1. Introduction

In February 1905 Pablo Picasso exhibited 33 works and some drawings at the Galerie Serrurier in Paris. The first eight works in the exhibition were listed under the common title 'Les Saltimbanques' and did not have any other significant description. However, reading the review written by the poet Guillaume Apollinaire in *La Plume* on May 15, 1905, it is possible to identify most of them.
Acrobat Family (Fig. 1a) was most likely one of the eight works in the series 'Les Saltimbanques' and is in the text referred to as: 'raising future acrobats among familiar monkeys'.

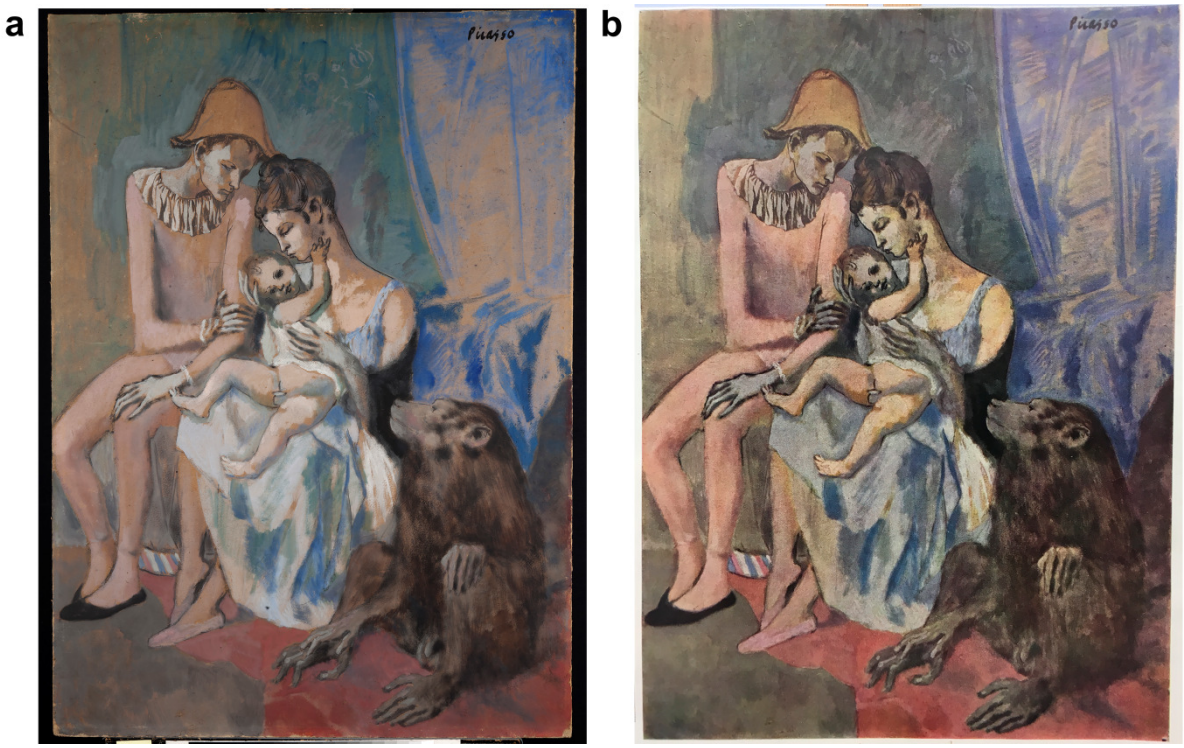

Fig. 1 Pablo Picasso, *Acrobat Family*, 1905, 104×75×0.3 cm, GKM699. Current state of the artwork (a), compared to a printed archival document from 1964 (b). ©GKM Photo

Among the eight works exhibited at the Galerie Serrurier, two themes can be distinguished. One focused on the family, depicting the fatherhood of the harlequin, and the second emphasizing the circus where the harlequin is associated with the acrobats. In the *Acrobat Family* Picasso merges these themes in a pyramidal composition comparable to the depiction of the holy family in renaissance art. In October 1905 the famous collector and art patron Leo Stein bought it together with the *Girl with a basket of flowers,* something that boosted Picasso's carrier [1].
From different catalogue sources, the most common medium on the artist's production on cardboard between 1905 and 1906 appears to be gouache. In the *Acrobat Family* this is suggested by the general matt appearance of the unvarnished surface, and by the look of the pigments under magnification, which show embedded fibres and the presence of holes left by evaporated water bubbles (Fig. 2a-f). However, under reflected and raking light some areas appear shiny, suggesting the use of a technique with a fatty element, like oil (Fig. 2g). It is reported that Picasso used a technique called '*essence*' (oil paint that has been heavily diluted with turpentine, causing the leaching of much of the oil) in his *Saltimbaque in Profile* and *Girl in a Chemise* from the same period [2].

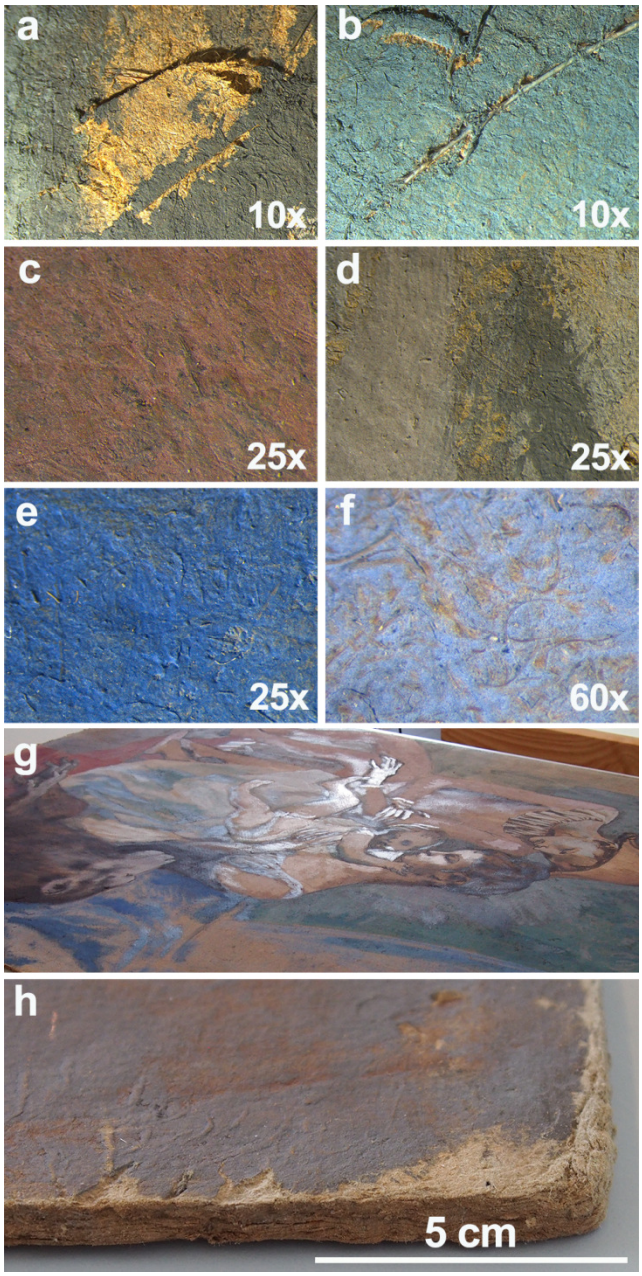

Fig. 2 Macrophotographs of details from the painting (a-f); image of the painting under reflected light (g); detail of the corner showing delamination of the cardboard (h).

Because of the work's particularly sensitive materials, the museum has always been restrictive in terms of loans. Recently, a more thorough examination was initiated to document carefully the current condition of the painting. The first step was a visual examination to compare the present appearance with archival photo documentation and old catalogue pictures. Here it became clear that the blue pigments in the background appear to be severely discoloured (Fig. 1a, b). Further technical photography and fibre analysis showed a relation between the degradation of the cardboard and the pigment discoloration. The most sensitive and degraded areas are the edges and corners of the board, which show a delamination in the layered structure (Fig. 2h), probably also related to handling. Lately, analyses by XRF, FTIR, and UV-Vis-NIR reflectance spectroscopy were carried out to achieve a better understanding of the painting technique, identify the materials composition and provide explanations for the discolouration.

2. Experimental

2.1. Optical microscopy and technical photography

Microphotographs were taken with a Leica M80 stereo microscope, using 10x, 25x, and 60x magnification.
Visible and infrared imaging was carried out using a modified Canon EOS 5D Mark II camera, with an EF50mm f/2,5 Compact Macro Lens, and B+W 77mm UV/IR Cut MRC 486M and RG830 filters. For illumination tungsten-halogen lamps were positioned at ca. 20º to the painting. Near infrared false colour images (IRFC) were obtained following the protocol in the AIC guide [3].

2.2. X-ray Fluorescence Spectroscopy (XRF)

Elemental analysis was carried out using the Elio portable X-ray fluorescence (XRF) system from XGlab X and Gamma Ray Electronics. Measurements were conducted at 40 kV and 100 µA with an integration time of 120 seconds. The spatial resolution was about 1 mm^2.

2.3. Fibre optics reflectance spectroscopy (FORS)

FORS was performed with an FS4 Spectroradiometer (Malvern Panalytical). Spectra were collected in the range of 350–2500 nm, with a resolution of 3 nm (UV-vis) and 10 nm (NIR). The light probe was set at 45° from the surface normal, while the collecting fibre was held perpendicularly to the sample. The sampling area was about 3 mm ⌀. 64 spectra were averaged for each sample.

2.4. Fourier Transform Infrared Spectroscopy (FTIR)

FTIR spectra were recorded in reflection mode using the Alpha spectrometer (Bruker Optics). The measurements were carried out in the 7000–375 cm^{-1} range at a resolution of 4 cm^{-1} with 128 scans. The spatial resolution is about 28 mm^2 and the probe head-to-surface distance is higher than 1 cm.

3. Results and discussion

3.1. Support and painting technique

The cardboard support shows XRF profiles containing Fe and Ca as the main elements, together with minor amounts of Ba, Zn, S, Cu, Pb and Sr, and traces of K, Si and Al. Variable amounts of Zn can be detected everywhere and the peak in the painted areas is always weaker than in the cardboard. Therefore, Zn detected in the paint layer reasonably comes from the cardboard support, rather than being associated with zinc white.
FTIR and FORS spectra show signals of cellulosic material and kaolin (not shown), the latter being commonly used as a filler [4]. In addition, the presence of a carbonyl peak around 1727 cm^{-1} in the FTIR profile collected where the paint layer is absent, might indicate the presence of a sizing material. Although the position of the band suggests the use of a resin [5], the strong cellulose signals that dominate the spectrum preclude a more precise attribution.
Fibre analysis indicated that the cardboard is made of highly lignified mechanical wood pulp, with some traces of wool and cotton, as was typical of low-quality cardboard [2]. The board is slightly acidic, with a pH level of 5.5-6. Furthermore, fibres have a high lignin content which easily degrades into acidic products, speeding up the degradation process of the paper material.
Concerning the painting technique, differences in the C-H signals shapes and positions indicate two different types of binding medium which can be associated with the variable appearance of the paint layer: the matt surface shows strong and very sharp C-H signals at 2849, 2918 and 2955 (sh) cm^{-1}, possibly indicating a lipidic compound, likely oil; the shiny surface shows quite broad C-H signals (medium intensity) at 2854 and 2931 cm^{-1}, plausibly suggesting a resin (Fig. 3a) [5]. Because the non-invasive identification of binders and varnishes by reflection FTIR is often challenging, conclusive indications about the *essence* technique cannot be given. At the same time, even the presence of other organic compounds cannot be excluded.

3.2. White paint

The analyses carried out on the white areas revealed the presence of two different types of paint (Fig. 3a, b):

- *White I*: lead white (mainly cerussite with small quantities of hydrocerussite), very small amounts of Ba - probably barium sulphate - and possibly mixed with lead sulphate;

- *White II*: lead white (mainly hydrocerussite with small quantities of cerussite), large amounts of Ba - probably barium sulphate - and possibly mixed with lead sulphate;

The two types of white paints were used by Picasso in combination with other pigments and can be detected in other areas all over the painting.

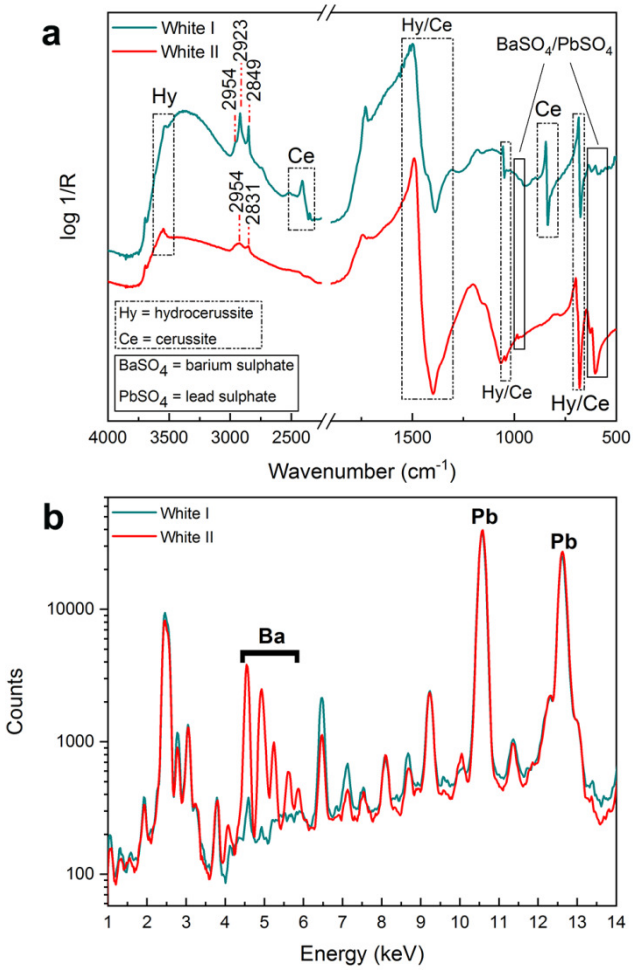

Fig. 3 Reflection FTIR (a) and XRF (b) spectra of *White I* and *II*.
(The attribution of the FTIR bands are based on [6]).

3.3. Red and pink paint

The presence of large amounts of Hg and an inflection point around 591 nm in the FORS profiles (Fig. 4a) indicate that vermilion was used to paint the majority of the red areas (*Red I*) [7]. The only exceptions are two dark red areas at the back of the monkey (*Red II*), where FORS spectra show two minima at ca. 519-22 and 551-55 nm (Fig. 4b), indicating the presence of an anthraquinone-derived lake (very likely of animal origin, such as carmine, kermes, lac etc.) [8]. Very small amounts of Hg have been detected almost everywhere, also in areas that are not red, suggesting the sparse use of vermilion or unintentional contamination.

Variable amounts of lead white and vermilion were mixed together to create different shades of pink, which were used to paint the flesh tone, the shoes of the woman and other details.

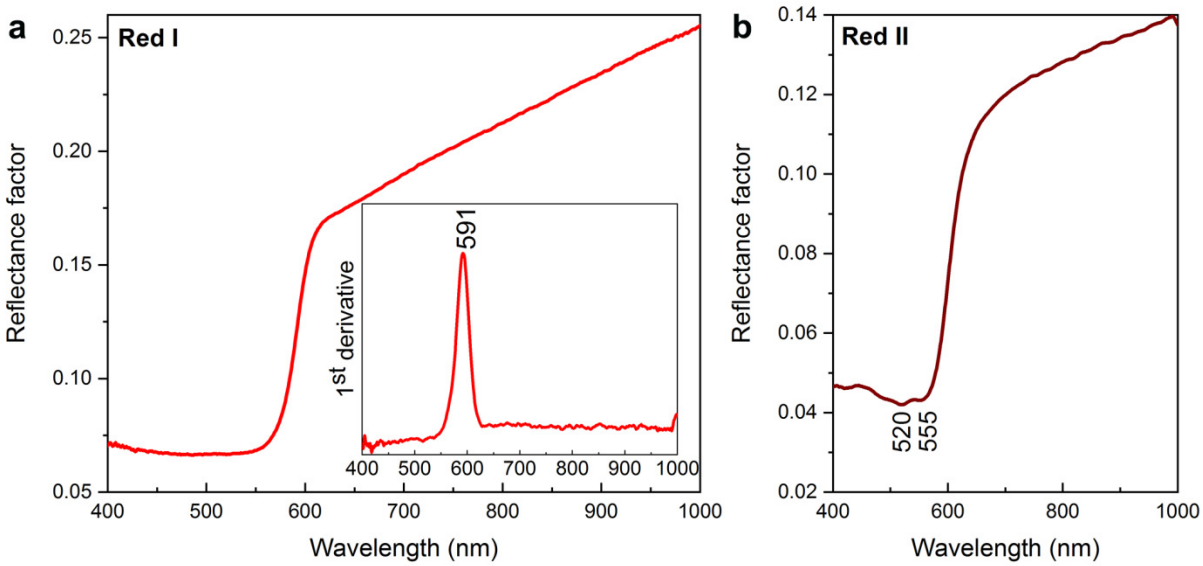

Fig. 4 FORS spectrum of *Red I* and its first derivative (a); FORS spectrum of *Red II* (b).

3.4. Black, grey and brown paint

Mainly two pigments were used to paint black, grey and brown areas: bone/ivory black (infrared peak at 2015 cm^{-1}, sometimes accompanied by features attributed to phosphate compounds and associated with large amounts of Ca together with small amounts of P) and Prussian blue (C-N band around 2096 cm^{-1} [9-11]).

Some areas (*Black I, Grey I, Brown I*) are painted using both pigments, while in others (*Black II, Grey II, Brown II*) only Prussian blue has been detected. Variable amounts of Hg can be found in all the above-discussed areas, although FORS possibly suggests the presence of small amounts of vermilion only in the brown hues. However, the occurrence of other pigments and/or dyes giving the brown colour to the paint cannot be ruled out.

3.5. Green paint

Two types of "greenish" paint have been identified on the painting: the first, detected on the dress of the woman and the face of the child (G*reen I*), is composed of a mix of Prussian blue and yellow ochre, as indicated by the FTIR and FORS results; the second, detected on the background (G*reen II*), seems to contain only Prussian blue as a colouring material (Fig. 5a, b) [11,12,8]. This greenish paint was probably produced by applying a diluted blue paint to the cardboard, and by playing with the transparency of the paint and the yellowish colour of the support. However, the additional presence of a yellow dye cannot be excluded, but the detection and identification of this type of compounds by non-invasive means is quite challenging.

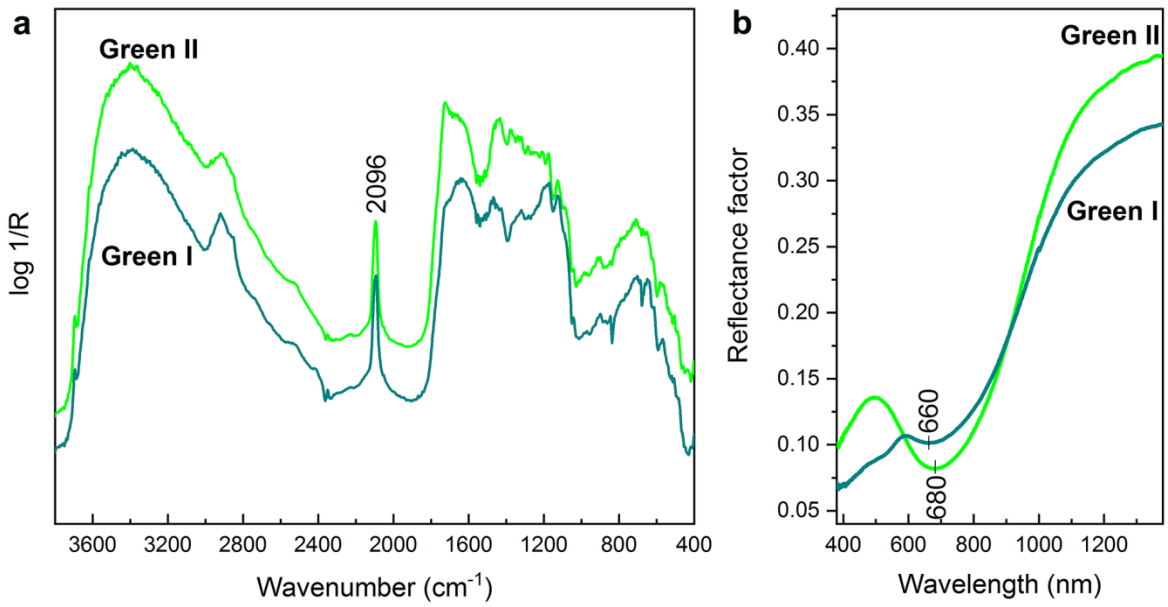

Fig. 5 Reflection FTIR (a) and FORS (b) spectra of *Green I* and *II*.

3.6. Blue paint

Two blue pigments where used by Picasso to paint the curtain, which is the area mostly affected by discolouration (Fig. 1a, b): the dark compound, highly absorbing in the IR image and appearing green in IRFC, is Prussian blue (*Blue I*); the compound transparent in IR, which turns pink/red in IRFC, is ultramarine (*Blue II*) (Fig. 6a). The former is characterized by a band around 2100 cm^{-1} in the FTIR spectrum and by a broad minimum around 700 nm in the visible spectrum; the latter can be easily identified thanks to a FORS absorption band around 600 nm and to FTIR bands at 450 and 980-998 cm^{-1} attributed to Si-O vibrations (Fig. 6b, c) [11,12,6].

The two pigments are often found together in the lower part of the curtain, suggesting that Picasso mixed them in various proportions to create different shades (the relative intensities of the Vis-NIR bands correspond to the relative amounts of the two blues) (Fig. 6c). Conversely, ultramarine is mainly identified in the upper part of the curtain, where Prussian blue is negligible. Weak signals of ultramarine in the FORS spectra are still detected even in the most faded areas where the pigment is barely visible by the naked eye (Fig. 6d, e).

Both pigments are known to be characterized by fading/discolouration problems. The poor lightfastness of Prussian blue has been observed since late mid-nineteenth century. The pigment was reported to have the tendency to fade upon exposure to light when mixed with white pigments [13,14]. The fading is due to a photo-redox process that breaks the electron transfer Fe^{II}–CN–Fe^{III} pathway and it can be variably affected by the copresence of other compounds (extenders, fillers, pigments), the substrates (canvas, paper), the environmental conditions and the manufacturing procedure [15-17]. .

The discolouration of ultramarine can be generated either by micro-fissures around the pigment particles in the paint layer (resulting from the disintegration of the binder), which scatter the light and make the paint surface appear patchy and whitish [18], or by the destruction of the sodalite cage framework (caused by both alkaline and acidic environment), which in turn triggers the release of the chromophores responsible for the colour [19-21].

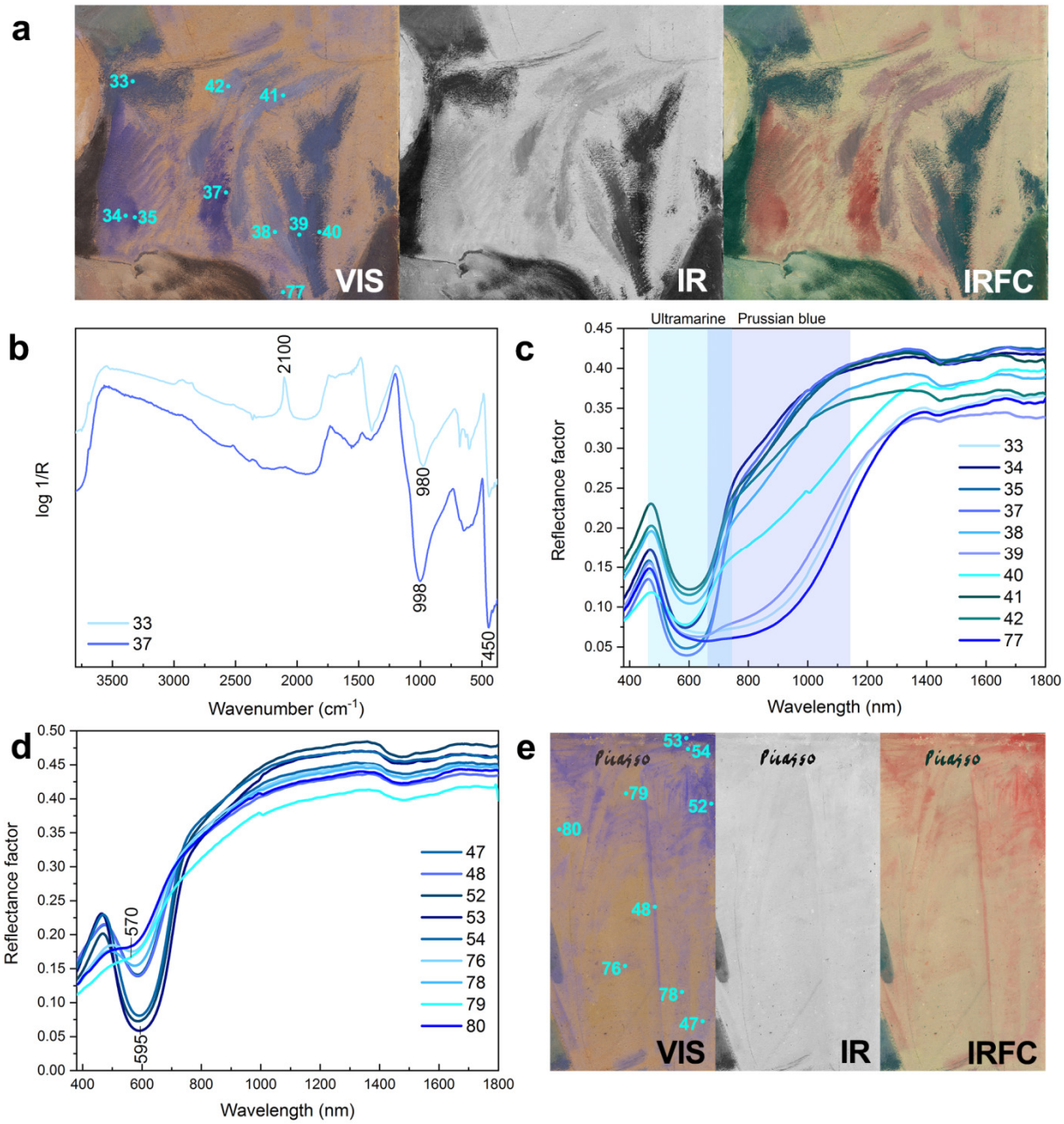

Fig. 6 Detail of the lower part of the curtain (a). FTIR (b) and FORS (c) spectra of blue areas painted with different mixtures of *Blue I* and *II*. FORS spectra of blue faded areas (d). Detail of the upper part of the curtain (e).

4. Conclusions

The analytical campaign provided valuable information on the material composition of the *Acrobat Family*, helping clarify uncertainties about the painting technique.

From the conservation point of view, taking into account all the findings, it proved that several concurrent factors are responsible for the discolouration of the *Acrobat Family*. The main extrinsic one is the light exposure, mainly affecting the Prussian blue. The intrinsic ones are the paint composition itself (fillers, extenders, other pigments) and, especially for the ultramarine, the acidity of the support.

The acidity of the cardboard cannot be controlled or mitigated in this specific case. Due to the presence of the paint layer, de-acidification procedures of the support cannot be carried out. The external factors, on the other hand, can be instead controlled to preserve the materiality and the identity of this masterpiece. Controlled lighting in

exhibition rooms, in house and during loans, is a policy already adopted by the museum. In addition, a microclimate frame has now been built to protect the painting from fluctuations of the outside RH-conditions and from mechanical damages. Finally, to reduce levels of gases and particulate air pollution, active carbon cloth has been added to the enclosure.

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