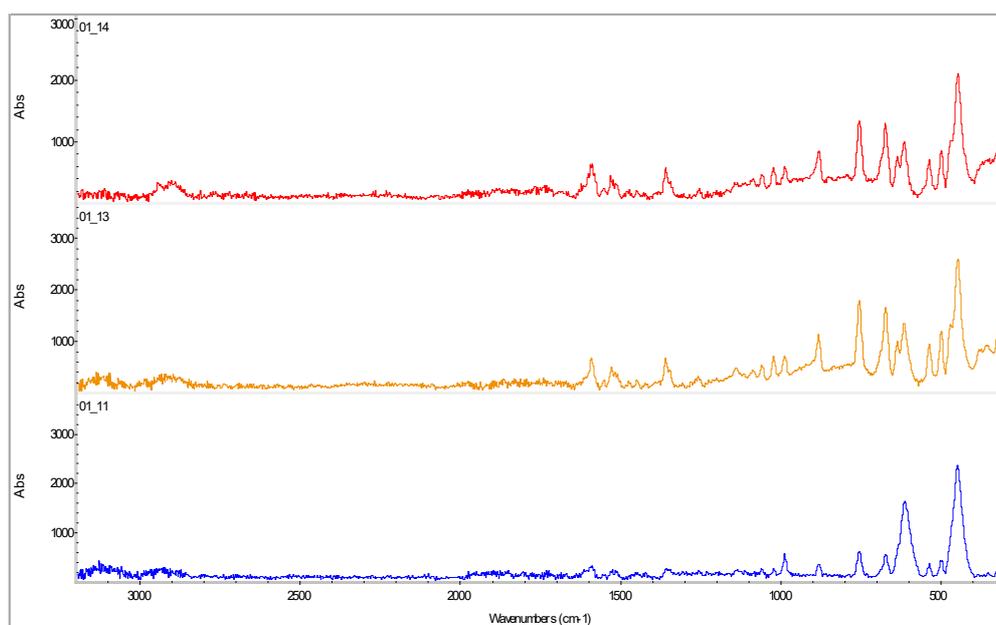


Figure 96 Raman spectra obtained for mauve/magenta details of measure points 01_11, 01_13 and 01_14 of drawing 01

Regarding mauve/magenta pigments on drawing 01, Figure 95 show the spectra of 01_1 and 01_7 measure points, which exhibit a strong luminescence when they are illuminated with UV light. The spectra highlight that, even if that areas seems to have been painted with a white pigment, they clearly show different peaks at $\sim 1594 - 1380 - 1346 - 877 - 679 - 557 - 543 - 369 - 346 \text{ cm}^{-1}$, which are attributed to Permanent Magenta pigment (Burgio and Clark, 2001). Even if the formulation is not declared, Winsor & Newton refers to that colour for a quinacridone-based pigment introduced in 1950's (winsornewton.com). Other traces of quinacridone-based pigment appear on other spectra related to some mauve details (01_11, 01_13, 01_14) (Figure 96), so on 01_1 and 01_7

points a mauve paint coat could have been painted and then covered with white paint, as a sort of *pentimenti*. Considering that in the measure points related to the background, the peaks of the quinacridone pigment are present in almost all spectra, the artist could have been painted a homogeneous mauve layer underneath. It is mixed with Titanium White in order to obtain a snowy effect.

On the other hand, the bright magenta pigment on drawing 03 (Figure 97) on measure point 03_4 could be identified as a lac dye, an anthraquinone-based pigment, since the characteristic peak at $\sim 1384 \text{ cm}^{-1}$ is present.

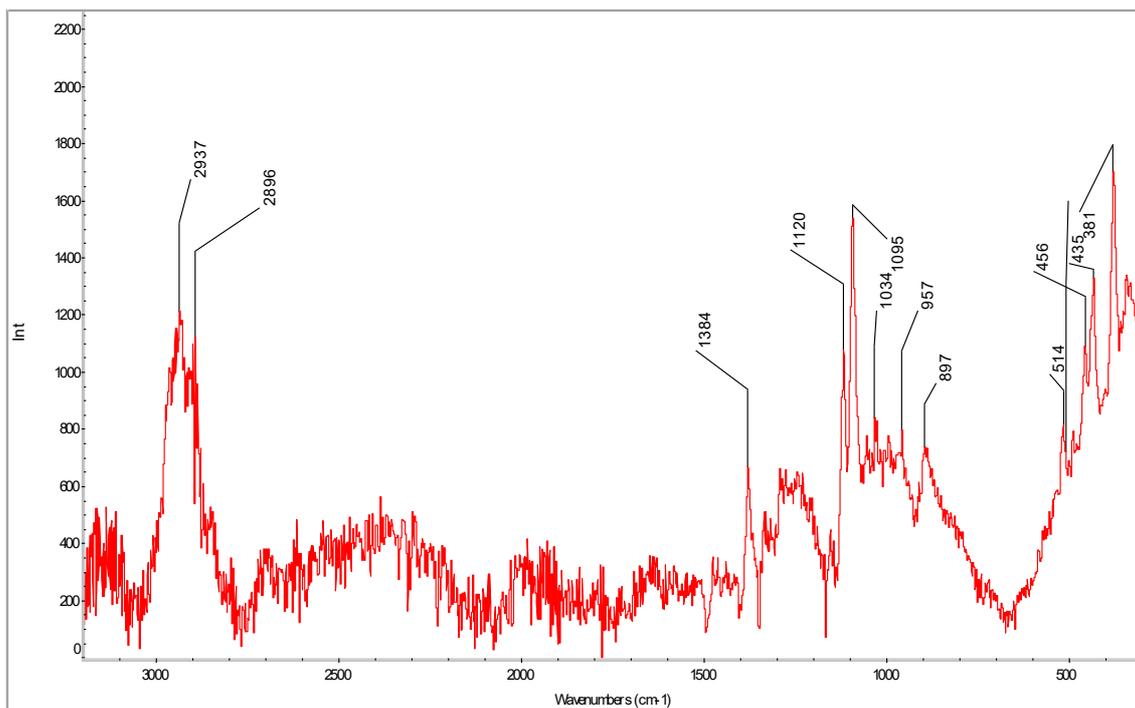


Figure 97 Raman spectra obtained for magenta detail of measure point 03_4 of drawing 03

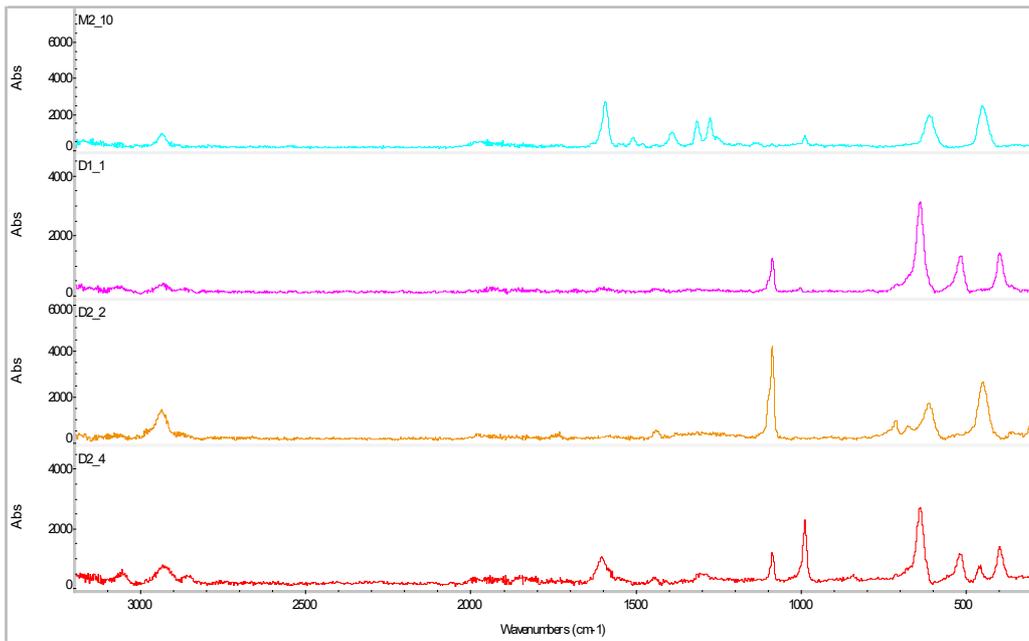


Figure 98 Raman spectra obtained for yellow/ochre details of drawing M2 and paintings D1 and D2

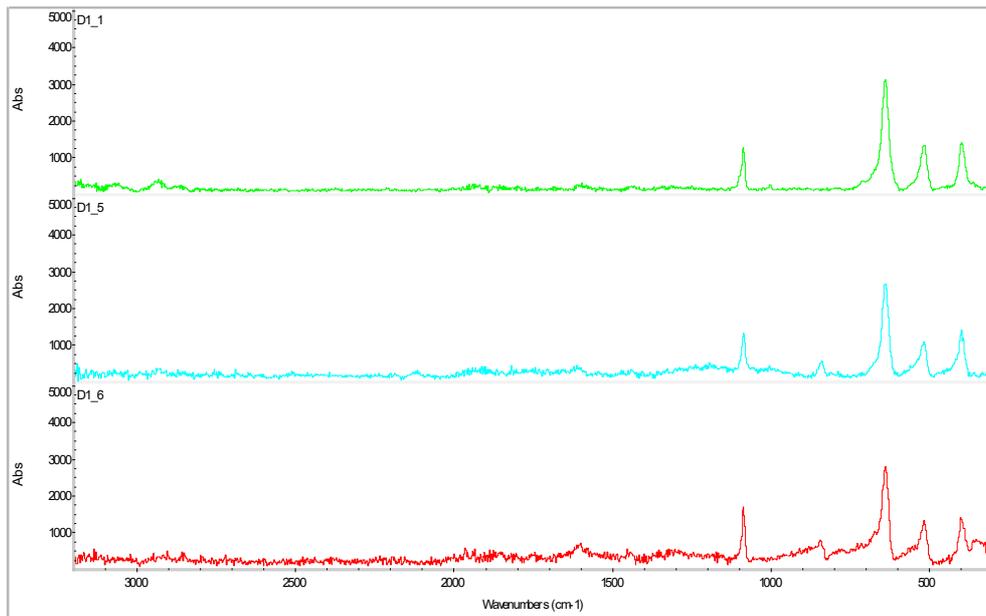


Figure 99 Raman spectra obtained for yellow/ochre details of measure points D1_1, D1_5 and D1_6 of painting D1

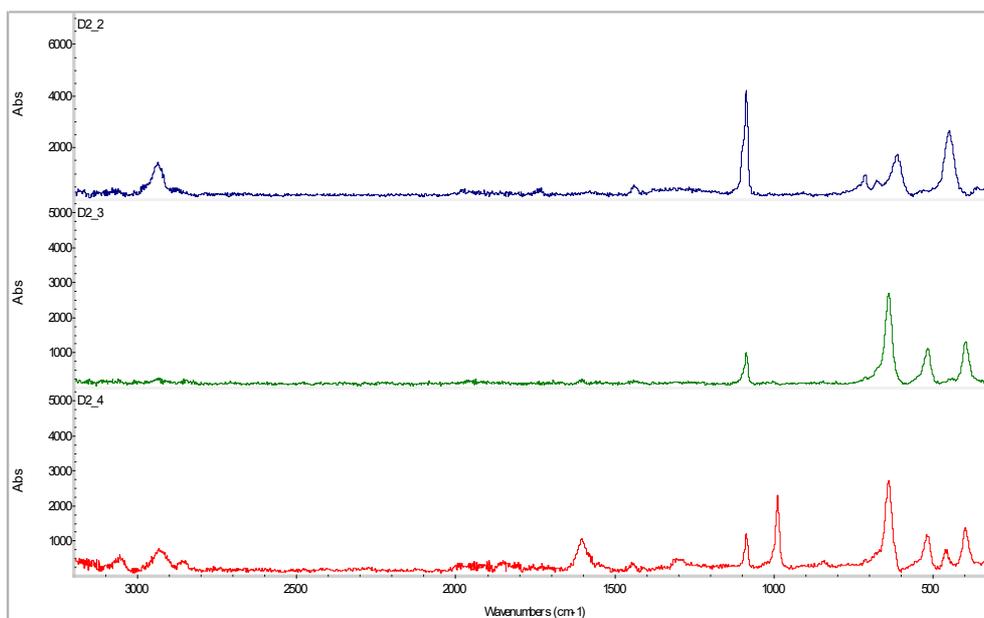


Figure 100 Raman spectra obtained for yellow/ochre details of measure points D2_2, D2_3 and D2_4 of painting D2

The identification of yellow and ochre pigments is a little challenging. *Figure 98* shows that the pigments used on drawing M2 are different from the ones employed on the two paintings D1 and D2. Regarding yellow pigment on drawing M2, peaks at $\sim 1596 - 1381 - 1313 - 1296 \text{ cm}^{-1}$ could be related to the presence of Pigment Yellow 95 (PY95) ($\text{C}_{44}\text{H}_{38}\text{Cl}_4\text{N}_8\text{O}_6$), named also Gamboge (Scherrer et al., 2009) (IRUG: Disazo condensation PY95) (artiscreation.com) (Burgio and Clark, 2001), an organic synthetic disazopigment obtained with condensation. It had probably been mixed with Phthalo Green for depicting some details in order to make green lighter or obtain different shades. On the other hand, the nature of yellow pigment on paintings D1 and D2 seems to be the same, used as alone as in mixtures. In *Figure 99*, peaks at $\sim 719 - 669 \text{ cm}^{-1}$ could be related to Pigment Yellow 81 (PY81) ($\text{C}_{36}\text{H}_{32}\text{Cl}_4\text{N}_6\text{O}_4$) and at $\sim 637-396 \text{ cm}^{-1}$ related to Pigment Yellow 83 (PY83) ($\text{C}_{36}\text{H}_{32}\text{Cl}_4\text{N}_6\text{O}_8$), two disazo (diarylide) pigments which were made available around 1940's (Scherrer et al., 2009) (artiscreation.com). In some points, PY81 could have been mixed together (*Figure 100*) with another yellow pigment, that is Pigment Yellow 74 (PY74) ($\text{C}_{18}\text{H}_{18}\text{N}_4\text{O}_6$), a monoazo (acetoacetic arylide) pigment, available since 1940's, on painting D1, since there are peaks at $\sim 1600 - 1438 - 828 - 717 - 512 \text{ cm}^{-1}$ (Scherrer et al., 2009). PY74 was probably mixed with PY83 and Titanium White in some points on painting D2 (*Figure 100*).

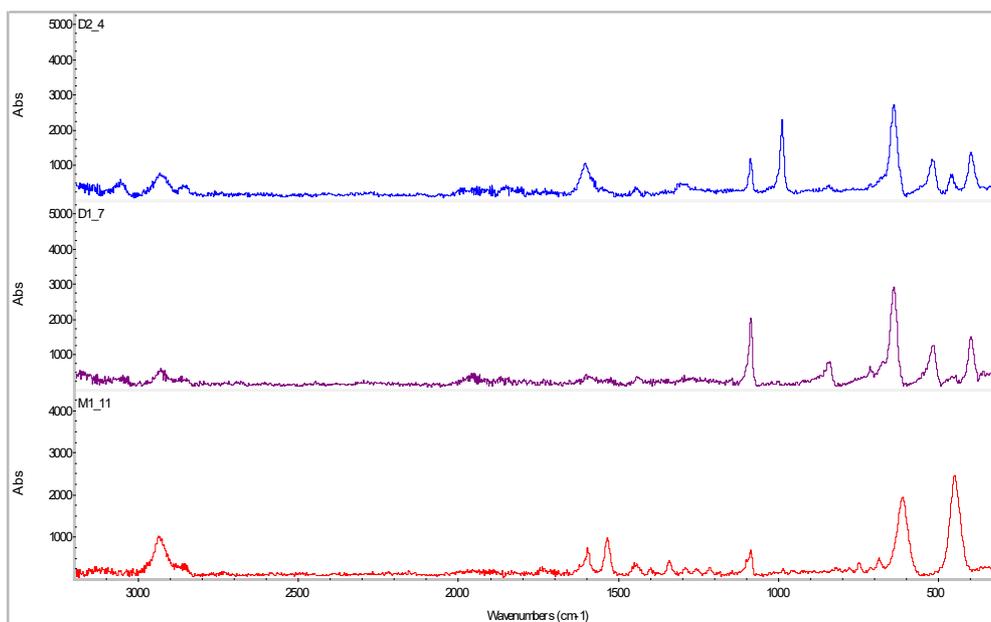


Figure 101 Raman spectra obtained for brown details of measure point M1_11 of drawing M1 and of measure points D1_7 and D2_4 of painting D1, D2

The brown details used on drawing M1 and paintings D1 and D2 are different. In *Figure 101* related to paintings D1 and D2, there are peaks at $\sim 1610 - 1341 - 1300 - 842 - 635 - 395 - 362 \text{ cm}^{-1}$, related to Pigment Brown 23 (PBr23), a disazopigment obtained with condensation (Scherrer et al., 2009) (IRUG: Disazo condensation pigment PBr23). On the other hand, peaks at $\sim 1620 - 1359 - 1289 \text{ cm}^{-1}$ in *Figure* related to measure point M1_ of drawing M1 are attributed to Pigment Brown 25 (PBr25) ($\text{C}_{24}\text{H}_{15}\text{Cl}_2\text{N}_5\text{O}_3$), a monoazo (benzimidazolone) pigment (Scherrer et al., 2009) (IRUG: Benzimidazolone PBr25) available since 1960's. Brown pigments are mixed with yellow ones and Titanium White in some points in order to obtain different shades.

The identified pigments and dyestuff through Raman analysis are summarized in *Table 4*.

Artwork	Colour	Peak (cm^{-1})	Reference (cm^{-1})	Pigment/dye
01; 02; 04; M1; M2; D1; D1	White	610 447	609 445	Titanium White (PW6 titanium dioxide)
01; 02	White	987 633	989 633	Barium sulphate
M1; M2; D1; D2	White	1089	1089	Gypsum/Chalk
01; 02; 03; 04	Red/Orange	1601 1594 987	1607	Azoic dye, probably a monoazopigment (β -naphthol) (PR112). In the case of 03, it is ambiguous because it could be related also to a lac dye. Then, for 04 it could be mixed with another kind of azoic dye.
02	Red/Orange	1607 1526 1480 1309 987 676	1607 1527 1482 1309 987 678	Studio Red (Hansa Red formula: $\text{C}_{17}\text{H}_{13}\text{N}_3\text{O}_3$) (PR3), a β -naphthol-based pigment.
04	Orange	1599 1555 1530 1278 1161 1045	1598 1555 1532 1280 1167 1048	Azoic dye, probably a disazopigment (PO13)

		397	398	
01	Mauve	1594 1382 882 676 551 543 360	1594 1380 877 679 557 543 369	Quinacridone dye mixed with Titanium White to obtain a snowy effect.
03	Magenta	1384	1384	Anthraquinone dye, probably a lac dye
02	Blue	1143 668 534 495	1144 670 533 495	Cobalt Cerulean Blue (PB35 cobalt stannate)
03	Blue	2152 2094 526	2154 2094 528	Prussian Blue (PB27 iron hexacyanidoferrate)
02; M1; M2	Blue	1530 1451 1341 1216 1145 1037 952 751 685 590 255 231	1534 1454 1341 1212 1140 1037 954 747 686 591 255 231	Phthalo Blue (copper phthalocyanine)
03; 04; M1; M2	Green	1538 1338 1288 1213 1086 818 776 741 685	1538 1339 1292 1214 1080 817 775 738 683	Phthalo Green (copper phthalocyanine)
M2	Yellow/Ochre	1592 1388 1311 1280	1596 1381 1313 1296	Pigment Yellow 95 (PY95)
D1; D2	Yellow/Ochre	639 395	637 396	Pigment Yellow 81(PY81)
D1; D2	Yellow/Ochre	712 676	719 669	Pigment Yellow 83 (PY83)
D1; D2	Yellow/Ochre	1599 1438 839 710 515	1600 1438 828 717 512	Pigment Yellow 74 (PY74)
M1	Brown	1617 1345 1293	1620 1359 1289	Pigment Brown 25 (PBr25)
D1; D2	Brown	1607 1345 1307 841 638 395 360	1610 1341 1300 842 635 395 362	Pigment Brown 23 (PBr23)

Table 4 Raman peaks, reference and identified pigments

4.4 Micro-Invasive analysis

Some micro-samples were collected from the two drawings M1 and M2, which are conserved and exposed in the museum. In particular, one sample was collected from the drawing M1, then five samples were collected from the drawing M2. They were observed with a microscope and then micro – Raman Spectroscopy analysis was performed in order to characterize the pigments and compare the results with the ones presented in the previous section.

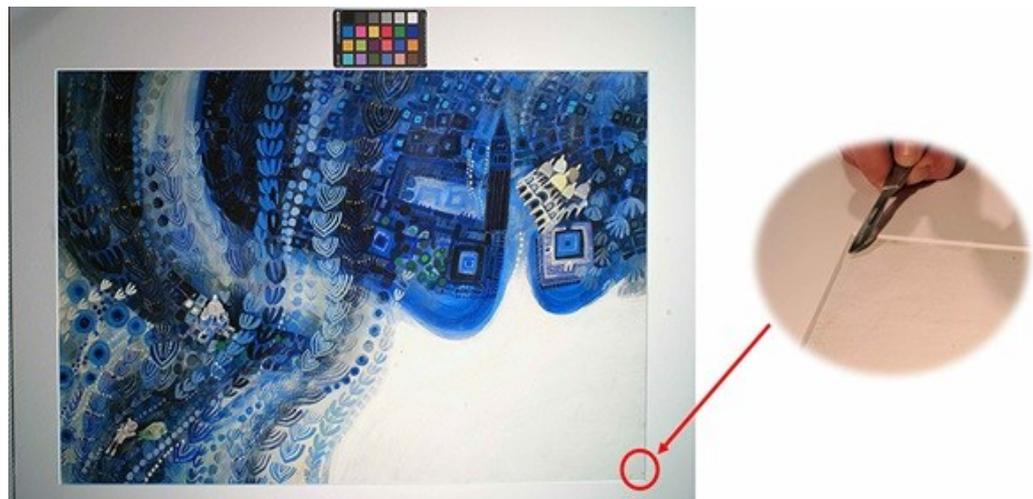


Figure 102 Points where samples were collected on drawing M1

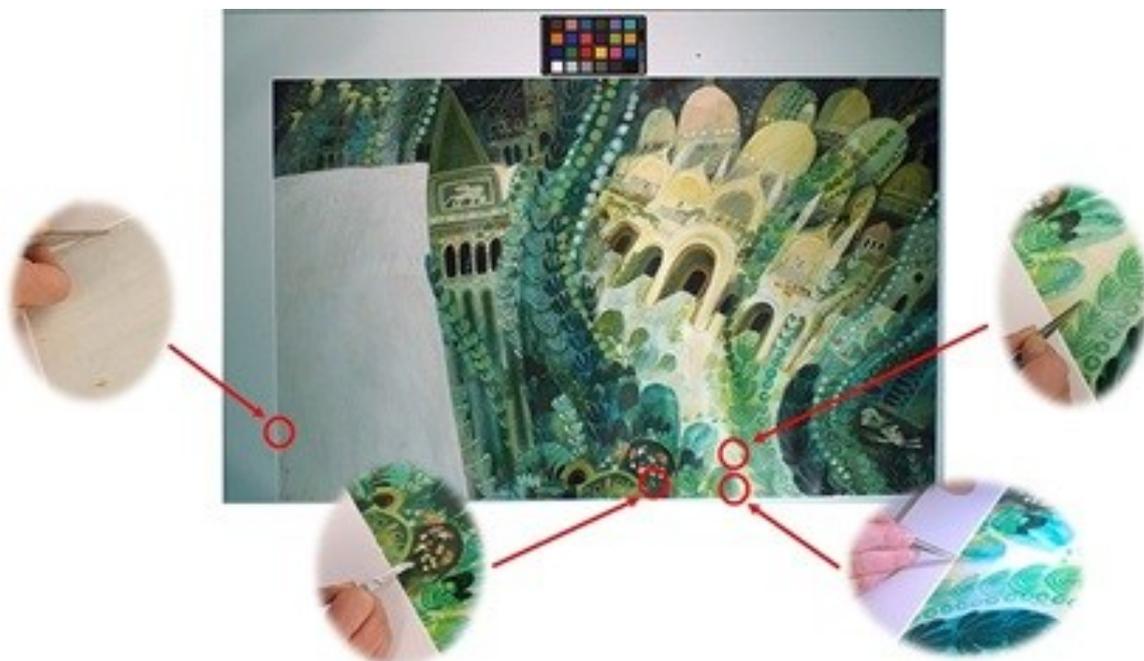


Figure 103 Points where samples were collected on drawing M2

4.4.1 Microscope (Vis)

The inspection of the samples' surfaces was done by mean of a microscope only in one range of the spectrum, that the visible one, in order to study the conservation state and to detect any possible sign of some degradation phenomena. The samples were observed using three different magnifications: 10x, 20x, 40x.

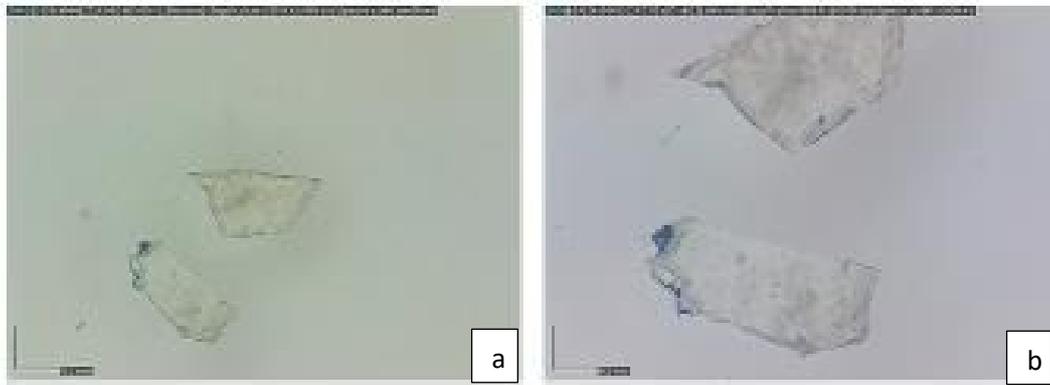


Figure 104 Sample M1_1 taken from drawing M1 at 20x (a) and 40x (b) magnifications

Sample M1_1 (Figure 104) was taken from the right corner below, in correspondence to the white coloured area and where there was an imperceptible colour detachment of the pictorial layer. Two small fragments were observed. Their colour results to be white but blue traces are present along the sides, probably due to some colour traces also from the recto. The pictorial layer appears quite homogeneous but the white zone presents some parts with a colour change. It could be also due to the fact that the pictorial layer is not so thick in the sampling area and the paper support is perceptible below.

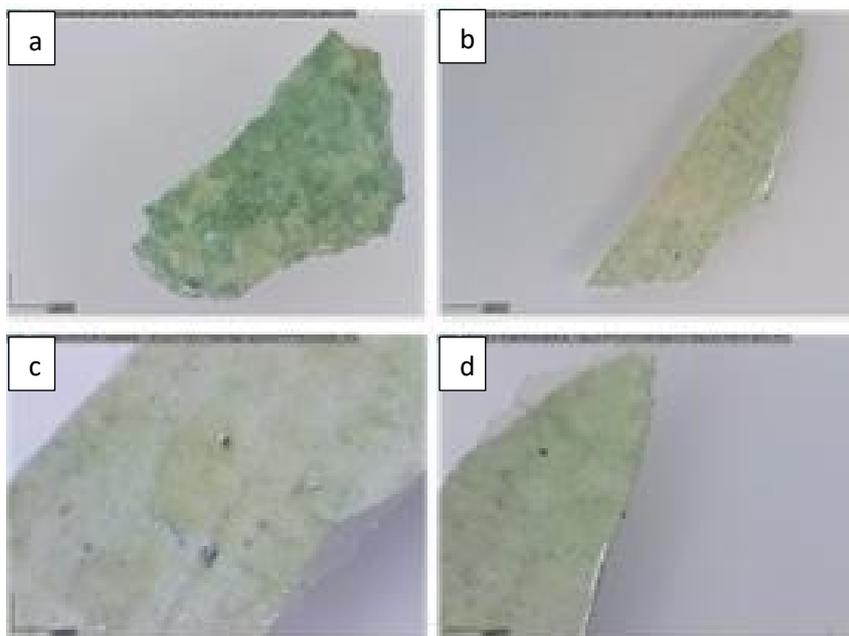


Figure 105 Sample M2_1 taken from drawing M2 at 40x (a) magnification; sample M2_2 taken from drawing M2 at 10x (b) and 40x (c,d) magnifications

The first sample of M2 drawing (M2_1) was taken from a green detail in the middle part of the lower side (*Figure 105a*), in correspondence to one of the green zones of the algae. The surface results to be shiny and a superficial transparent layer is visible along one side of the sample, so a protective varnish layer was probably applied on the surface. The pictorial layer seems to have been realized using a mixture of different colours since green, yellow and white zones are detectable. Any evident sign of occurring degradation phenomena is visible. The pictorial layer appears to be realized with quite material colours.

Sample M2_2 was taken in correspondence to the greenish/yellowish background in the middle of the lower side (*Figure 105b, 105c, 105d*). The surface appears shiny and a transparent superficial layer is distinguishable along one side of the sample and so a protective varnish layer is probably present. The pictorial layer seems to be constituted by a mixture of different colours, that is yellow white and a bit of green. The surface does not appear homogeneous and some dark depositions are present, they could be traces of other colours employed by the artist or also of impurities of the paper support. The pictorial layer appears to be realized with quite material colours and there are not evident signs of degradation phenomena.

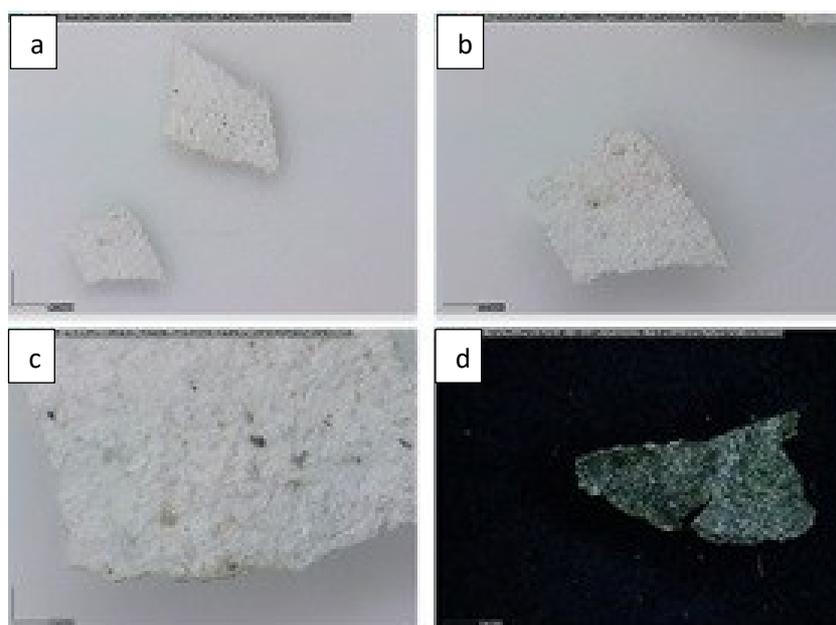


Figure 106 Sample M2_3 taken from drawing M2 at 10x (a), 20x (b) and 40x (c) magnifications; sample M2_4 taken from drawing M2 at 20x (d) magnifications

Sample M2_3 was taken from the white coloured area on the lower left side (*Figure 106a, 106b, 106c*). The two fragments probably belong to the paper support since there is no traces of colours or preparation layer. The surface does not appear homogenous and there are traces of impurities but there are no evident signs of degradation phenomena.

Sample M2_4 was collected from a dark green detail in the lower side of the M2 drawing, in correspondence to the children group (*Figure 106d*). The surface appears shiny for this sample as well, so probably a protective varnish layer was applied. The pictorial layer does not appear homogenous and probably the detail was created employing only a dark green colour alone. In the

upper side, the paper support is visible a bit and was probably due to the colour detachment phenomena observed in that drawing.

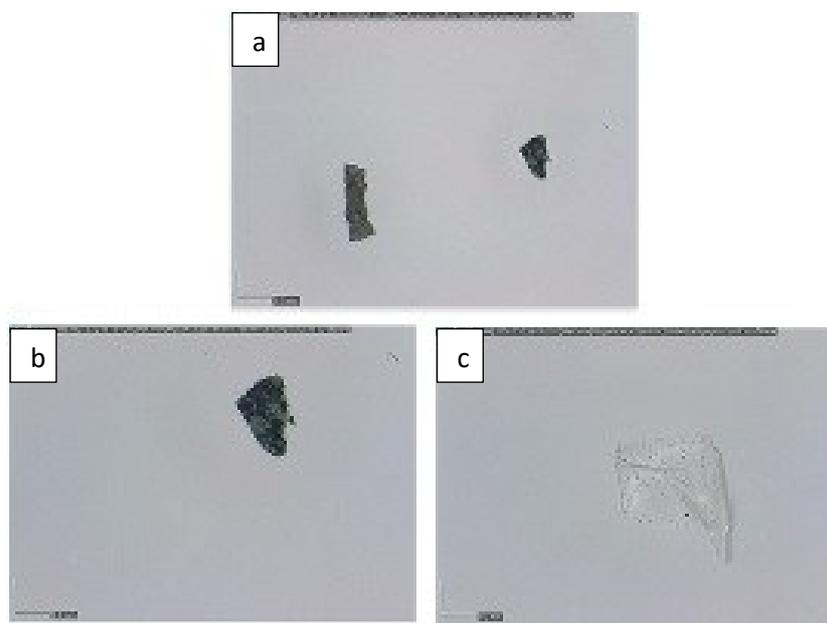


Figure 107 Sample M2_caduta taken from drawing M2 at 20x (a), 40x (b) and 40x (c) magnifications

Sample M2_caduta was not directly collected from a certain area of the artwork but it was the result of a colour detachment and collapse, so its specific origin was unknown. Two of the three fragments belong to the pictorial layer, then the other one probably belongs to the paper support. The coloured fragments are different: one presents a pictorial layer depicts with a combination of green and blue colours while the other one appears greyish but some traces of the same green and blue colours are visible. In one case, the paper support is visible and, in both samples, the surface does not appear really homogenous. The third fragment seems to be very thin and some traces of blue colour are visible on the whole surface.

4.4.2 Micro – Raman Spectroscopy

The drawing samples were analysed using micro – Raman spectroscopy in order to obtain more information regarding the materials used for the realization of the two drawings M1 and M2 exposed in the museum. In particular, the pigments were determined and then compared with the results obtained with Raman Spectroscopy that were presented and discussed in the previous sections. The samples were analysed and observed at two different magnifications: 10x and 50x.

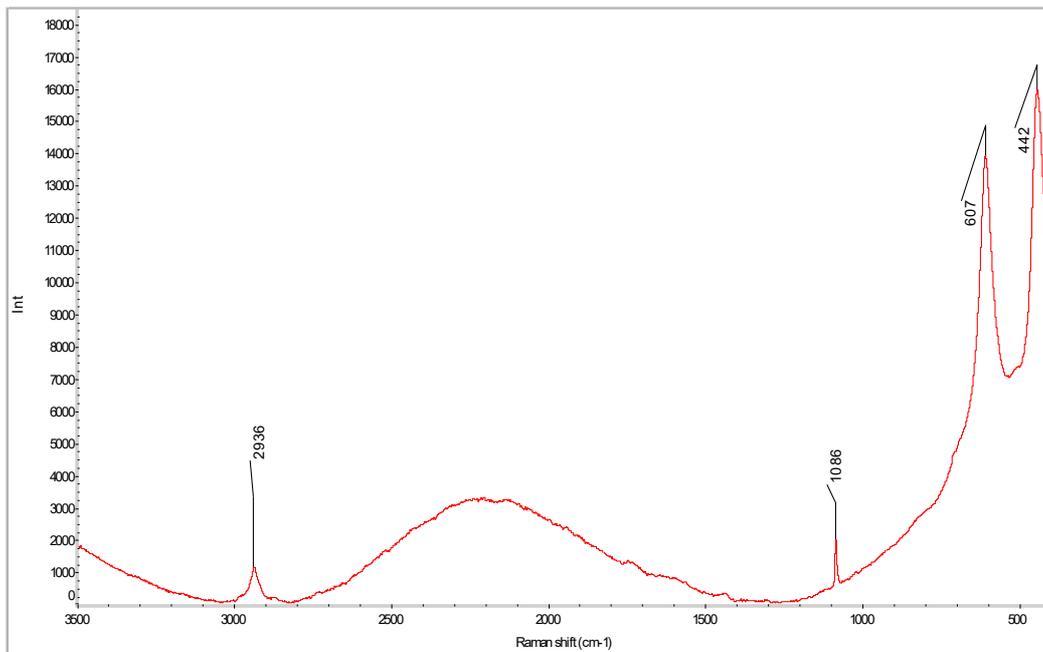


Figure 108 Micro – Raman spectra obtained for white detail of measure point M1_1 10x 6 of drawing M1. The peaks revealed the presence of Titanium White (TiO₂) and calcite (CaCO₃)

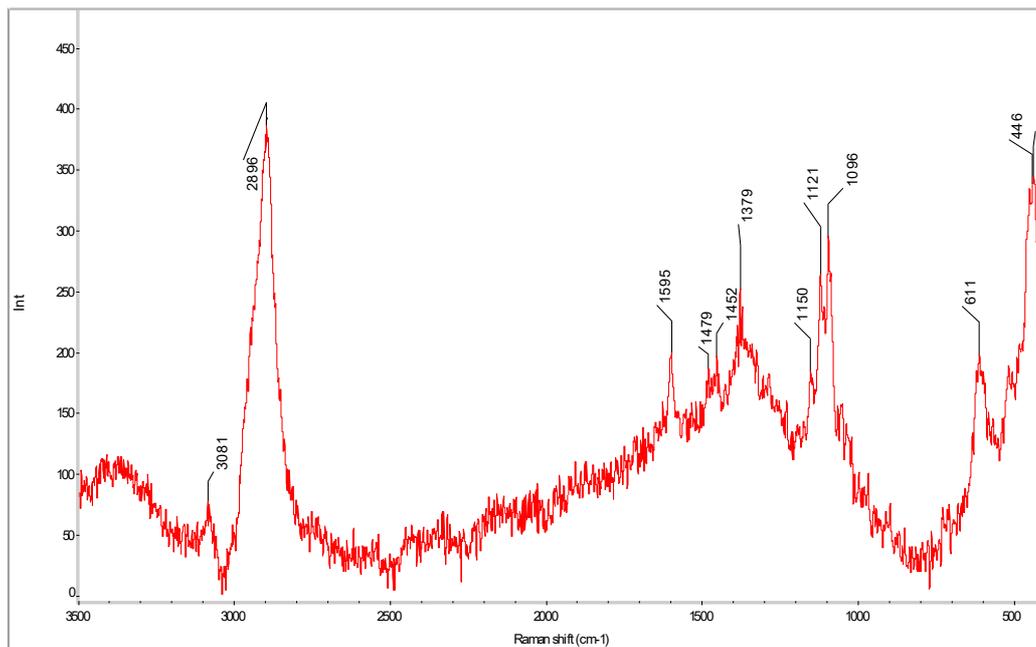


Figure 109 Micro – Raman spectra obtained for white detail of measure point M1_1 50x 2 of drawing M1. The peaks revealed the presence of Titanium White (TiO₂) calcite (CaCO₃) and the composition of paper support.

Regarding the sample M1_1 from drawing M1, in all the white areas, the characteristic peaks at $\sim 447\text{-}609\text{ cm}^{-1}$ (Figure 108) related to Titanium White (TiO_2) are visible (Burgio, Clark, 2001) (Caggiani et al., 2016) and this result is in accordance to the previous ones obtain with Raman Spectroscopy and FORS. The blue colour could be identified as Phthalo Blue (copper phthalocyanine, PB15) since the characteristic peaks at $\sim 1527\text{ - }1451\text{ - }1341\text{ - }1143\text{ - }1037\text{ - }952\text{ - }747\text{ - }680\text{ - }590\text{ - }255\text{ - }231\text{ cm}^{-1}$ are present (Caggiani et al., 2016) and this result is in accordance to the previous ones.

In some points, the peaks relative to the composition of the paper support are present. In particular, in the M1_1 50x 2 (Figure 109) the two bands related to cellulose are visible at $\sim 1096\text{ cm}^{-1}$ (C-O-C of β -glycosidic linkage of cellulose and hemicellulose) and at $\sim 1121\text{ cm}^{-1}$ (C-O-C of the α -glycosidic linkage of hemicellulose) (Costantini et al., 2021). Two bands related to the presence of lignin are visible at $\sim 1452\text{ cm}^{-1}$ and at $\sim 1595\text{ cm}^{-1}$ (Costantini et al., 2021). The strong peak at $\sim 2896\text{ cm}^{-1}$ could be related to cellulose as well, since it is related to C-H stretching.

In almost all points of measure, the presence of calcite (CaCO_3) is evident, since the characteristic peak at $\sim 1086\text{ cm}^{-1}$ is well visible (Caggiani et al., 2016). Probably, it suggests the presence of a homogenous preparatory layer made of chalk and it would be in accordance to the previous results obtained with Raman Spectroscopy.

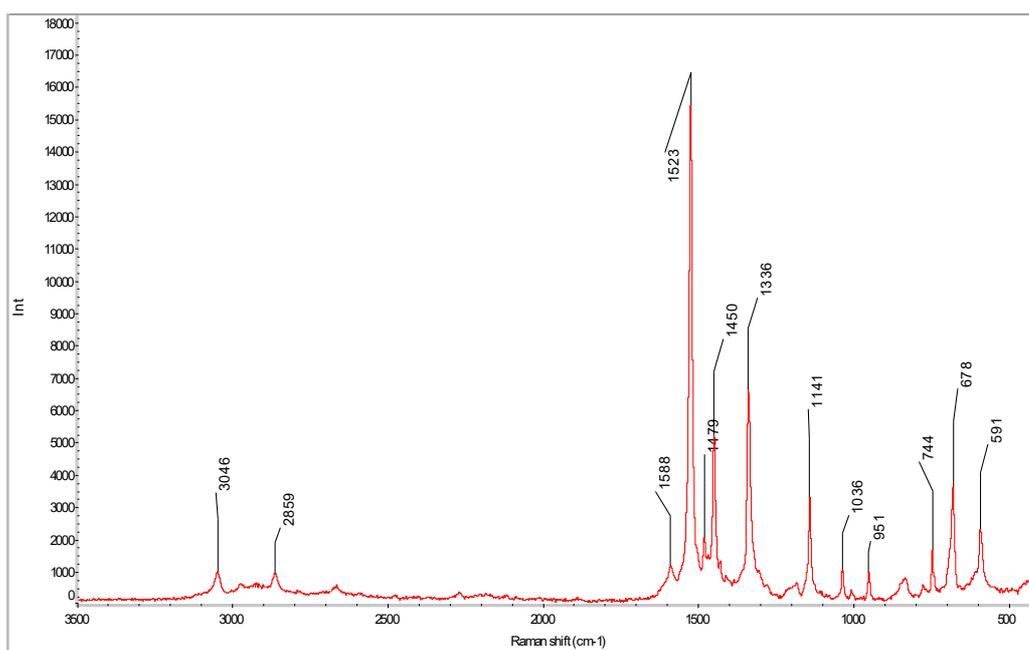


Figure 110 Micro – Raman spectra obtained for blue detail of measure point M2_4 50x 3 of drawing M2. The peaks revealed the presence of Phthalo Blue (copper phthalocyanine, PB15).

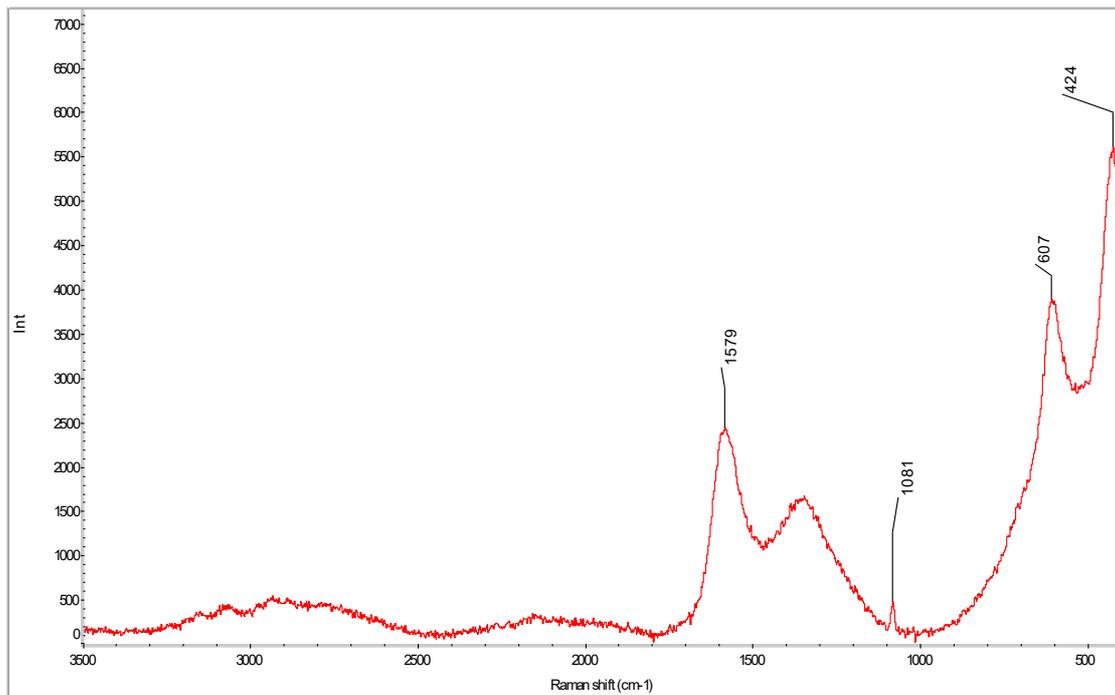


Figure 111 Micro – Raman spectra obtained for white detail of measure point M2_3 50x 5 of drawing M2.

Regarding drawing M2, the white areas were depicted using Titanium White (TiO_2) as well, since the characteristic peaks are visible at $\sim 447 - 609 \text{ cm}^{-1}$ (Burgio, Clark, 2001) (Caggiani et al., 2016), as shown in *Figure 111*. The green colour could be Phthalo Green (copper phthalocyanine, $\text{Cu}(\text{C}_{32}\text{Cl}_{16}\text{N}_8)$) since the characteristic peaks at $\sim 1536 - 1503 - 1388 - 1340 - 1284 - 1080 \text{ cm}^{-1}$ are present (Caggiani et al, 2016) (*Figure 110*). The measure points M2_3 50x 5 and M2_3 50x 6 (*Figure 111*) are related to a black spot but the spectra suggest only that that black coloured could contains amorphous C (Burgio, Clark, 2001) (Caggiani et al., 2016). The spectrum of the measure point M2_4 10x 1 (*Figure 110*) shows that probably, Phthalo Green has been mixed with Phthalo Blue in order to obtain different colour shades. Additionally, the spectrum of M2_4 10x 3 related to a blue spot confirms that the blue colour is Phthalo Blue. The traces of brown colour could be Pigment Brown (PBr25), a monoazopigment (benzimidazolone) (Scherrer et al., 2009) (IRUG: Benzimidazolone PBr25).

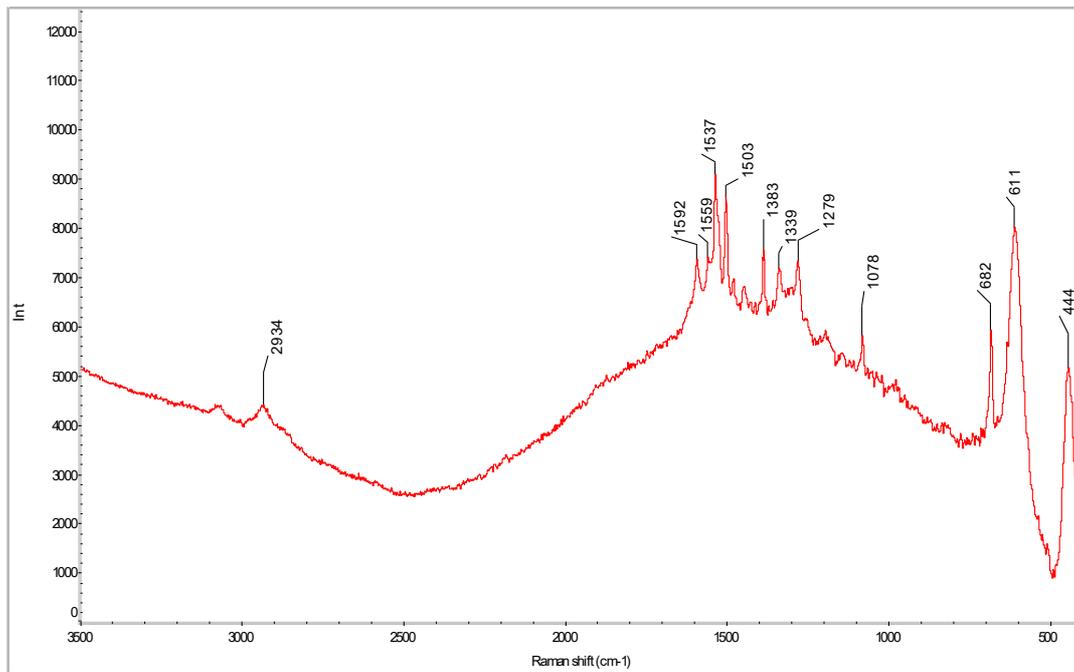


Figure 112 Micro – Raman spectra obtained for green detail of measure point M2_1 50x 3 of drawing M2. The peaks revealed the presence of Phthalo Green (copper phthalocyanine, $\text{Cu}(\text{C}_{32}\text{Cl}_{16}\text{N}_8)$).

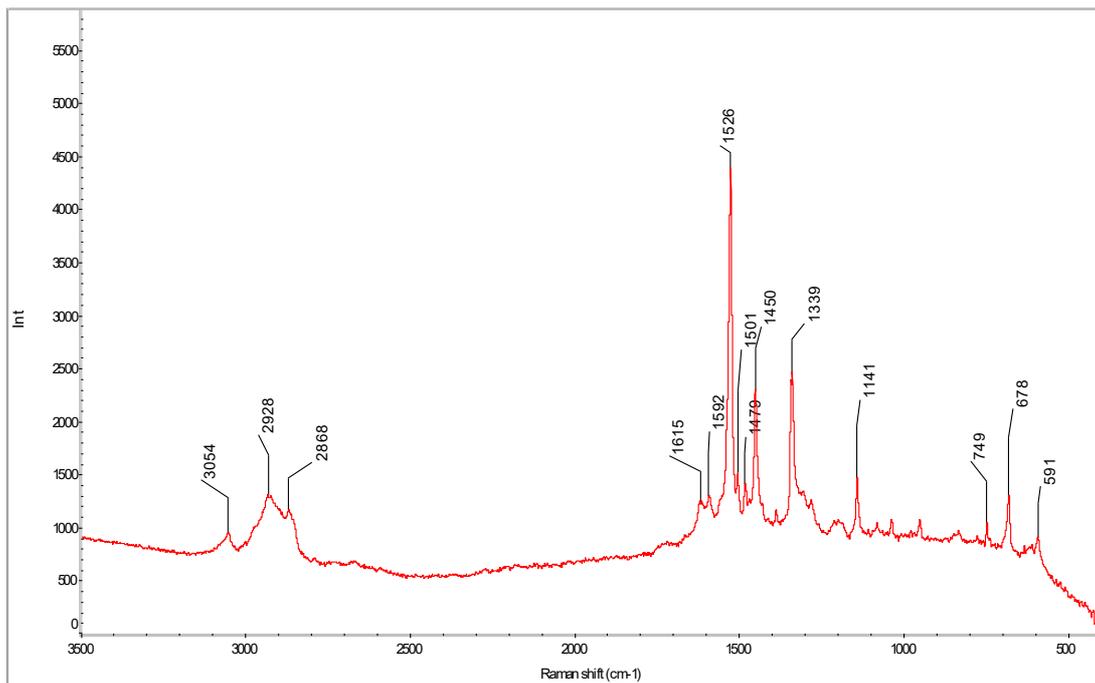


Figure 113 Micro – Raman spectra obtained for green detail of measure point M2_1 50x 4 of drawing M2.

In almost all samples, a transparent and translucent layer is visible, so probably a protective varnish was employed in order to protect the pictorial layer from external agents and to make the surface lighter. The measure point M2_1 50x 4 (Figure 113) is relative to that transparent layer and that product could maybe be identified as a resin. The origin of resins is terpenoid and “their Raman spectra contain features that can be attributed to $\nu(\text{C}=\text{C})$ stretching vibrations, typical bands

between 1800 and 1600 cm^{-1} . Then, “Raman bands in the region between 1480 and 950 cm^{-1} can generally be attributed to $\delta(\text{CH})$, $\delta(\text{CH}_2)$ and $\delta(\text{CH}_3)$ deformations and $\nu(\text{CC})$ stretching vibrations” (Vandenabeele et al., 2007). But the spectrum is more similar to the Phthalo Blue spectrum (Caggiani et al., 2016). In fact, many colour traces are present on that layer so probably the measure was taken in correspondence of a blue colour trace. The presence of blue is plausible since it could have been mixed with green to create different colour shades. In order to obtain more precise information on the varnish layer, a FT-IR analysis would be performed in the future since that technique is more suitable to identify varnishes.

Since a transparent layer is present, the UV fluorescence examination showed no results, except for some points where the paint layer was quite thin. In fact, when a “UV fluorescence becomes useless if a layer of dirt or a varnish cover the paint since the UV light will be absorbed by the external layer” (Cosentino, 2015).

The measure points related to the paper support show the characteristic peaks of Titanium White (TiO_2) at $\sim 447 - 609 \text{ cm}^{-1}$ and two peaks related to the presence of calcium carbonate (CaCO_3) at $\sim 1086 - 710 \text{ cm}^{-1}$ (Burgio, Clark, 2001) (Caggiani et al., 2016). Also in this case, a preparatory layer made of chalk could have been painted in order to prepare a homogeneous surface, in accordance to the results obtain with Raman Spectroscopy.

4.4.3 Fourier Transform Infrared spectroscopy – Attenuated Total Reflection (FTIR – ATR)

The samples from drawings M1 and M2 were investigated by means of Fourier Transform Infrared Spectroscopy – Attenuated Total Reflection (FTIR – ATR) in order to characterize both organic and inorganic components, including the binder, pigments and inorganic filler and extenders. Information regarding the materials’ composition and so the technique used by the artist were acquired.

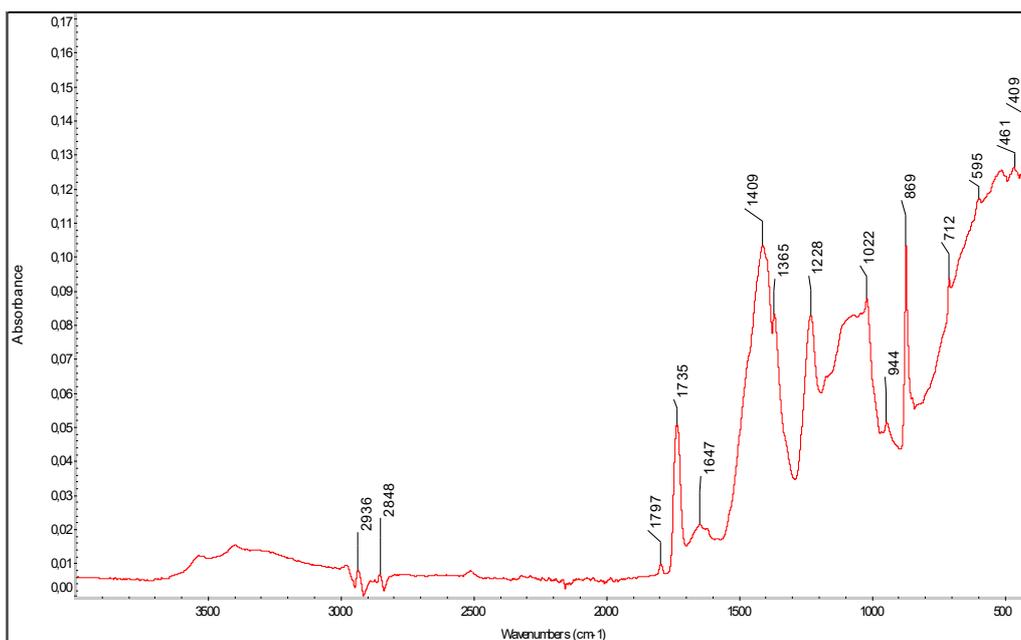


Figure 114 FTIR-ATR spectra obtained for sample M1_1 of drawing M1

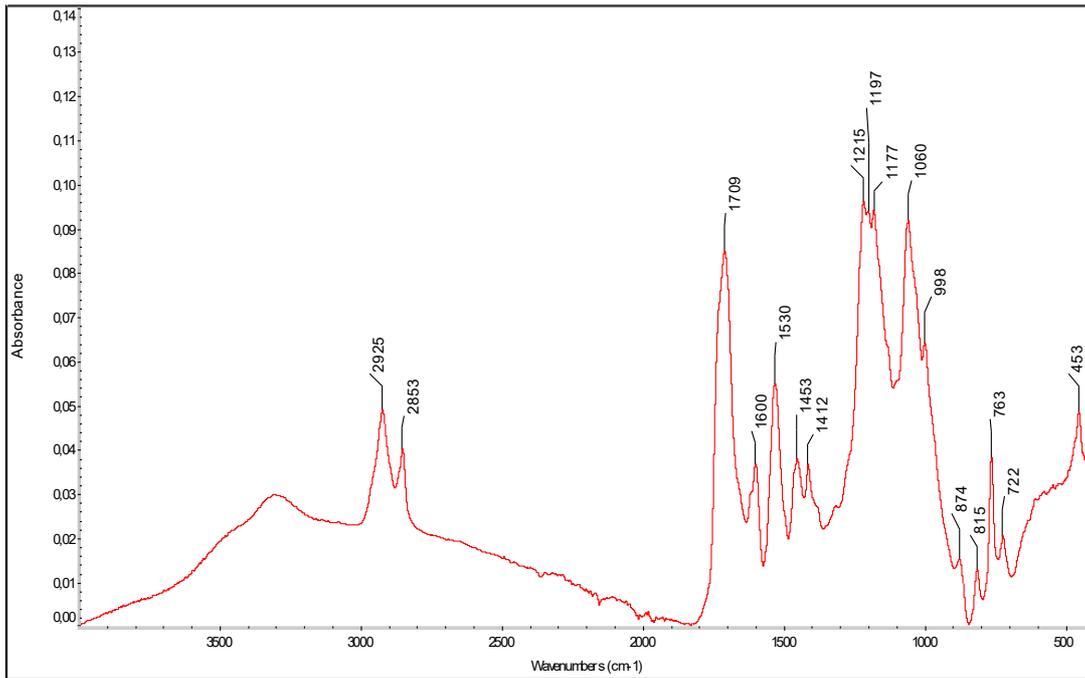


Figure 115 FTIR-ATR spectra obtained for sample M2_2 of drawing M2

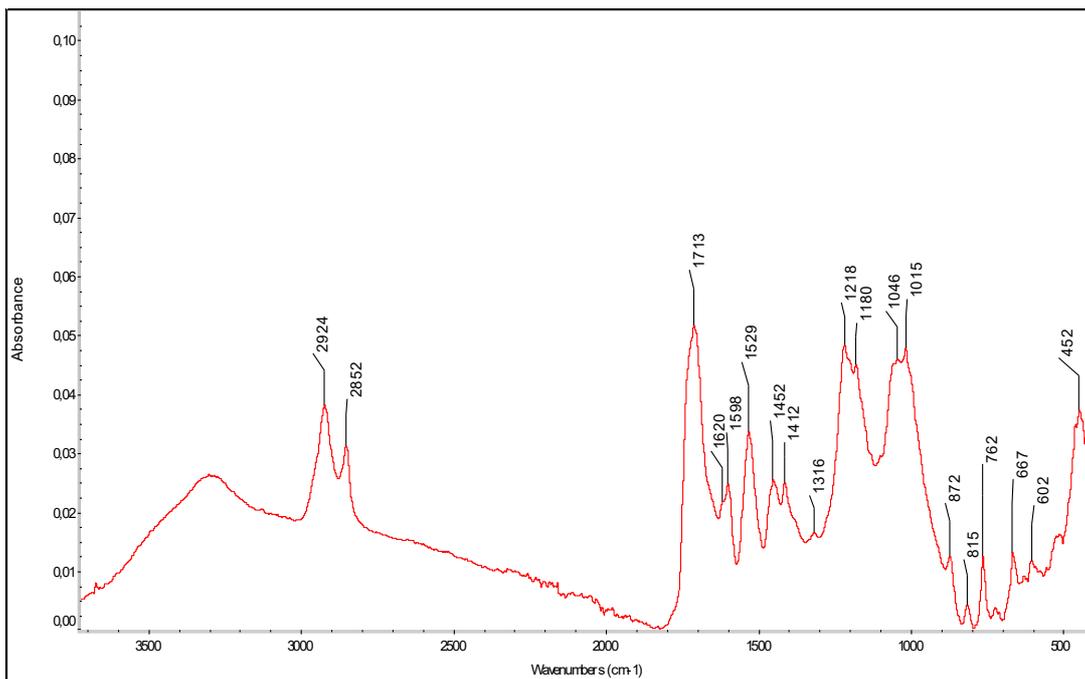


Figure 116 FTIR-ATR spectra obtained for sample M2_4 of drawing M2

The spectra suggest that the binder formulation could be an acrylic emulsion. In almost all spectra, bands at $\sim 2920 - 2850 \text{ cm}^{-1}$ related to aliphatic stretching C–H vibrations are present and in samples M2_1, M2_2 (Figure 115) and M2_4 (Figure 116) from drawing M2, the C=C aromatic stretching vibration bands at ~ 1600 and 1452 cm^{-1} were detected. These peaks suggest the presence of styrene in binder formulation (Fardi et al., 2018). In samples M1_1 (Figure 114) and M2_3, bands at $\sim 1730 - 1225 \text{ cm}^{-1}$ were observed due to the carbonyl C=O stretching that could suggest the

presence of nBA-MMA copolymer (Fardi et al., 2018) (Izzo et al., 2014). The presence of inorganic extenders or fillers was detected. In particular, the bands at $\sim 1412 - 872 - 710 \text{ cm}^{-1}$ are characteristic of calcium carbonate (CaCO_3) and are visible in all spectra. The peaks at $\sim 1179 - 1063 - 981 \text{ cm}^{-1}$ suggest the presence of barium sulphate (BaSO_4) in spectra of the samples M2_1 and M2_2 (spectra/chem). In acrylic formulations, extenders like calcium carbonate and barium sulphate “are used to add bulk to paint, to achieve a desired surface texture or appropriate rheological properties, and to reduce the cost of the formulation. [...] The addition of the extenders is particularly necessary with certain modern pigments, notably the phthalocyanine colours, to reduce their tinting strength to those of the other pigments” (Learner, 2004). In samples M1_1 and M2_3, bands at $\sim 1650 - 1415 - 1375 - 1026 \text{ cm}^{-1}$ are characteristic of the cellulose, in fact these two samples are mainly related to the paper support (Papliaka et al., 2010) (Derrick et al., 1999).

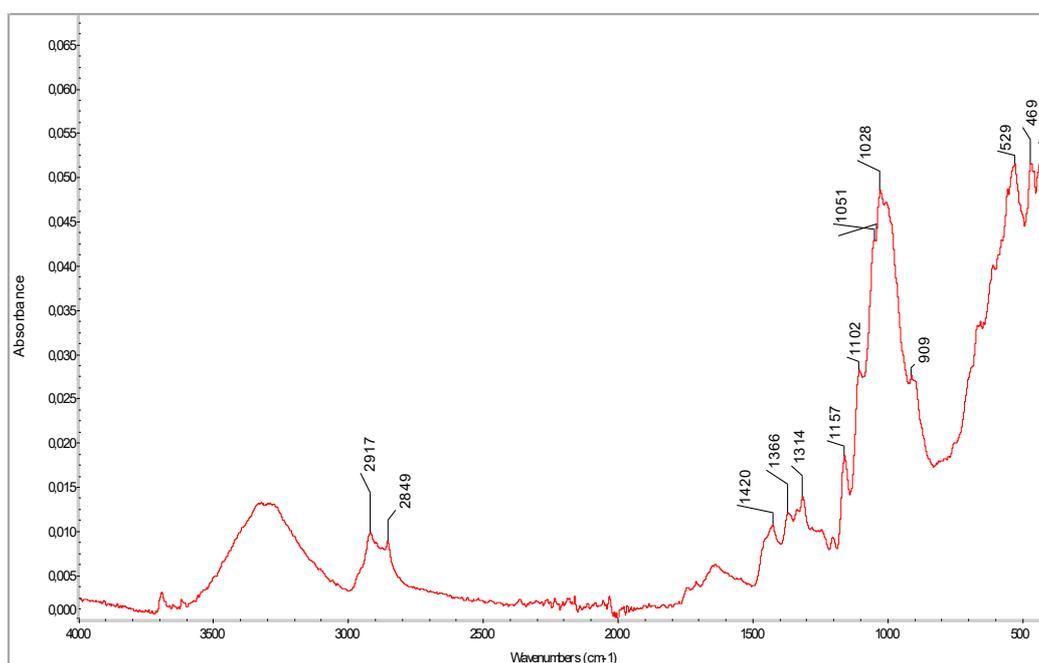


Figure 117 FTIR-ATR spectra obtained for paper of the sample from an unknown drawing

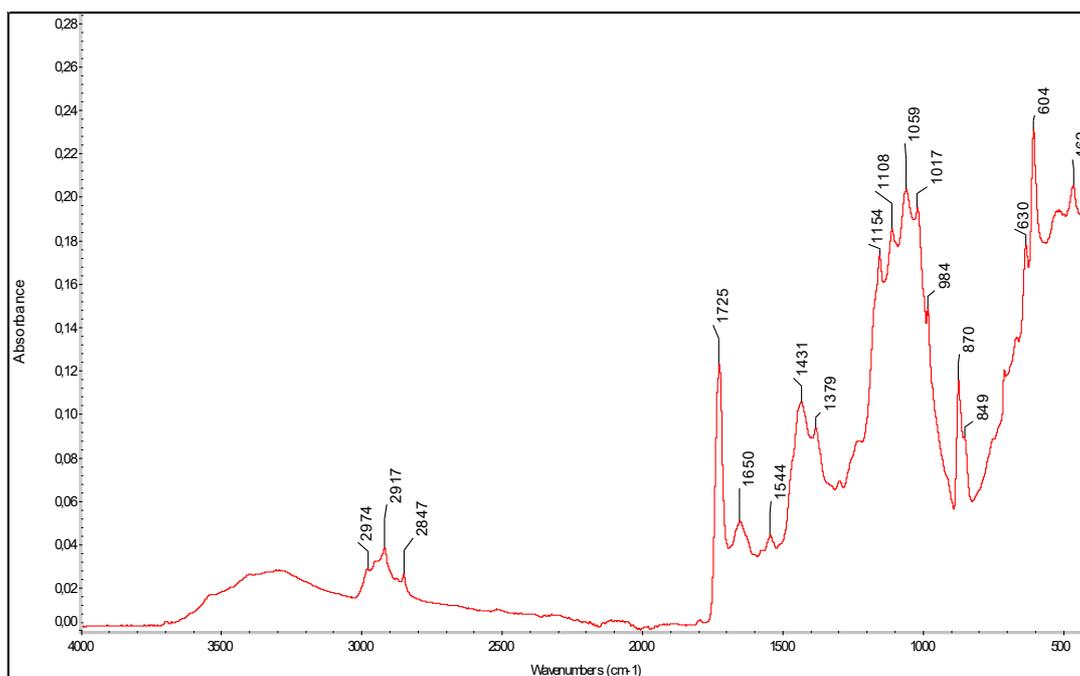


Figure 118 FTIR-ATR spectra obtained for brown coloured part of the sample from an unknown drawing

Another sample coming from an unknown drawing was taken into consideration in order to obtain additional information about the artistic materials used by Štěpán Zavřel. The spectra related to the paper support shows bands at $\sim 2920 - 1420 - 1366 - 1314 - 1157 - 1051 - 1028 - 909 \text{ cm}^{-1}$ are characteristic of the cellulose (Papliaka et al., 2010) (Derrick et al., 1999). Peaks at $\sim 529 - 469 - 423 \text{ cm}^{-1}$ suggest the presence of chalk, probably used as a filler or an alkaline reserve (spectra/chem) (Costantini et al., 2021). In fact, as reported in other investigations, calcium carbonate (CaCO_3) “was employed also like the alkaline reserve for the paper support to neutralize the acidic nature of some components of cellulose (lignin) and avoid its oxidation and acidic hydrolysis” (Costantini et al., 2021). Regarding the brown coloured part, the spectra suggest the presence of an acrylic emulsion as binder, in particular a copolymer of nBA-MMA (n-butyl acrylate and methyl methacrylate). Bands at $\sim 2920 - 2850 \text{ cm}^{-1}$ related to aliphatic stretching C–H vibrations are present. Peaks at $\sim 1730 \text{ cm}^{-1}$ related to C=O stretching, $\sim 1430 \text{ cm}^{-1}$ related to C–H bond, $\sim 1384 \text{ cm}^{-1}$ related to C–H vibrations and C–O stretching bands at $\sim 1158 \text{ cm}^{-1}$ are characteristic of butyl acrylate units in copolymer (Fardi et al., 2018). Other peaks at $\sim 1108 - 1063 - 981 - 634 - 603 \text{ cm}^{-1}$ are related to the presence of barium sulphate (BaSO_4), probably added as extender (spectra/chem).

4.5 Binders and artistic techniques

One of the aims of this study is to analyse and understand not only the pigments and dyes used by Štěpán Zavřel, but also to investigate the artistic techniques which he could have been employed to create the selected drawings. In order to confirm the hypothesis, a series of different painted mock-ups made with modern commercial paints with different binders – that is, acrylic vinylic oil and Arabic gum – were analysed by means of FORS technique. The obtained spectra have been compared to the spectra obtained for the in-situ analysis of the Zavřel’s drawings, in particular, the

spectral range associated to the binders (1000 nm – 2500 nm) was observed and used for a comparison.

In addition, a series of tempera/gouache and watercolours paint coats were painted on paper for watercolours in order to analyse them by means of FORS and comparing the results as well. Such a comparison was useful to speculate on the materials and artistic technique employed by Zavřel and have a more complete overview over his painting techniques.

A comparison between the FORS spectra of painted mock-ups and the ones obtained with the analysis of the drawings was done, considering the assumptions made about what the artist declared regarding the techniques he used for each drawings' series, in particular. The results are presented and discussed below.

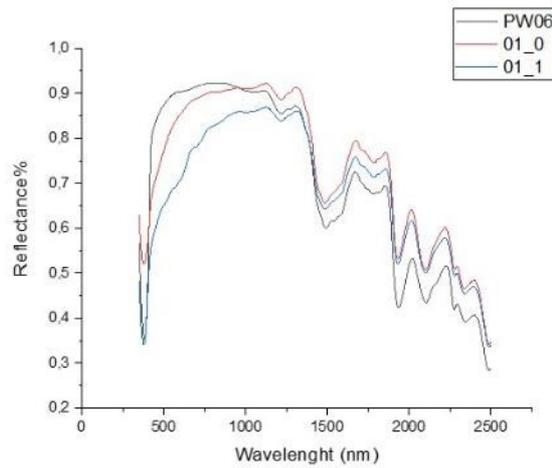


Figure 119 FORS spectra obtained for PW06 containing Arabic gum as binder and white details of drawing 01

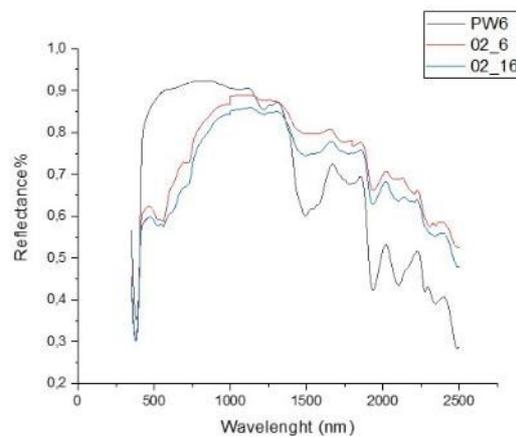


Figure 120 FORS spectra obtained for PW06 containing Arabic gum as binder and white details of drawing 02

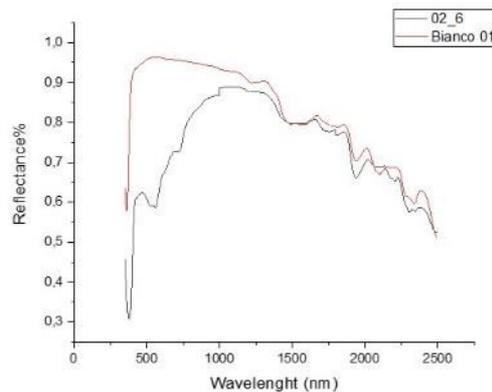


Figure 121 FORS spectra obtained for Bianco 01 (Giotto), declared as *tempera* and white details of drawing 02

Regarding drawing 01 from the book *Sterntaler* (1969), it was assumed that it was depicted with tempera technique, which is more probably gouache technique as explained in the dedicated paragraph. Gum Arabic could have been the medium and the comparison with the FORS spectra related to the coloured layer containing gum Arabic showed some correspondence in the range

between 1000 nm – 2500 nm (*Figure 119*). A strong absorption band is visible at ~ 1450 nm related to O-H stretch first overtone of H₂O and another strong absorption band related to O-H deformation and C-H stretching of arabino-galactan is present at ~ 2100 nm (Dong et al., 2017). Another slight absorbance related to C-H stretch second overtone of CH₂ of galactose/arabinose is visible at ~ 1210 nm. Another strong absorption band is present at ~ 1935 nm and it is related to O-H stretch and O-H deformation of H₂O (Dong et al., 2017). So, the drawing 01 presents gum Arabic as main binder and that confirms that it was created with gouache technique. On the other hand, drawing 02 which is part of the same series, was created using the same gouache technique since the comparison between FORS spectra showed a correspondence to the range spectrum related to the presence of gum Arabic (*Figure 120*), even if the results are a little ambiguous. In fact, *Figure 121* shows that a white measure point of drawing 02 has the same profile of the spectra of the paint mock-up made with tempera colour *Bianco 01*. There are some absorption bands at ~ 1450 nm (O-H stretching) and ~ 1935 nm and ~ 2323 nm related to CH stretch of arabino-galctan but they are not very strong (Dong et al., 2017). Probably, the paints employed for the creation of drawing 02 contained gum Arabic in their composition but it was not the main percentage. In conclusion, the results confirm that both drawings 01 and 02 from the same series for the book *Sterntaler* (1969) could have been created by Zavřel using the gouache technique.

Regarding the declared employed artistic technique, that is *tempera*, it is important to highlight that during the 19th and 20th century there were many complex mixtures of different binders that were generically called tempera, especially regarding the composition of colour tubes. They may have been contained egg mixed with fig milk, resins, gums or wax treated with basic additives. Other mixtures containing milk, alone or with egg, oil and chalk, and casein, that may have been mixed with gelatine, glycerine and wax or with chalk. In some cases, tempera was also a mixture of animal glue, glycerine and water, like for the Italian painter Francesco Michetti (Bensi, 2015).

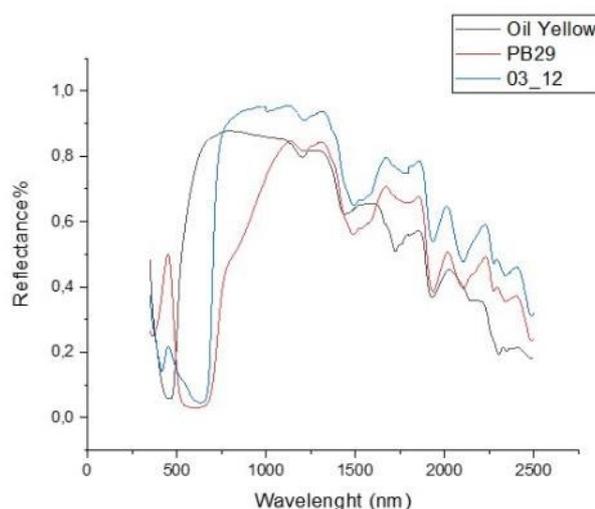


Figure 122 FORS spectra obtained for PB29 containing Arabic gum as binder, yellow containing oil as binder and blue details of drawing 03

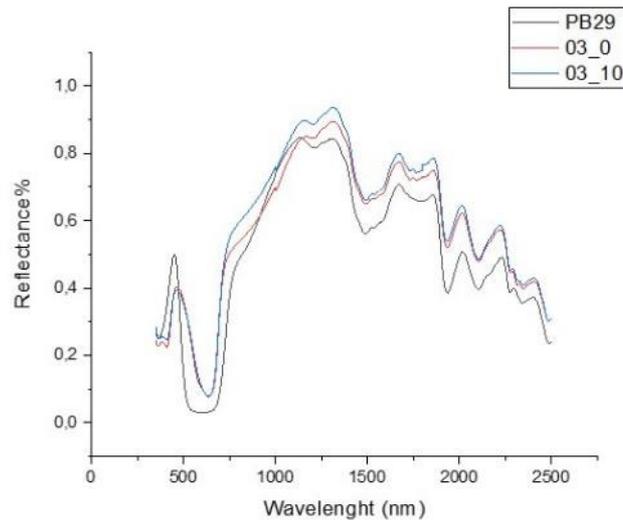


Figure 123 FORS spectra obtained for PB29 containing Arabic gum as binder and blue details of drawing 03

Drawing 03, part of the series for the book *Il Sale vale più dell'Oro* (1968), was supposed to have been drawn with oil pastels but, comparing the FORS spectra, the spectrum range related to the binder seems to be more similar to the spectra of paint coats containing gum Arabic (Figure 122, 123). In fact, also in those spectra, characteristic absorption bands of gum Arabic are visible at $\sim 1210 - 1450 - 1935 - 2100 - 2323$ nm (Dong et al., 2017). It is important to underline that chemical composition of pastels had been studied less frequently than other artistic techniques, such as oil paints, and there are few published studies on the analysis of artworks made with friable media and dry painting materials (Tenorio et al., 2019). First of all, defining the general composition of pastels is useful: their main components are both organic, that is the binders of the sticks, fixative, and organic colourants; and inorganic components, that is pigments and extenders. However, the composition of pastel painting results to be extremely varied throughout centuries and that variability was introduced by the artists themselves, in many cases. Binders were formulated in order to obtain the desired texture of the sticks, since different colours showed different formulations. The most antique pastels showed the presence of Arabic and tragacanth gum, fig milk and proteinaceous materials such as animal glue and milk. Later, olive and linseed oil were introduced and finally, the industrial production of the 20th century tended to use “Arabic and tragacanth mucilage” (Tenorio et al., 2019). In addition, the investigation of organic components that make up the pastel binders and fixatives are difficult using non-destructive spectroscopic approaches. This fact is mainly due to the very low amount of binder required to make the pastel stick, that also represents a source of degradation since it is particularly vulnerable to paint loss. For this reason, the use of fixatives became a common practice, especially at the end of the 18th century (Tenorio et al., 2019).

Considering all those information, it is reasonable that gum Arabic could be the main pastels medium in the composition of the sticks used by Štěpán Zavřel to create the drawing 03. Maybe, an oily binder is present in the formulation but it could be a lower percentage in the paint. This result

would be coherent considering the main composition of modern pastels and the period in which Zavřel drew that series. Taking this result into account, it is evident that in many cases, the commercial industrial composition of art materials could be chemically different than what was declared by sellers.

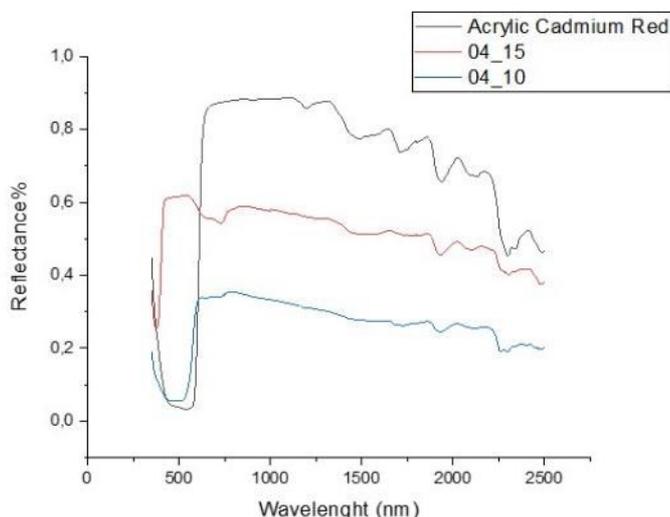


Figure 124 FORS spectra obtained for Cadmium Red containing an acrylic binder and white and orange details of drawing 04

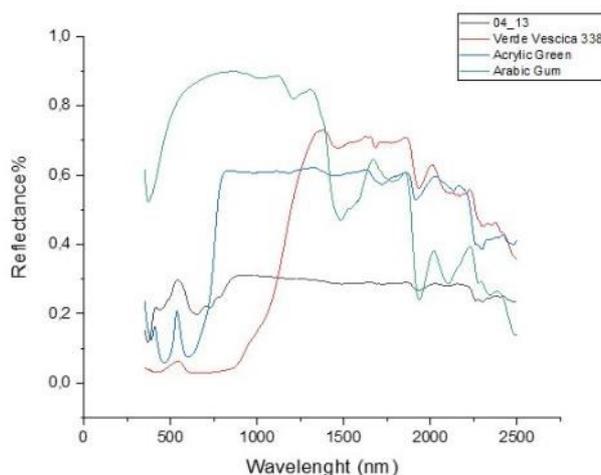


Figure 125 FORS spectra obtained for Verde Vescica 338 (Maimeri), declared as gouache, Green containing Arabic gum as binder, pure Arabic gum and green details of drawing 04

Drawing 04, whose series was not identified and so the dating, was assumed to be depicted using acrylic colours. The comparison between the FORS spectra of the paint coats containing an acrylic binder and the ones of the analysis showed a correspondence in the region between 1000 nm – 2500 nm (Figure 124, 125). So, that confirmed that 04 was drawn using colours containing an acrylic binder.

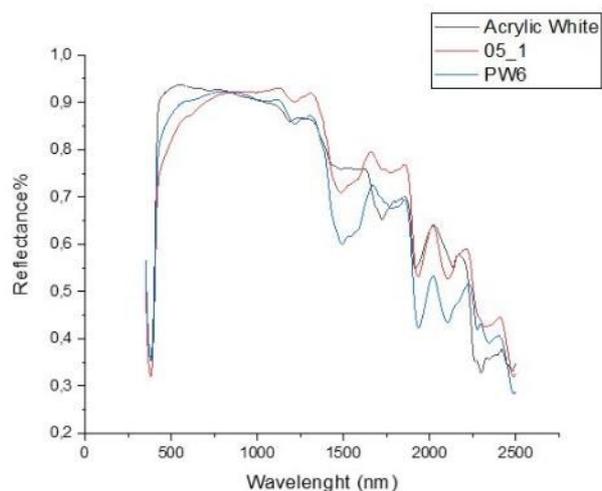


Figure 126 FORS spectra obtained for PW6 containing Arabic gum as binder, white containing an acrylic binder and white details of drawing 05

Drawing 05 from the series for the book *In cammino con Dio* (1996) was supposed to be drawn with gouache technique. The FORS spectra related to the coloured layers containing gum Arabic in their composition was compared to the FORS spectra of the in-situ analysis and some correspondence in the spectrum range between 1000 nm – 2500 nm is noticeable (Figure 126). In some cases, the results seem to be a little ambiguous, probably because almost all the details have been depicted with colour mixtures. Also in this case, the comparison confirmed the presence of Arabic gum as binder for drawing 05 and that confirmed that that series was drawn by Zavřel by means of gouache technique as well. In fact, the spectra in Figure 118 show characteristic absorption bands at ~ 1450 – 1770 – 1935 – 2100 nm (Dong et al., 2017).

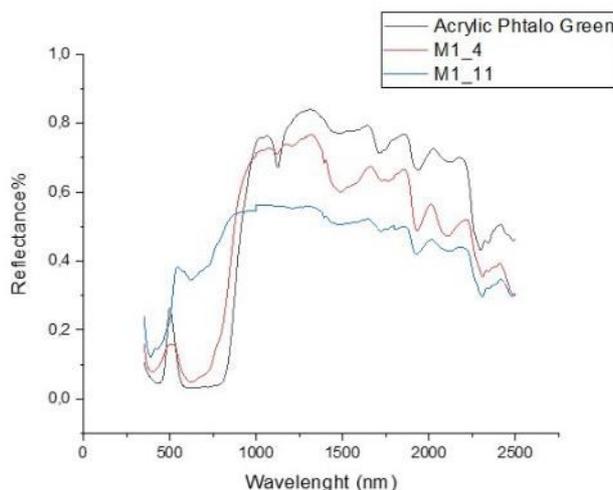


Figure 127 FORS spectra obtained for Phthalo Green containing an acrylic binder and green details of drawing M1

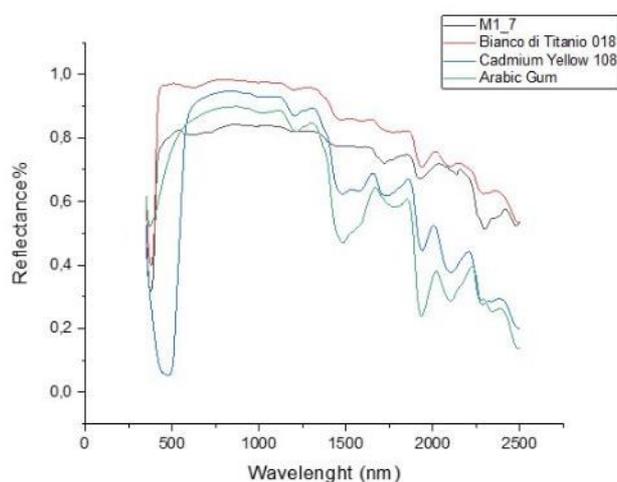


Figure 128 FORS spectra obtained for Bianco di Titanio 018 (Maimeri), declared as gouache, Cadmium Yellow 108 (Winsor & Newton), declared as watercolour, pure Arabic gum and white details of drawing M1

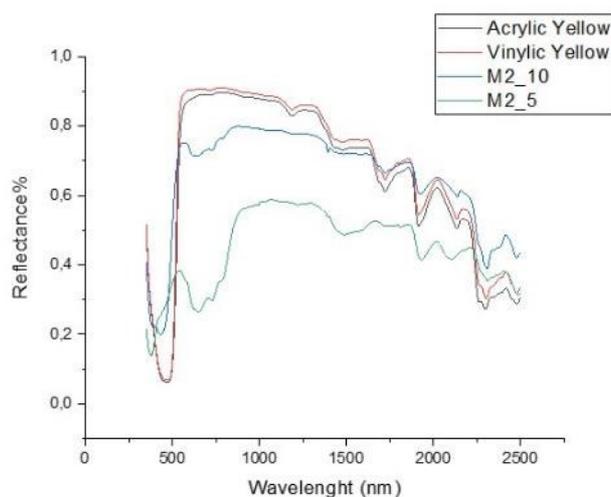


Figure 129 FORS spectra obtained for yellow containing an acrylic and vinylic binder and green/ochre details of drawing M2

Drawing M1 from the series created for the book *Un sogno a Venezia* (1974) was supposed to be created using acrylic paint. The comparison with the FORS spectra of the coloured layers containing acrylic binder showed a correspondence in the region between 1000 nm – 2500 nm (Figure 127, 128), so it confirmed that Zavřel used acrylic paint to draw M1. On the other hand, drawing M2, which was part of the same series, showed quite ambiguous results (Figure 129). The comparison could highlight that this drawing could have been depicted with vinyl paint instead of acrylic paint as declared. This hypothesis could be confirmed also considering the main degradation phenomenon, that is colour fading. In fact, considering the durability of paints, vinyl paint is not as

flexible as acrylic paint and as a consequence, can crack or peel over time. As in many cases, Zavřel may have been used as acrylic paint as vinylic one to draw these drawings from the same series, especially the green and yellow/brown details, maybe because he wanted to obtain different shades or effects. However, the results are not so clear and maybe this could be an aspect that could be investigated more in detail in the future.

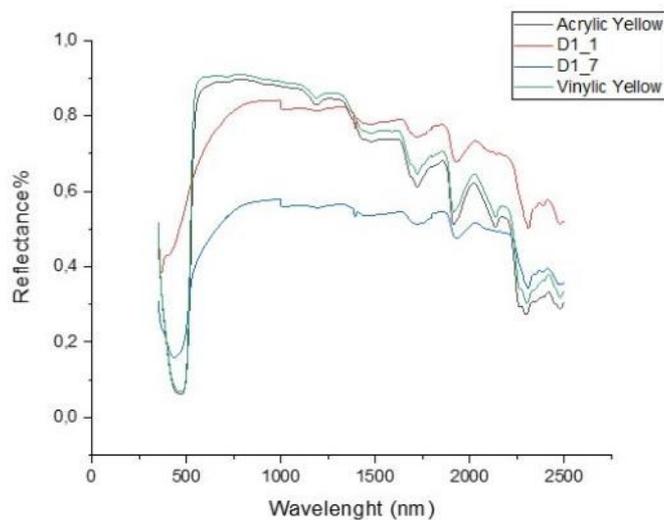


Figure 130 FORS spectra obtained for yellow containing an acrylic and vinylic binder and ochre details of painting D1

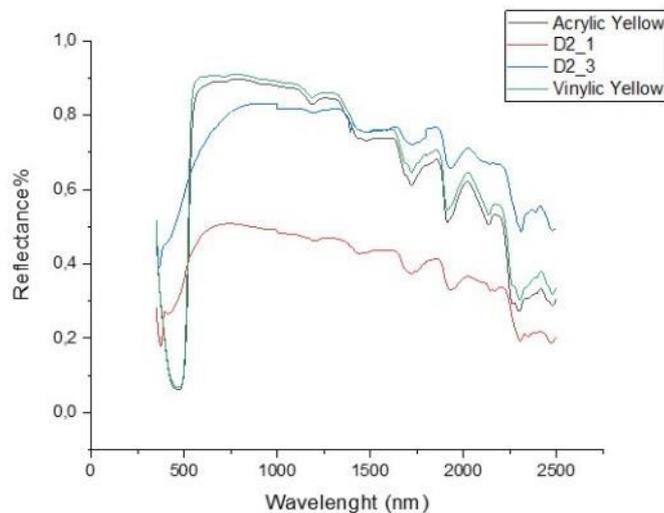


Figure 131 FORS spectra obtained for yellow containing an acrylic and vinylic binder and ochre details of painting D2

The two paintings on canvas D1 and D2 (1973) were supposed to be painted using acrylic paint. The comparison between FORS spectra showed quite ambiguous results since this painting seemed to be painted as with acrylic paint as with vinylic paint. However, some spectra seemed to be more similar to paint coats containing acrylic binder, so acrylic paint is the most probable hypothesis (Figure 130, 131).

The comparison between spectra from the case studies and the paint coats created with tempera/gouache and watercolours confirmed that drawings 01 and 02 contained Arabic gum as binder and that drawing 02 was created using *tempera/gouache* colour tubes (*Figure 121*). Drawing 03 contains Arabic gum as the main binder and probably there is a part of oily binder but it is not a predominant component. Drawing 04 seems to have been probably depicted by means of acrylic paints. The drawing 05 showed that white details contain Arabic gum as binder for sure, since the results appear a little ambiguous for other colours like brown and ochre but it is probably due to the fact that those details are the results of colour mixtures. Generally, Arabic gum seems to be the main binder present in that drawing. Drawings M1 and M2 were depicted with acrylic paint and Arabic gum is not present as binder. The paintings D1 and D2 were not depicted using colours containing Arabic gum as binder, so they were probably depicted using acrylic or vinylic paints.

4.6 Statistical analysis of data

In order to obtain more reliable results concerning the composition of binders in different drawings or measure points, a statistical approach was performed by means of Principal Component analysis (PCA) method. The FORS spectra of the measure points of the drawings and paintings were subjected to the multivariate statistical analysis together with a dataset of 48 reference FORS spectra of painted mock-ups used for a comparison in the previous section, as well. The reference spectra contained acrylic, vinylic, oil, gum Arabic as binders and 32 of them are declared as commercial tempera/gouache and watercolours paints, which were added for a better discrimination. The spectral range useful for the identification of the binder composition is between 1000 – 2500 nm and the PCA was applied to NIR spectra in that range for all spectra. The first two principal components (PC1, PC2) resulted to be the most significant for each multivariate analysis. The obtained score plots are presented in *Figure 132, 133, 134*. Generally, PC2 showed a clear separation between paints containing gum Arabic (positive score values) and containing acrylic binder (negative score values) but intermediate score values are noticeable in many points, probably highlighting the presence of mixtures. On the other hand, PC1 seems to be more sensitive to the colour response. It presented positive score values for almost all the painted mock-ups containing acrylic, vinylic, oil and gum Arabic but it showed negative score values for many points which show a weak and almost flat FORS response. In particular, many measure points of drawing 04, drawing 05, painting D1 and painting D2, taken in correspondence of dark coloured details, appear to be outliers. Intermediate score values could highlight a weaker FORS response but clearer enough to be associated to an area delimited by PC2.

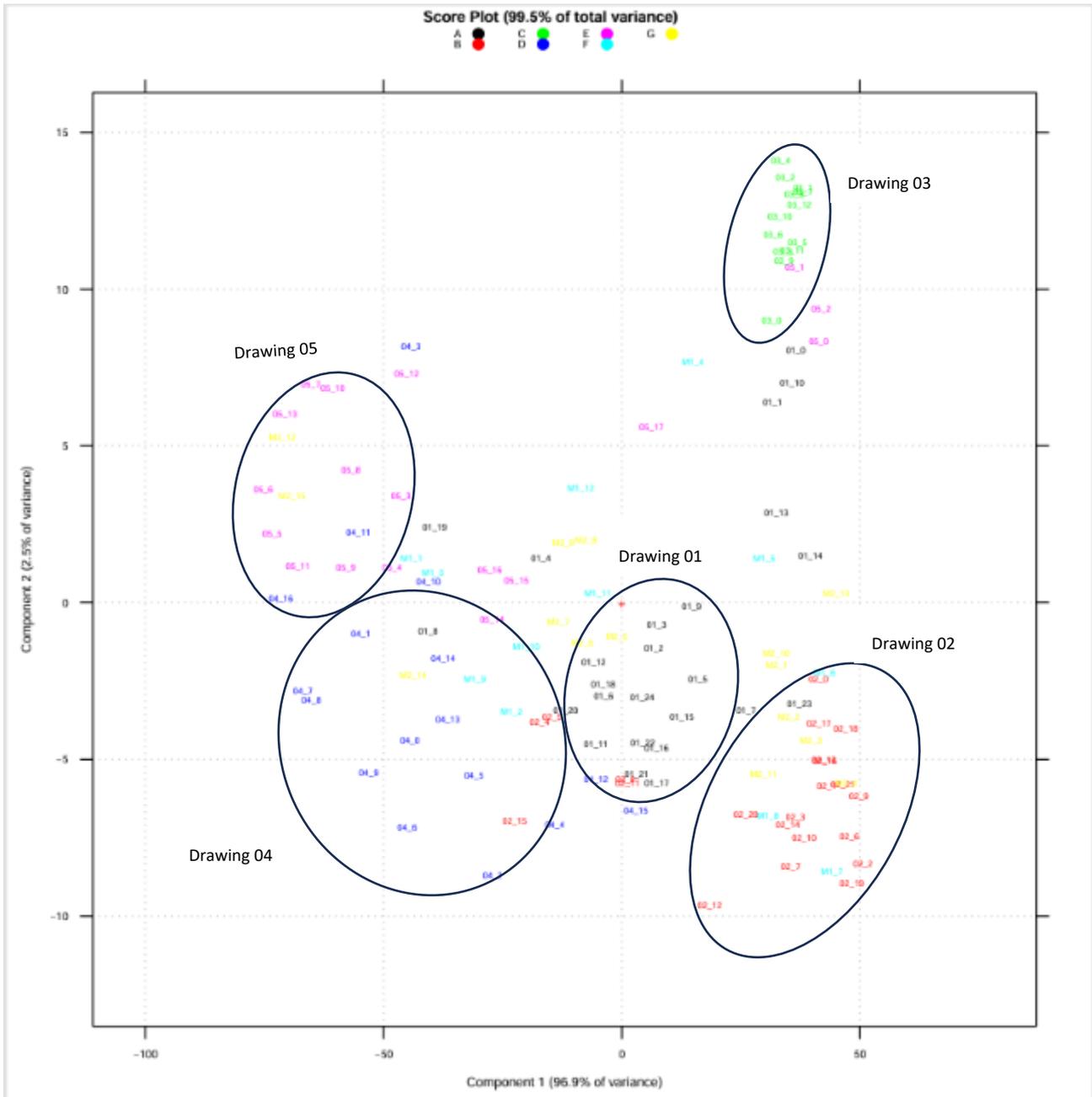


Figure 132 PCA score plot of all measure points from all the seven drawings

Type Name	Artwork/Painted mock-up
A ●	Drawing 01
B ●	Drawing 02
C ●	Drawing 03
D ●	Drawing 04
E ●	Drawing 05
F ●	Drawing M1
G ●	Drawing M2

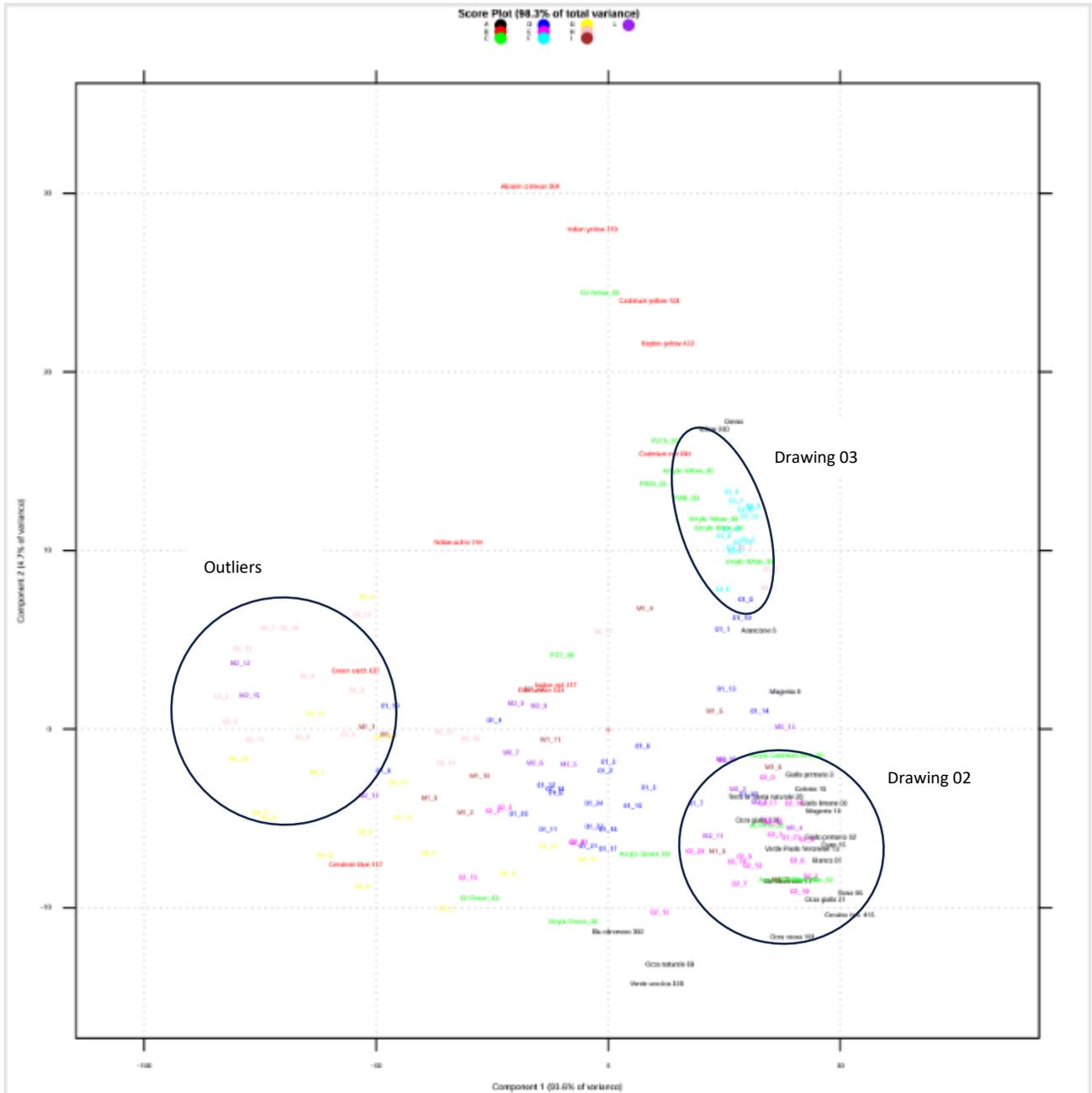


Figure 133 PCA score plot of all measure points from all the seven drawings and the paint mock-ups

Type Name	Artwork/Painted mock-up
A ●	Tempera/gouache paint
B ●	Watercolours
C ●	Acrylic/Vinylc/Oil/gum Arabic mock-ups
D ●	Drawing 01
E ●	Drawing 02
F ●	Drawing 03
G ●	Drawing 04
H ●	Drawing 05
I ●	Drawing M1
L ●	Drawing M2

Considering the binders for each drawing and their similarities in composition, the measure points are precisely located in the case of drawings 01, 02 and 03 (*Figure 132*). In particular, measure points related to drawing 03 appear to be an isolated cluster respect to the others and only a few points of drawings 01 and 05 are located in the same area, so probably they contain a similar binder composition. On the other hand, the points of drawings 01, 02, 04, M1 and M2 are located in a different area and probably also in that case, those drawings have similarities in binder composition. The plot in *Figure 133* shows that the measure points of drawings 02 and M2 are precisely located in the reference cluster corresponding to acrylic binder. On the other hand, points of drawings 01, 04, 05 and M1 are not precisely located even if they are in the same area defined to reference points corresponding to acrylic and commercial tempera/gouache mock-ups. Points related to drawings 03 are located in the area mainly delimited by mock-ups containing gum Arabic, even if some mock-ups containing acrylic and vinylic binder are present. Some points of drawings 01, 05 and M1 are located in that area, so probably they have a similar composition, according to the FORS comparison of the previous section. Finally, there are a cluster of points of drawings 04, 05 and M2 that appear to be outlier. Considering the FORS spectra of those measure points, they appear almost flat and the response is very weak, probably because those measurements were taken in correspondence of dark coloured areas.

The PCA could indicate that drawing 01 contains mainly an acrylic binder but some points seem to indicate the presence of gum Arabic, as shown with FORS spectra, so probably a mixture could be present or some details could have been painted with different colours containing gum Arabic as main binder. On the other hand, drawing 02 contains acrylic binder and it was drawn probably using tempera/gouache commercial paints, as declared by Zavřel himself and drawing 01 was created with tempera/gouache paints, as well. Drawing 03 could contain gum Arabic as the main component but probably a mixture with acrylic or vinylic component is present. As already said previously, modern pastels' formulation is complex and probably, gum Arabic is present and some fixatives or extenders contained in acrylic and vinylic reference mock-ups could be present in drawing 03, as well. In this case, the results seem to be different than what the artist declared. Regarding drawing 04, it seems to have been drawn using acrylic paints similar to the ones used for depicting drawing 01 and 02, confirming the results presented in the previous section. Drawing 05 shows that some measure points are similar to the ones of drawing 03, so it could contain gum Arabic or a mixture with acrylic components, since other points are similar to drawings 01, 02 and 04. This result could suggest that commercial tempera/gouache paints could have been used by Zavřel, confirming his declaration. Finally, drawings M1 and M2 from the same series seem to contain an acrylic binder since they are in the area delimited by acrylic reference and they are similar to each other, presenting negative score values. This result confirms the previous ones discussed in the previous sections and Zavřel's indications.

III. Conclusions

In the present study, the artistic materials and techniques used by the Czech artist Štěpán Zavřel were investigated. Seven drawings and two paintings on canvas conserved in Štěpán Zavřel Museum in Sarmède (Treviso, Italy) were selected and analysed by means of non-invasive techniques, that is technical photography, microscopy, FORS and Raman spectroscopy. Additionally, five micro-samples were collected from two of the drawings and investigated with microscopy, micro – Raman spectroscopy and FTIR – ATR spectroscopy. Painted mock-ups were prepared using tempera/gouache paints and watercolours in different colour shades. Another series containing acrylic, vinylic, oil and gum Arabic as binders already prepared was taken into account. The mock-ups were analysed by means of FORS and the spectra compared to the ones acquired for the case studies, in order to investigate the binder's nature. Finally, a multivariate approach based on principal component analysis (PCA) was used to highlight differences and similarities in composition of case studies' measure points and painted mock-ups references, allowing the identification of binder's nature and so the artistic technique.

The results showed that the nature of colour palette was coherent to the colours generally used in the second half of the 20th century. Specifically, white details were depicted using Titanium White in all artworks. On drawing 01 and drawing 02 it was probably mixed with Barium sulphate and a preparatory homogenous layer was depicted with chalk only on drawing M1, drawing M2, painting D1 and painting D2. Green details were all depicted with Phthalo Green in drawing 03, drawing 04, drawing M1 and drawing M2. Blue pigments resulted to be different: on drawing 02, Cobalt Blue was employed, since Prussian Blue was used on drawing 03 and Phthalo Blue on drawing M1 and drawing M2. The characterization of red/orange details was ambiguous in some cases but it could be an azoic dye on drawing 01 and drawing 02, probably Hansa Red monoazopigment (β -naphthol); on the other hand, the results for drawing 03 are uncertain since it was not clear if the orange pigment could be a monoazopigment or a lac dye. On drawing 04, the orange details were depicted using a disazopigment (PO13). Mauve details on drawing 01 and drawing 05 were probably depicted employing a quinacridone-based dye mixed with Titanium White to obtain different shades. The magenta detail on drawing 03, was probably depicted with an anthraquinone dye (lac dye). The yellow/ochre areas seem to have been painted with different synthetic organic pigments, used alone or as mixtures. In particular, on drawing M2, yellow details were probably depicted using a disazopigment (PY95); on both paintings D1 and D2, a combination of a disazopigment (PY81, PY83) and a monoazopigment (PY74) was probably used. Finally, the brown pigments were identified as a monoazopigment (PBr25) on drawing M1 and a disazopigment (PBr23) on both paintings D1 and D2.

On drawing M1 and drawing M2, the presence of a protective varnish was detected.

Concerning the binders, FTIR – ATR spectroscopy on samples from drawing M1 and drawing M2 highlighted the presence of an acrylic emulsion, in particular the presence of styrene on drawing M2. Barium sulphate (BaSO_4) and calcium carbonate (CaCO_3) used as extenders were detected as well.

Regarding the artistic techniques, FORS comparison and PCA analysis mainly confirmed the materials which was declared by the artist, except for drawing 03. In fact, drawing 01 and drawing 02 seemed to have been depicted using commercial tempera/gouache paints and so drawing 05. On the other hand, drawing 04, drawing M1, drawing M2, painting D1 and painting D2 were painted employing acrylic paints. Some points showed intermediate score values, suggesting the presence of mixtures in their formulation. About drawing 03, Zavřel declared to had employed oil pastels but the analysis highlighted the presence of gum Arabic instead of an oily binder. As reported in literature (Tenorio et al., 2019), the modern pastels' composition is extremely various and gum Arabic was mentioned in formulations. The obtained results were summarized in tables presented in the *Annex*.

Concerning the state of conservation, the artworks showed good conditions. The most noticeable details were the presence of small paint detachments on drawing 02, drawing 04, drawing M1 and drawing M2. Some ageing cracks were also detected on painting D1 and painting D2, probably mainly due to the tension of the canvases.

In order to obtain more information on Zavřel's materials, additional analysis should be performed in the future, especially regarding the binders' formulation. Moreover, a deeper investigation on drawing 05 should be done for obtaining a complete characterization and a richer view on Štěpán Zavřel's artworks.

Annex

Resume of the pigments and dyes identifies in all the analysed artworks:

	White	Orange/red	Mauve/ Magenta	Blue	Green	Yellow/Ochre	Brown
01	Titanium White (TiO ₂)	Hansa Red monoazopigment (β-naphtol)	Quinacridone	-	-	-	-
02	Titanium White (TiO ₂); Barium sulphate (BaSO ₄)	Hansa Red monoazopigment (β-naphtol)	-	Cobalt Blue (PB35 cobalt stannate)	-	-	-
03	-	Monoazopigment	Lac (laccic acid)	Prussian Blue (PB27 ferric ferrocyanine)	Phthalo Green (copper phthalocyanine)	-	-
04	Titanium White (TiO ₂)	PO13 Disazopigment (pyrazolone)	-	-	Phthalo Green (copper phthalocyanine)	-	-
05	Titanium White (TiO ₂)	-	Quinacridone	-	-	-	-
M1	Titanium White (TiO ₂); Chalk (CaCO ₃)	-	-	Phthalo Blue (PB15 copper phthalocyanine)	Phthalo Green (copper phthalocyanine)	-	PBr25 Monoazopigment (benzimidazolone)
M2	Titanium White (TiO ₂); Chalk (CaCO ₃)	-	-	Phthalo Blue (PB15 copper phthalocyanine)	Phthalo Green (copper phthalocyanine)	PY95 Disazopigment (condensation)	-
D1	Titanium White (TiO ₂); Chalk (CaCO ₃)	-	-	-	-	PY81 – PY83 Disazopigment (diarylide); PY74 Monoazopigment (acetoacetic arylide)	PBr23 Disazopigment (condensation)
D2	Titanium White (TiO ₂); Chalk (CaCO ₃)	-	-	-	-	PY83 Disazopigment (diarylide); PY74 Monoazopigment (acetoacetic arylide)	PBr23 Disazopigment (condensation)

Resume of the pigments and dyes on drawing 01:

Colour	Raman	FORS	Conclusion
White	Titanium White	Titanium White, Lithopone	Titanium White was used to paint the white coloured details; on the other hand, it could have been mixed with Barium sulphate in order to create a first homogeneous layer.
Orange	PR53 Monoazopigment (β -naphthol)	Azoic dye	The reddish orange colour could be an azoic dye.
Mauve purple	Quinacridone magenta (?)	Quinacridone dye, Titanium White	The mauve colour could be a quinacridone based dye mixed with Titanium White to obtain a snowy effect.

Resume of the pigments and dyes on drawing 02:

Colour	Raman	FORS	Conclusion
White	Titanium White; Barium sulphate	Titanium White; Lithopone	Titanium White was used to paint the white coloured details; on the other hand, it could have been mixed with Barium sulphate in order to create a first homogeneous layer.
Orange	PR53 Monoazopigment (β -naphthol)	Azoic dye	The reddish orange colour could be an azoic dye.
Blue	Cobalt Blue (PB35 cobalt stannate)	Cobalt Blue	Cobalt Blue was used to paint the blue coloured details and mixed with Titanium White to create different shades.

Resume of the pigments and dyes on drawing 03:

Colour	Raman	FORS	Conclusion
Blue	Prussian Blue (PB27 ferric ferrocyanide)	Prussian Blue (PB27 ferric ferrocyanine)	The blue details could have been depicted using Prussian Blue (PB27).
Green	Phthalo Green (copper phthalocyanine)	Phthalo Green (copper phthalocyanine)	The green details could have been depicted with a Phthalo Green (copper phthalocyanine).
Orange	Monoazopigment	Lac dye	The results are a little ambiguous, since it is not clear if the orange colour could be a monoazopigment or a lac dye.
Magenta	Lac (anthraquinone)	-	The magenta details could have been depicted with an anthraquinone dye.

Resume of the pigments and dyes on drawing 04:

Colour	Raman	FORS	Conclusion
White	Titanium White	Titanium White	Titanium White was used to paint the white coloured details.
Orange	PO13 Disazopigment (pyrazolone)	-	The orange details were depicted using a disazopigment (PO13).
Green	Phthalo Green (copper phthalocyanine)	Phthalo Green (copper phthalocyanine)	The green details could have been depicted with Phthalo Green (copper phthalocyanine).
Black	Vine Black	-	The black colour could be Vine Black but the results are quite uncertain.

Resume of the pigments and dyes on drawing M1:

Colour	Micro-Raman (samples)	Raman	FORS	Conclusion
White	Titanium White; Chalk	Titanium White; Chalk	Titanium White	Titanium White was used to paint the white coloured details; on the other hand, chalk could have been used to prepare a first homogeneous preparatory layer.
Green	-	Phthalo Green (copper phthalocyanine)	Phthalo Green (copper phthalocyanine)	The green details were depicted using Phthalo Green.
Blue	Phthalo Blue (PB15 copper phthalocyanine)	Phthalo Blue (PB15 copper phthalocyanine)	Phthalo Blue (PB15 copper phthalocyanine)	Phthalo Blue was used to paint the blue coloured details.
Brownish	-	PBr25 Monoazopigment (benzimidazolone)	-	The brown details were probably depicted using a monoazopigment (PBr25).

Resume of the pigments and dyes on drawing M2:

Colour	Micro-Raman (samples)	Raman	FORS	Conclusion
White	Titanium White; Chalk	Titanium White; Chalk	Titanium White	Titanium White was used to paint the white coloured details and probably to prepare a homogeneous white surface; on the other hand, chalk could have been used to prepare a first homogeneous preparatory layer.
Green	Phthalo Green (copper phthalocyanine)	Phthalo Green (copper phthalocyanine)	Phthalo Green (copper phthalocyanine)	Phthalo Green was used to paint the green coloured details.
Blue	Phthalo Blue (PB15 copper phthalocyanine)	-	-	Phthalo Blue could have been mixed with Phthalo Green to create different shades.
Yellow	-	PY95 Disazopigment (condensation)	-	The yellow details were probably depicted using a disazopigment (PY95).
Brown	PBr25 Monoazopigment (benzimidazolone)	-	PBr24 Chrome Antimony Titanate	The brownish/ochre colour could have been depicted with a monoazopigment or a Chrome Antimony Titanate, a good non-toxic Naples Yellow substitute.

Resume of the pigments and dyes on painting D1:

Colour	Raman	FORS	Conclusion
White	Titanium White; Chalk	Titanium White	Titanium White was used to paint the white coloured details; on the other hand, chalk could have been used to create a first homogeneous preparatory layer.
Yellow	PY81 – PY83 Disazopigment (diarylide); PY74 Monoazopigment (acetoacetic arylide)	-	The yellow details were depicted using a mixture of disazopigments (PY81, PY83) and a monoazopigment (PY74).
Brown	PBr23 Disazopigment (condensation)	-	The brown details were depicted using a disazopigment (PBr23).

Resume of the pigments and dyes on painting D2:

Colour	Raman	FORS	Conclusion
White	Titanium White; Chalk	Titanium White	Titanium White was used to paint the white coloured details; on the other hand, chalk could have been used to create a first homogeneous preparatory layer.
Yellow	PY83 Disazopigment (diarylide); PY74 Monoazopigment (acetoacetic arylide)	-	The yellow details were depicted using a mixture of a disazopigment (PY83) and a monoazopigment (PY74).
Brown	PBr23 Disazopigment (condensation)	-	The brown details were probably depicted using a disazopigment (PBr23).

Resume of the binders of all the analysed artworks:

Artwork	Declared artistic technique	FORS	Conclusion
01	Tempera coprente (gouache)	Arabic gum	01 was created using gouache technique since Arabic gum was identified as binder.
02	Tempera coprente (gouache)	Arabic gum	02 was created using gouache technique since Arabic gum was identified as binder.
03	Oil pastels	Arabic gum	03 was created using pastels containing Arabic gum as binder instead of oil as declared. Probably, an oily binder could be present but it is not the predominant one.
04	Acrylic paint	Acrylic	04 was created using colours containing an acrylic binder.
05	Tempera coprente (gouache)	Arabic gum	05 was created using gouache technique since Arabic gum was identified as binder, even if some spectra show ambiguous results.
M1	Acrylic paint	Acrylic	M1 was created using colours containing an acrylic binder.
M2	Acrylic paint	Vinylic/Acrylic	M2 showed ambiguous results and seemed it was created using colours containing a vinylic binder instead of an acrylic one.
D1	Acrylic paint	Acrylic/Vinylic	D1 showed ambiguous results and seemed it could have been created using colours containing an acrylic binder as well as a vinylic one.
D2	Acrylic paint	Acrylic/Vinylic	D2 showed ambiguous results and seemed it could have been created using colours containing an acrylic binder as well as a vinylic one.

Resume of the pigments and binders of all the analysed artworks:

	White	Orange/red	Mauve/ Magenta	Blue	Green	Yellow/Ochre	Brown	Binder
01	Titanium White (TiO ₂)	Hansa Red monoazopigment (β-naphthol)	Quinacridone	-	-	-	-	Gum Arabic; acrylic
02	Titanium White (TiO ₂); Barium sulphate (BaSO ₄)	Hansa Red monoazopigment (β-naphthol)	-	Cobalt Blue (PB35 cobalt stannate)	-	-	-	Gum Arabic; acrylic
03	-	Monoazopigment	Lac (laccic acid)	Prussian Blue (PB27 ferric ferrocyanine)	Phthalo Green (copper phthalocyanine)	-	-	Gum Arabic
04	Titanium White (TiO ₂)	PO13 Disazopigment (pyrazolone)	-	-	Phthalo Green (copper phthalocyanine)	-	-	Acrylic
05	Titanium White (TiO ₂)	-	Quinacridone	-	-	-	-	Gum Arabic; acrylic
M 1	Titanium White (TiO ₂); Chalk (CaCO ₃)	-	-	Phthalo Blue (PB15 copper phthalocyanine)	Phthalo Green (copper phthalocyanine)	-	PBr25 Monoazopigment (benzimidazolone)	Acrylic
M 2	Titanium White (TiO ₂); Chalk (CaCO ₃)	-	-	Phthalo Blue (PB15 copper phthalocyanine)	Phthalo Green (copper phthalocyanine)	PY95 Disazopigment (condensation)	-	Acrylic
D1	Titanium White (TiO ₂); Chalk (CaCO ₃)	-	-	-	-	PY81 – PY83 Disazopigment (diarylide); PY74 Monoazopigment (acetoacetic arylide)	PBr23 Disazopigment (condensation)	Acrylic
D2	Titanium White (TiO ₂); Chalk (CaCO ₃)	-	-	-	-	PY83 Disazopigment (diarylide); PY74 Monoazopigment (acetoacetic arylide)	PBr23 Disazopigment (condensation)	Acrylic

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