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Evolution of Liu Kang's Palette and Painting Practice for the Execution of Female Nude Paintings: The Analytical Investigation of a Genre

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Abstract: The comprehensive technical investigation of female nude paintings by the Singapore pioneer artist Liu Kang (1911–2004) provided the evidence for a discussion of the evolution of his palette of colours and his working process for expression in this genre, particularly the execution of female bodies. As the artist's free expression in classical nude paintings was limited by the censorship imposed by the Singapore government, the investigated artworks span two periods, 1927–1954 (early career) and 1992–1999 (the "golden years", during which censorship policies were relaxed). Hence, eight paintings from the Liu family and National Gallery Singapore were selected for non- and micro-invasive analyses of the paint layers. The obtained results were supplemented with archival sources to elucidate certain aspects of Liu Kang's working practice. The investigation revealed the importance of drawing and sketching studies in the development of artistic ideas. The analytical techniques, such as polarised light microscopy (PLM), field emission scanning electron microscope with energy dispersive spectroscopy (FE-SEM-EDS) and attenuated total reflectance–Fourier transform infrared spectroscopy (ATR-FTIR), enabled us to observe a transition from the yellow iron-based tonal ranges of skin colours to complex pigment mixtures composed of additions of cobalt blue, ultramarine, Prussian blue, Cr-containing yellow(s) and green(s), cadmium yellow, orange and/or red and organic reds, revealing the artist's more liberal use of colours and his experimentation with their contrasting and complementary juxtaposes. In terms of painting technique, the artist's comparatively laborious paint application using small brushes quickly gave way to a more effortless manipulation of the paint using bigger brushes and the incorporation of palette knives. Moreover, visible light (VIS), near-infrared (NIR) and X-ray radiography (XRR) imaging techniques led to the discovery of a hidden composition in one investigated artwork, which bears resemblance to the nude painting known only from an archival photograph. Additionally, for the first time, the archival search provided photographic evidence that Liu Kang used oil paint tubes from Royal Talens and Rowney in the 1990s. Overall, this in-depth investigation contributes to the understanding of Liu Kang's approach to the female nude painting and may assist conservators and art historians in studies of twentieth-century commercial paints.

Keywords: Liu Kang; pigment identification; SEM-EDS; FTIR; IRFC; PLM; X-ray; hidden paintings

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1. Introduction

Liu Kang (1911–2004) is considered a major and influential figure of Singapore's visual arts of his time. Born in China, Liu Kang graduated in 1928 from Xinhua Arts Academy in Shanghai and moved to Paris, where he studied at the Académie de la Grande Chaumière

in Montparnasse (1929–1932). During that time, he was attracted to Impressionism, Post-Impressionism and Fauvism [1], which influenced many of his artworks. That exposure is particularly evident in his vibrant use of colours and a variety of adopted painting techniques [2]. In 1933, he returned to Shanghai and took charge of the faculty of Western art at the Shanghai Art Academy—China's leading art teaching institution. He continued painting and teaching in Shanghai until the outbreak of the Second Sino-Japanese War (1937–1945). The war drove him to Malaya, where he struggled to develop artistically due to the Japanese Occupation (1941–1945). Liu Kang settled in Singapore permanently in 1945 and pursued the quest of developing his own artistic style. His career became increasingly prominent after 1952 when he visited the Indonesian island of Bali. The trip had a profound effect on Liu Kang and inspired him to contribute to the Nanyang style of painting, which refers to a regional art movement initially practised by a group of migrant Chinese painters in Singapore between the late 1940s and the 1960s. The style reflects Southeast Asian subject matter and involves techniques derived from the School of Paris and traditional Chinese ink painting [3]. However, Liu Kang's artistic development did not end with the established Nanyang style. He often retraced his steps and reworked old themes, such as in the study of nudes.

The theme of nudes accompanied the artist during his student and teaching years in Shanghai, emigration to Malaya and throughout his oeuvre in Singapore, including his "golden years". At the age of 92, he was still attending life drawing sessions at the Lasalle-SIA College of the Arts organised by Group 90, an informal group of Singaporean artists studying and promoting nudity as an art form [4,5]. Liu Kang's predilection for the depiction of nudes can be elucidated by his admiration of the human body as the perfect creation in itself. He expressed his thoughts in a 1953 essay: "The human body, which contains the endowments of nature, is a mould that is the most curvaceous, has the most exquisite and forceful lines, and exudes the most subtle and delightful lustre in the world" [6]. Liu Kang reaffirmed the importance of artistic studies of the human body almost a half-century later, in 2002: "With elements such as proportion, symmetry and texture for the artist to deliberate upon, the human body is truly the most beautiful form in the universe" [7].

Interestingly, despite Liu Kang's mastery of nudity as a form of art in the countless drawings created during his entire career (Figure 1a,b), the theme is underrepresented in his paintings. The artist did not engage in the painting of nude figures due to censorship laws in multi-ethnic Singapore as well as concerns over moral sensitivity. Hence, there is a significant gap spanning nearly 40 years (from around 1954 to 1992) when he abandoned this genre. In a 1993 interview, he recalled: "I never really had the opportunity to paint and show nudes in the past. The climate in the country was conservative and what you could show in an exhibition was controlled. The police would come to an exhibition and ask for the nudes to be removed, or request that not too many are shown" [8]. This account is consistent with a newspaper article reporting the banning by the Singapore Young Men's Christian Association art club of four nude pastel artworks during the annual exhibition in 1952. According to the statement by an official, the decision was made to prevent public moral outrage: "We do not mind art for art's sake but moralists may be shocked when art is superimposed" [9]. In 1970, Liu Kang wrote: "Confucian philosophy [is] not open-minded towards the naked human body. It is nearly impossible for local artists to have an opportunity to draw nudes" [10]. Hence, the artist worked on nude figures mainly in the form of drawings instead. He considered life drawing as essential to mastering fundamental art skills [11] and a relatively convenient form of expression as, compared to paintings, it required less time and storage space. In addition, he probably self-censored by disguising his painting of semi-nudes in Bali as a depiction of the Balinese way of life (Figure 1c). Despite his apparent self-censorship, Liu Kang strongly disagreed with the imposed limitation of the artistic expression of ideas and publicly defended nude painting as an artistic genre. In a 1987 interview, he stated that "[nudity in art] was not entirely a Western concept because it was once popular in China and India" [12].

Figure 1. (**a**) Liu Kang, *Nude*, 1968, pastel on paper, 56 × 38 cm. (**b**) Liu Kang, *Nude*, 1969, pastel on paper, 46 × 65 cm. (**c**) Liu Kang, *Balinese woman and children*, 1962, oil on canvas, 98.5 × 131.5 cm. Gift of the artist's family. Collection of National Gallery Singapore.

In the 1990s, it finally became possible for Liu Kang to return to painting nudes more openly. Although conservative voices fixedly advocated the fully dressed human body in art as being in accordance to Oriental moral concepts [12,13], the 1992 Censorship Review Committee Report recognised the need for balance between artistic creativity and the safeguarding of moral values. Interestingly, the report did not mention nudity in paintings, but its subsection, "nudity in calendars, posters, magazines and newspapers", stated that "nudity itself is not obscene or offensive to many people" [14]. In a 1993 interview, Liu Kang concluded: "Recently, I have a sense that people are more open-minded here and I was fired up again to paint nudes. I guess I am making up for the lost time" [8]. Indeed, Liu Kang's nude paintings from the 1990s represent the culmination of the artist's lifelong exploration of one of his special subjects.

The available information seems to suggest that the artist's exploration of nudity in paintings spans two periods: 1927–1954 (early career) and 1992–1999 (the "golden years"). The theme reveals an evolution of the artist's painting expression from realism to different variants of modernism, including the Nanyang style [15,16]. Although the execution of female nudes from his early career is consistent with the technique known from his other genres of the same period, the nudes from the 1990s represent an unconventional experimentation with colour and brushwork, which can be elucidated from his 1997 essay: "Though my paintings are guided by a central principle in terms of style, there were some short periods when there would be styles or works that took an entirely different direction from my established style. This was due to the fluctuations of my mood" [17].

Hence, this study aims to investigate the development of the artist's approach to nude paintings by focusing on the pigment mixtures and painting techniques for depicting nude female bodies. Factors such as brushwork and colour palette were crucial for the characterisation of the forms of the figures and their skin tones. This research builds upon and expands the scope of the earlier analytical investigations of Liu Kang's paintings [2,18,19], and, for the first time, sheds light on the artist's palette of colours and painting techniques within one genre. The obtained results can provide conservators and art historians with a better understanding of Liu Kang's painting process.

2. Materials and Methods

2.1. Materials

The research in this paper focuses on eight paintings of nudes created during two periods, 1927–1954 and 1992–1999, from the Liu family and National Gallery Singapore collections (Figures 2 and 3). Two paintings represent the pre-war, Shanghai years. One was created during the unplanned emigration to Malaya, and five other paintings represent Liu Kang's career twilight in the 1990s. It should be noted that the final year of the first period (1927–1954) corresponds to the 1954 nude painting on canvas known only from the

archival photograph taken by the artist in the 1950s (Figure 4). The painting was executed in a typical Nanyang style by the artist after his trip to Bali in 1952 [19]. Although the information about the artwork remains unknown, its unpublished photograph is presented in this study for documentation purposes.

Figure 2. The paintings by Liu Kang: (**a**) *Nude*, 1927, oil on canvas, 45 × 60 cm; (**b**) *Nude*, 1934, oil on canvas, 45.5 × 55 cm; (**c**) *Nude*, 1940, oil on canvas, 38.5 × 46 cm; (**d**) *Nude*, 1995, oil on canvas, 66 × 76 cm; (**e**) *Nude*, 1992, oil on board, 42 × 97 cm. Paintings (**a**–**c**) are from Liu Kang family collection. Images courtesy of Liu family. Paintings (**d**,**e**) are gifts of the artist's family. Collection of National Gallery Singapore. White arrows indicate sampling areas.

In total, 62 paint samples from the artworks were analysed. Where possible, the samples were extracted from the surface paint layers in the areas of the existing losses. Table 1 summarises the inventory and technical data of the paintings, and Figures 2 and 3 indicate sampling areas for the analyses. It should be noted that the progressive numbering of the samples is not consistent due to the poor quality of some material, which was excluded from further analyses.

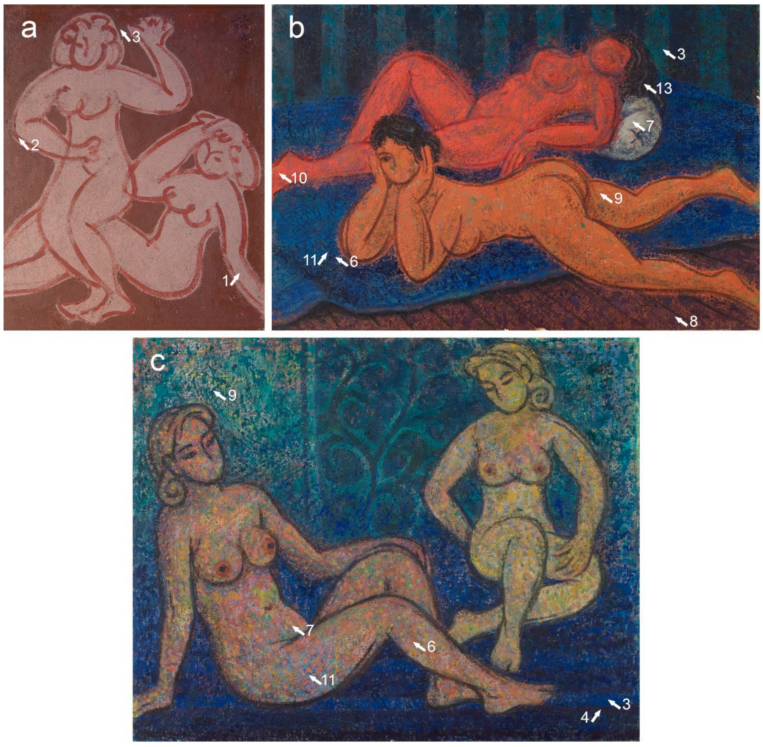

Figure 3. The paintings by Liu Kang: (**a**) *Two nudes*, 1996, oil on board, 43 × 36 cm; (**b**) *Beauties at rest II*, 1998, oil on canvas, 85 × 127 cm; (**c**) *In conversation*, 1999, oil on canvas, 61 × 76 cm. Painting (**a**) is from Liu Kang family collection. Image courtesy of Liu family. Paintings (**b**,**c**) are gifts of the artist's family. Collection of National Gallery Singapore. White arrows indicate sampling areas.

Figure 4. Archival photograph of a nude painting on canvas, 1954. Liu Kang family collection. Image courtesy of Liu family.

Table 1. Inventory and technical information of the paintings by Liu Kang included in this study.

Title and Inventory Number	Owner	Date	Dimensions H × W (cm)	Primary Support
Nude	Liu family	1927	45 × 60	Canvas
Nude	Liu family	1934	45.5 × 55	Canvas
Nude	Liu family	1940	38.5 × 46	Canvas
Nude, 2003-03259	NGS	1992	42 × 97	Board
Nude, 2003-03265	NGS	1995	66 × 76	Canvas
Two nudes	Liu family	1996	43 × 36	Board
Beauties at rest II, 2003-03470	NGS	1998	85 × 127	Canvas
In conversation, 2003-03305	NGS	1999	61 × 76	Canvas

2.2. Methods

This research relied on a multi-analytical approach that prioritises the use of non-invasive imaging techniques to preliminarily characterise the surfaces of paintings and pigment mixtures. These techniques involved visible light (VIS), ultraviolet fluorescence (UVF), reflected ultraviolet (UVR) and near-infrared (NIR). Pigment distribution and sampling areas were tentatively determined by combining the aforementioned imaging techniques with infrared false-colour (IRFC) manipulation, which enabled us to discriminate between the areas of same colour that had been achieved with different pigments. NIR and X-ray radiography (XRR) were employed to verify the presence of underlying preparatory drawings and earlier compositions.

The micro-invasive techniques involved extraction of the paint samples and their analyses in cross-sections to obtain vital information concerning their organic and inorganic components. Hence, optical microscopy (OM), polarised light microscopy (PLM), field emission scanning electron microscope with energy dispersive spectroscopy (FE-SEM-EDS) and attenuated total reflectance-Fourier transform infrared spectroscopy (ATR-FTIR) were employed.

The results of the analytical methods were supplemented with photographs of the artist at work, revealing some interesting details of his painting practice, including painting materials and tools. Liu Kang also made sketches of his models in preparation for painting; therefore, these sketches were included in this study as an integral element, providing a better understanding of the artist's approach to the subject matter. The sketches allowed us to trace the evolution of the ideas, which were finalised in the paintings.

2.2.1. Technical Photography

The images of the paintings were acquired using a modified to full-spectrum (360–1100 nm) Nikon 850 DSLR camera equipped with a Nikon AF Micro NIKKOR 60 mm f/2.8D lens (Tokyo, Japan) and a set of bandpass filters for different spectral ranges [20–22]. For imaging calibration, the X-Rite ColorChecker Passport (Grand Rapids, MI, USA) and American Institute of Conservation Photo Documentation (AIC PhD) target were used [20]. As a source of illumination, two 500 W halogen lamps were used for VIS imaging. The illumination of the UVF and UVR photography was provided by two lamps fitted with eight 40 W 365 nm UV fluorescence tubes. VIS and UVF images were acquired with X-Nite CC1 and B+W 415 filters coupled together. UVR photography was taken with Andrea "U" MK II filter, while NIR was performed with Heliopan RG1000 filter (Gräfelfing, Germany) mounted on the camera lens. The IRFC images were obtained by manipulating VIS and NIR photographs with Adobe Photoshop CC according to American Institute of Conservation protocol [23].

2.2.2. Digital Microscopy

Digital microscopy of the paintings was carried out using Keyence VHX-6000 (Osaka, Japan), with a zoom lens operating at magnifications of 20×–200×. Built-in Keyence software—VHX-H2M2 and VHX-H4M—was used for measurement analyses.

2.2.3. XRR

X-ray radiography of the paintings was conducted with a Siemens Ysio Max digital system (Munich, Germany) with a detector of dimensions 35 × 43 cm and a resolution of 7 million pixels. The radiographic images were captured at 40 kV, 0.5–2 mAs, 4 s acquisition time and 100 cm distance between the X-ray source and detector. The acquired images were processed using iQ-LITE, followed by Adobe Photoshop CC software for final alignment and merging.

2.2.4. Preparation of Samples

Paint samples for the cross-sections analyses were embedded in acrylic resin—ClaroCit from Struers (Cleveland, OH, USA). Samples selected for the PLM analyses were prepared as dispersions on microscope slides in a mounting medium, Meltmount from Cargille (Cedar Grove, NJ, USA), with a refractive index of 1.662, and covered with a cover glass.

2.2.5. OM and PLM

The structures of the paint samples were examined in reflected VIS and UV light on a Leica DMRX polarised microscope (Wetzlar, Germany) providing 100×, 200× and 400× magnifications. PLM of the pigments was carried out in transmitted VIS light at the same range of magnifications following the workflow developed by Peter and Ann Mactaggart [24]. The samples were photographed using a Leica DFC295 digital camera.

2.2.6. FE-SEM-EDS

The paint cross-sections were mounted on conductive carbon tapes and analysed with a Hitachi SU5000 FE-SEM (Tokyo, Japan) coupled with Bruker XFlash® 6/60 EDS (Billerica, MA, USA). The SEM, backscattered electron mode (BSE), was operated at an acceleration voltage of 20 kV, low vacuum mode at 50–60 Pa, 50–60 intensity spot, 180 s acquisition time and 10 mm working distance. The data collection and processing were performed with Bruker ESPIRIT 2.0 software.

2.2.7. ATR-FTIR

ATR-FTIR spectroscopy was performed on paint cross-sections using a Bruker Hyperion 3000 FTIR microscope equipped with a mid-band MCT (Mercury Cadmium Telluride) detector, coupled with a Vertex 80 FTIR spectrometer. The ATR objective (20×) equipped with a germanium crystal was used for the compression of the samples. The background was measured with 64 scans before each acquisition. A total of 64 scans were acquired for each sample at a resolution of 4 cm^{-1} over the spectral range 4000 to 600 cm^{-1}. Data were processed and interpreted using Bruker Opus 7.5 software. The interpretation of data was conducted using the reference spectra in the material collection of the Institute for Conservation, Restoration and Study of Cultural Heritage, Nicolaus Copernicus University, spectral library of the Infrared and Raman Users Group (IRUG) [25], as well as Database of ATR-FTIR spectra of various materials [26].

3. Results and Discussion

3.1. Pigments

The presented results of the pigment analyses and the discussion focus on the mixtures primarily used by Liu Kang for the depiction of nude figures. However, due to sampling limitations, certain tonal ranges of the skin colours were not fully investigated. Hence, the analyses of the paint mixtures from the drapery settings of the compositions supported a

tentative assessment of the pigment mixtures used for achieving skin colours and enabled us to confirm the use of certain pigments found at low concentrations in the skin colours.

The painterly settings, although being integral parts of the compositions, were treated by the artist with less attention; therefore, their technical characterisation was simplified to the prevailing pigment constituents. For clarity of the presented results, we organised them in sections corresponding to the paintings, which were arranged in the chronological order of their creation. The overview of the data is presented in Appendix A, Table A1.

3.1.1. Nude (1927)

The flesh colour of the model was probably achieved by interplaying yellow, red, green and blue hues to create highlights, mid-tones and shadows, as can be exemplified by the detail VIS image of the model's calf (Figure 5a). The bluish shadow underline may be associated with ultramarine or cobalt blue, based on its red representation in the IRFC imaging (Figure 5). The greenish mid-tone turns grey-blue in IRFC, suggesting the use of green earth or emerald green (Figure 5). Although the IRFC result is not conclusive, the use of emerald green (PG21) is likely, based on its identification in the green backdrop (sample 4). The elemental analyses of the green backdrop revealed the co-location of As and Cu elements, whereas FTIR measurements exhibited the intensive ester group stretching band at 1554, 817 (As-O stretch), 766 and 634 cm^{-1}, which could be assigned to emerald green (Figure 6) [27]. However, the latter peak is overlapped by the concomitant presence of lithopone in the investigated paint sample. The lithopone was confirmed by IR absorption bands at 1184, 1108, 1072, 983, 634 and 607 cm^{-1} [26]. A pink light reflection along the shadow on the model's calf was imaged orange in the IRFC (Figure 5); thus, it could be linked with an organic red rather than red iron-containing earth as the latter would appear greenish-brown in the IRFC imaging [20,28].

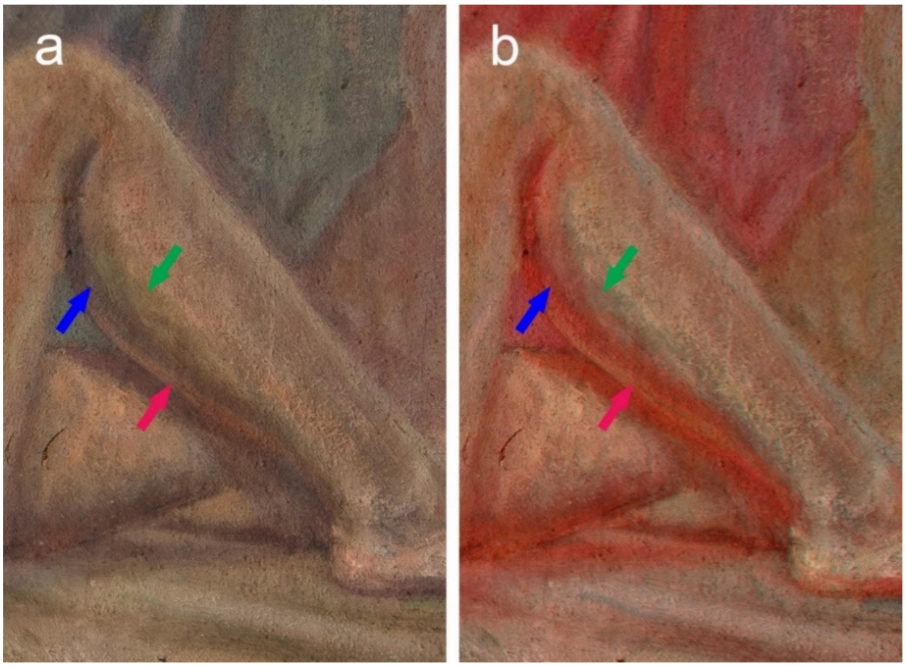

Figure 5. Detail of *Nude* (1927), imaged in VIS (**a**) and IRFC (**b**). The arrows indicate the areas of interest in VIS and their IRFC colour change: blue arrow—bluish shadow turns red; green arrow—greenish mid-tone turns grey-blue; red arrow—pink light reflection turns orange.

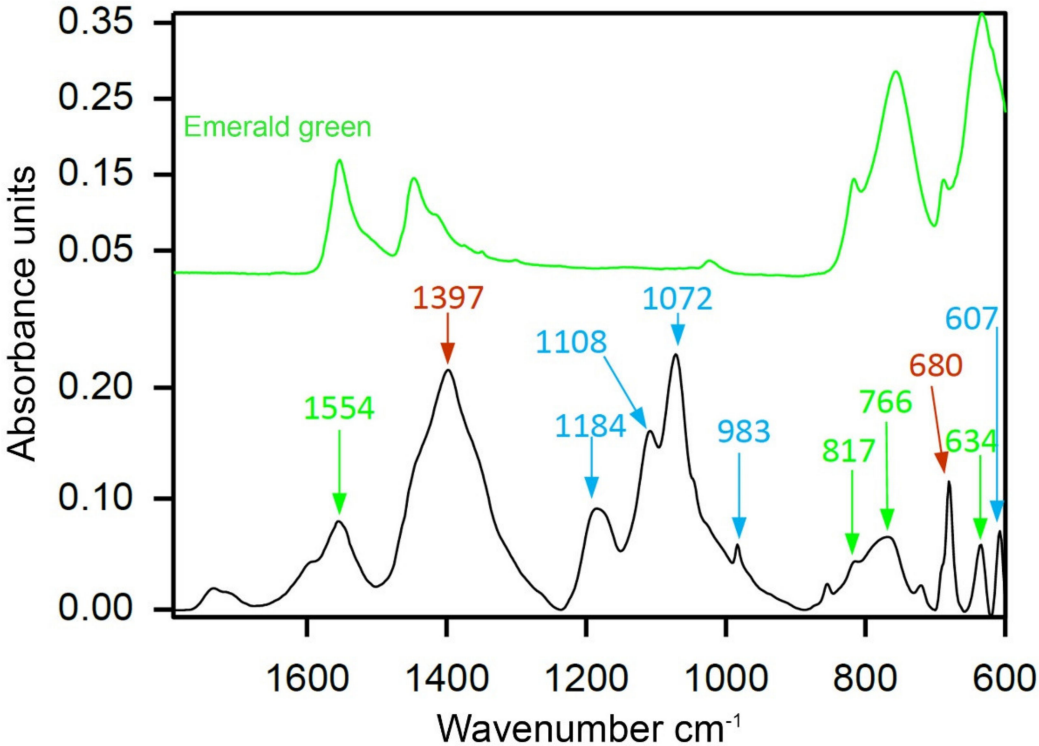

Figure 6. ATR-FTIR spectra of the green paint of sample 4 extracted from *Nude* (1927) with labelled (green) marker peaks of emerald green and reference spectra of the same pigment. Bands labelled in red indicate lead white and bands labelled in blue refer to lithopone. However, band 634 cm^{-1} is indicative of both emerald green and lithopone.

The brighter tints of the model's skin (sample 7) predominantly involved lead white (PW1), based on a strong Pb-signal and FTIR absorption peaks at 3533, 1394 (CO_3^{2-} asymmetric stretching), 1046, (CO_3^{2-} symmetric stretching), 852, 836, (CO_3^{2-} bending), 768 and 680 cm^{-1} (CO_3^{2-} bending) [29]. An admixture of lithopone (PW5) and/or barium white (PW21) and zinc white (PW4) is assumed, based on the FTIR detection of the characteristic peaks in the SO_4^{2-} group at 1186, 1109, 1072, 983 (the symmetric stretching vibration), 636 and 608 cm^{-1} (the out-of-plane bending vibration) and by SEM-EDS recording of Zn- and Ba-signals. It is worth noting that S was not detected in the sample probably due to the strong Pb Mα_1 signal overlapping the weaker S Kα_1 signal. A trace presence of Ca may suggest chalk (PW18) contamination. Interestingly, the co-location of As and Cu elements detected with SEM-EDS in the solitary green particles present in sample 7 permitted attribution to emerald green (Figure 7).

The model's dark hair was executed using the wet-on-dry technique with complex pigment mixtures, as illustrated in the VIS microscopic image and SEM-EDS elemental distribution maps of sample 10 (Figure 8). The SEM-EDS analysis of the bottom layer of the paint recorded signals of Fe, Ca, Si, Mn and P. This result combined with the FTIR absorption peak at 1032 cm^{-1} seems to point to either umber (PBr7) (Si-O-Si asymmetric stretching) [30,31] or bone black (PBk9) (PO_4^{3-} stretching) [30,32,33]. The presence of Na, Al, Si and S elements seems to point to an admixture of ultramarine (PB29), also observed with PLM (blue particles with low refractive index appear red with Chelsea filter). Traces of As and Cu elements evidence contamination with emerald green, which was confirmed to have been used more distinctly in other parts of the composition. The reddish upper layer of the same sample is an equally complex pigment mixture. Judging from the PLM observation of a good deal of red particles with a unique low refractive index and SEM-EDS detection of a strong Al-signal, organic red, probably on the Al-based substrate, was assumed. Meanwhile, strong Ba- and S-signals may correspond to barium white, which is a common extender of lake pigments as well as lead white [34], also considered to be

present in the investigated pigment mixture. A trace presence of Zn allowed us to consider an admixture of zinc white or lithopone as Ba and S were already detected. The latter was also supposed with FTIR by peaks at 1167, 1104, 1071, 984, 632 and 606 cm^{-1}. The minor and trace presence of Cr, As and Cu elements suggests a contamination of Cr-containing green and/or yellow pigment(s) and emerald green. The detection of Ca, Fe and P elements suggests an admixture of bone black and/or iron-containing earth pigment. A single IR absorption peak at 1021 cm^{-1}, can be identified as an asymmetric Si-O-Si stretching band in iron-rich earth or can represent the $PO4^{3-}$ group in bone black.

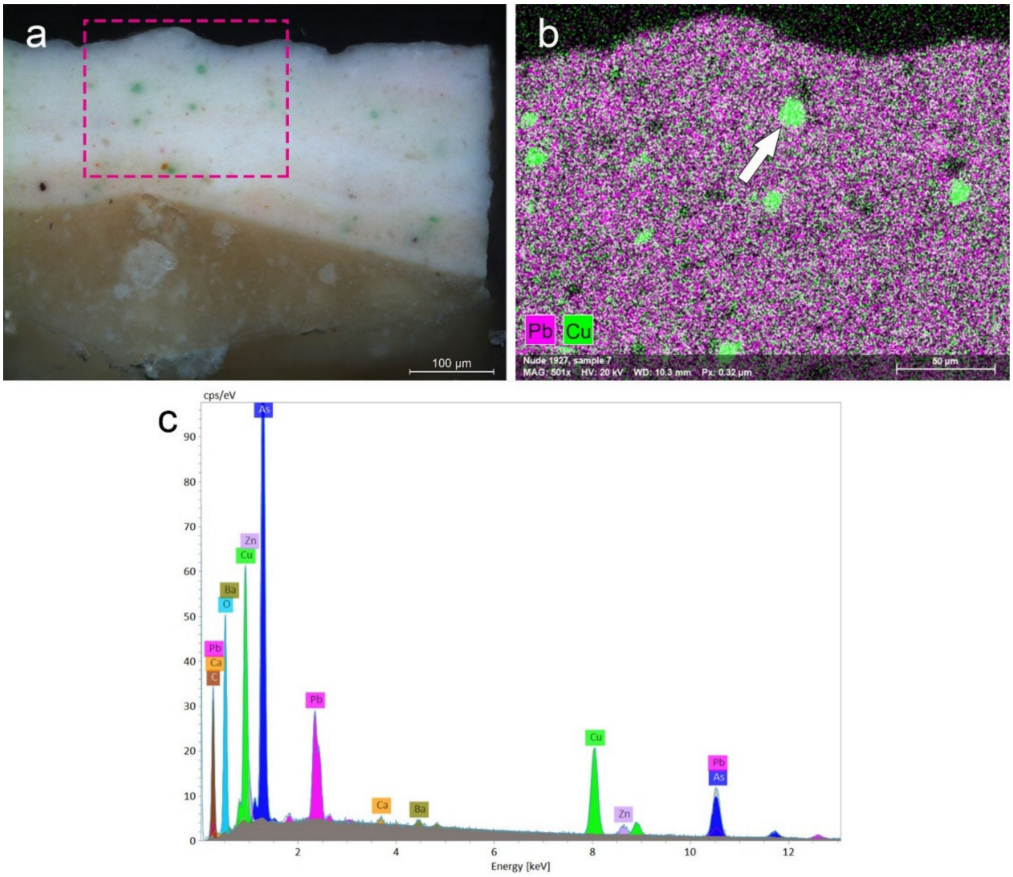

Figure 7. Microscopy image of the cross-section of sample 7 at 200× magnification, extracted from the area of the model's skin from *Nude* (1927) (**a**). The red rectangle indicates the area where the SEM-EDS elemental map was acquired. The corresponding SEM-EDS mapping of the skin colour paint (layer 2) (**b**) shows the distribution of lead (Pb) and copper (Cu) in the paint sample. The corresponding SEM-EDS spectra of the green particle (**c**) indicated with an arrow in SEM-EDS map (**b**) shows strong Cu- and As-signals, suggesting the presence of emerald green pigment particle.

Regarding the model's setting, as well as the emerald green in the green backdrop that was identified earlier (sample 4), the PLM enabled us to observe green particles with optical features typical for viridian (PG 18) (large and rough anisotropic green particles with high refractive index) [24,35] confirmed by the detection of a strong Cr-signal. Unfortunately, the FTIR identification of viridian was challenging due to the fingerprint region of this pigment (600–400 cm^{-1}) being behind the spectral range of the measurement. The analysed green paint was modified with some ultramarine suggested by SEM-EDS and PLM analyses, and white paint that could have a similar composition to that identified in other pigment mixtures of the investigated painting. Viridian, confirmed with PLM and SEM-EDS as the primary green pigment admixed with some ultramarine, was used for painting the light green textile underneath the model (sample 8). Moreover, the FTIR analysis permitted us to detect a low intensity band occurring at 794 cm^{-1} that could be indicative of viridian,

matching with the IRUG reference [36], while the other band at 1070 cm^{-1} that could support the characterisation of this green pigment was masked by the broad absorption band of lithopone.

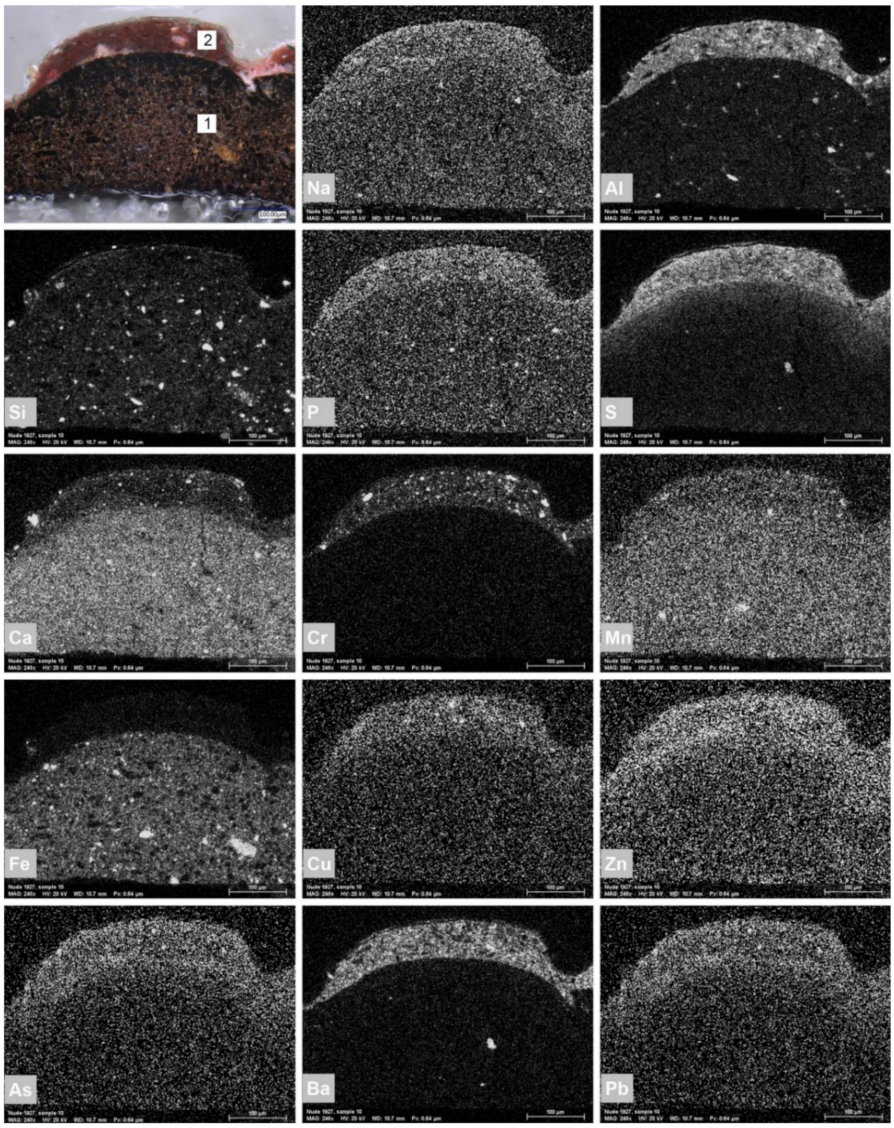

Figure 8. Microscopy image of the cross-section of sample 10 at 200× magnification, extracted from the area of model's hair from *Nude* (1927), photographed in VIS (top-left), followed by SEM-EDS maps showing the distribution of the detected elements. The greyscale corresponds to the intensity of the signal of each element: white equals high intensity, black means low intensity. A high intensity of Fe-, Ca-, Mn- and P-signals recorded from the layer 1 can be assigned to umber and bone black. The co-location of Al, P, S, Ca, Cr, Cu, Fe, Zn As, Ba and Pb in layer 2 suggests the presence of organic red, lead white, lithopone and/or barium white and zinc white, probably Cr-containing green(s) and/or yellow(s), emerald green, bone black and/or iron-containing earth pigment.

The analyses of the paint used for the brown backdrop (sample 2) revealed a complex mixture of pigments, probably composed of organic red on Al-containing substrate. PLM combined with SEM-EDS enabled us to identify admixtures of viridian, a trace presence of bone black and yellow iron-containing earth pigment (yellow, anisotropic particles with a high refractive index), and emerald green contamination.

PLM and SEM-EDS analyses of the red paint extracted from the model's pillow (sample 6) suggest the incorporation of organic red on an aluminium-based substrate with some bone black and white paint admixture. The analyses of sample 9 extracted from a

white painted area confirmed the use of lead white admixed with lithopone and/or barium white and zinc white, a pigment composition frequently found in other analysed samples of the paint layer.

3.1.2. Nude (1934)

Based on the PLM and SEM-EDS, the highlights and warm mid-tones of the flesh colour (sample 12, 11) involved varied concentrations of yellow iron-containing earth pigments. However, IR absorption peaks of kaolinite at 3696, 3622, ca. 1005, 912, 800 and 779 cm^{-1} enabled us to infer the presence of yellow ochre (PY43) in sample 11 [37,38]. This pigment was mixed with lithopone and/or barium and zinc whites to achieve different yellow tints. Cool greenish mid-tones were assessed based on their purple colour change in the IRFC (Figure 9), allowing us to infer the presence of Cr- or Co-containing green pigment. However, based on the PLM, SEM-EDS and FTIR analyses of the green backdrop (sample 4), a composition made of ultramarine and yellow iron-containing earth pigment could also be involved in the execution of cool mid-tones of the model's body. Her dark hair (sample 10) was achieved by mixing what is probably carbon black with ultramarine, resulting in a red appearance in IRFC. The colour intensity was controlled by adding a white paint resembling that identified in the flesh tone (sample 12) and the white pillow (sample 9).

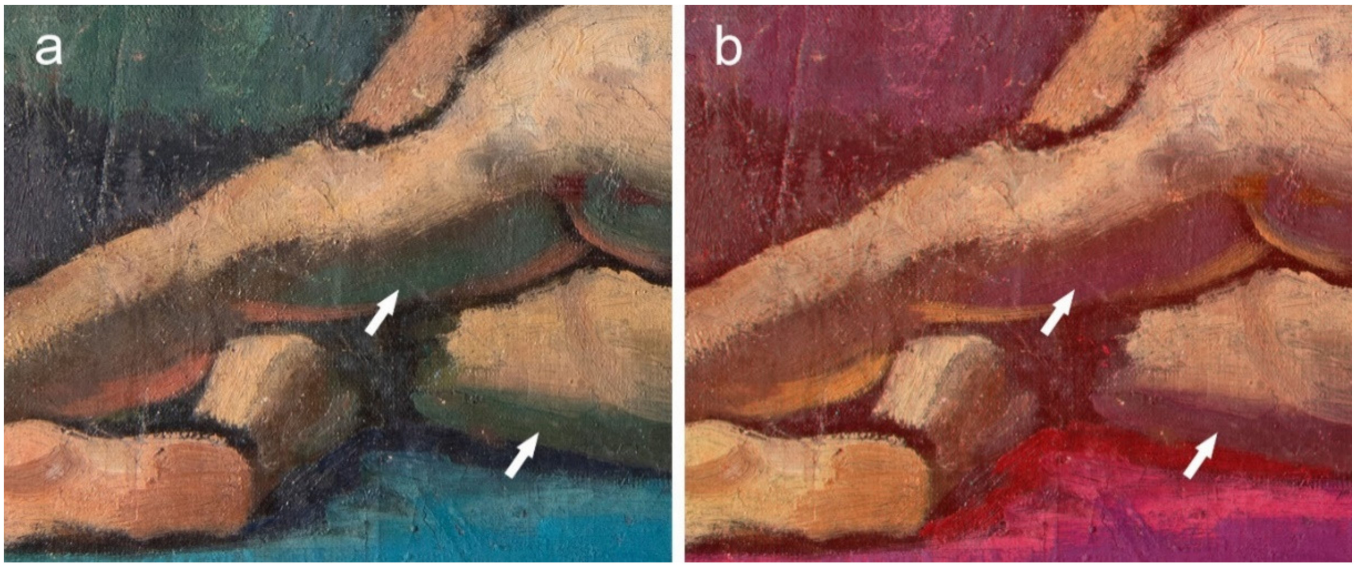

Figure 9. Detail of *Nude* (1934), illustrating the greenish mid-tones imaged in VIS (**a**) and purple IRFC result (**b**).

The palette of colours identified in the drapery setting is limited. Viridian and ultramarine prevail in all three blue tones (sample 6, 7, 8). Although a detection of an intensive IR absorption peak at 797 cm^{-1} (sample 6) was not satisfactory to make an unequivocal attribution to viridian [36], the combined evidence provided by PLM and SEM-EDS was sufficient to confirm the presence of this pigment. Interestingly, for the execution of a green backdrop, the artist incorporated ultramarine and yellow iron-containing earth pigment instead of viridian (sample 4). Elemental analyses of the white paint extracted from a white painted pillow (sample 9) enabled us to infer that the mixture is probably composed of lithopone and/or barium white and zinc white with admixtures of chalk and titanium white (PW6).

3.1.3. Nude (1940)

Here, the model's body was depicted without exploiting the potential of the cool mid-tones, which were successfully used in two earlier artworks. The figure was painted almost monochromatically using tints of yellow iron-containing earth pigment (sample 11, 12)

with added white paint, probably comprising lithopone and/or barium white and zinc white, chalk, titanium white and lead white. The composition of the white admixture is converging with the analyses of the white paint extracted from the pillow (sample 8). A dark brown paint (sample 10) used to delineate the model's shape is composed predominantly of umber, bone black, traces of Cr-containing yellow(s) [39] and white paint resembling that identified in sample 8. The black used for the model's hair (sample 9) is a mixture of bone black with yellow iron-containing earth pigment and ultramarine brightened with some white paint of similar composition as that identified in sample 8. Additionally, the paint mixture probably includes cadmium yellow (PY35) contamination based on the trace Cd- and S-signals. However, a coinciding presence of Ba and Zn elements may account for cadmopone (co-precipitated cadmium sulfide and barium sulfate) or zinc-modified light cadmium yellow [40].

The blue vertical strip of the background primarily consists of ultramarine with trace admixtures of bone black and Prussian blue (sample 14). This blue pigment in combination with the yellow iron-containing earth pigment and viridian was used for a green background (sample 2). The PLM and SEM-EDS analyses of the red paint from the ornament (sample 15) suggest the presence of organic red on Al-based substrate. A yellow ochre admixture is assumed based on the occurrence of Fe as well as on PLM observation and IR absorption peaks at 3691, 3619, 1026, 1007 and 913 cm^{-1}. Furthermore, the presence of ultramarine was detected by PLM, SEM-EDS and some FTIR absorption peaks at ca. 1000 (overlapping stretching bands for Si-O-Si and Si-O-Al masked by yellow ochre band), 680 and 660 cm^{-1} [41].

A yellow surface underneath the model was achieved with two types of yellow paint (sample 6, 7). A suite of elements indicative of cadmium yellow or its variant was found in sample 6. FTIR did not enable the precise characterisation of cadmium yellow due to its fundamental bands falling outside of the spectral range of the instrument [40]. A mixture predominantly composed of yellow iron-rich earth pigment was detected in sample 7.

Cadmium orange (PO20) and barium white or cadmium orange lithopone (co-precipitated cadmium sulfoselenide and barium sulfate) are probably the main ingredients of the orange paint extracted from the edge of the resting area (sample 5). The pigments are suggested based on the SEM-EDS detection of Ba, Cd, S and Se. An admixture of some organic red on Al-containing substrate was assumed based on the PLM observation and detection of Al-signal. The green space beneath (sample 3) primarily consists of ultramarine and yellow iron-containing earth pigment. The latter pigment appears as a main component of a few isolated yellow brushstrokes in that area (sample 4).

3.1.4. Nude (1992)

In this painting, the female body was executed almost monochromatically with minimal modelling of the form resembling the painting approach to *Nude* (1940). Two samples extracted from the highlight (sample 5) and mid-tone (sample 6) reveal the use of complex mixtures of pigments. The highlights were achieved by mixing umber with some organic red on Al-containing substrate and bone black brightened with titanium white, zinc white, chalk and lead white. FTIR analyses of the mid-tone paint enabled the identification of synthetic alizarin lake (PR83:1) by some characteristic absorption peaks at 1640, 1592, 1350, 1260, 1043 and 720 cm^{-1} [42]. The mid-tone paint also contains red iron-rich earth pigment and trace admixtures of cadmium yellow or its variant and bone black. The intensity of the paint was probably controlled by adding titanium white extended with chalk, lead white, lithopone and/or barium and zinc whites. The dark hair (sample 7) was achieved by mixing bone black with umber and probably modified with some white paint; however, the complexity of the investigated paint makes it difficult to ascertain the exact ingredients of white admixture.

The analyses of two paint samples (sample 1, 8) from the background confirmed a consistent presence of red iron-rich earth pigment, bone black and white paint composed of titanium, zinc, lead whites and chalk. The red paint from an apple (sample 2) contains a

synthetic alizarin lake on aluminium-based substrate confirmed by FTIR absorption peaks at 1636, 1589, 1528, 1464, 1360, 1348, 1287, 1267, ca. 1030, 838, 719, 670 and 655 cm^{-1} and SEM-EDS Al-signal (Figure 10) [42–44]. This pigment was combined with cadmium yellow or its variant, red iron-rich earth pigment, some bone black and white, probably of a similar composition as that identified in sample 6. The highlight brushstroke from the apple (sample 4) contains a mixture of cadmium yellow and/or orange or their variants, yellow iron-containing earth pigment, synthetic alizarin lake and a good deal of commonly used white paint such as that identified in samples 2 and 6.

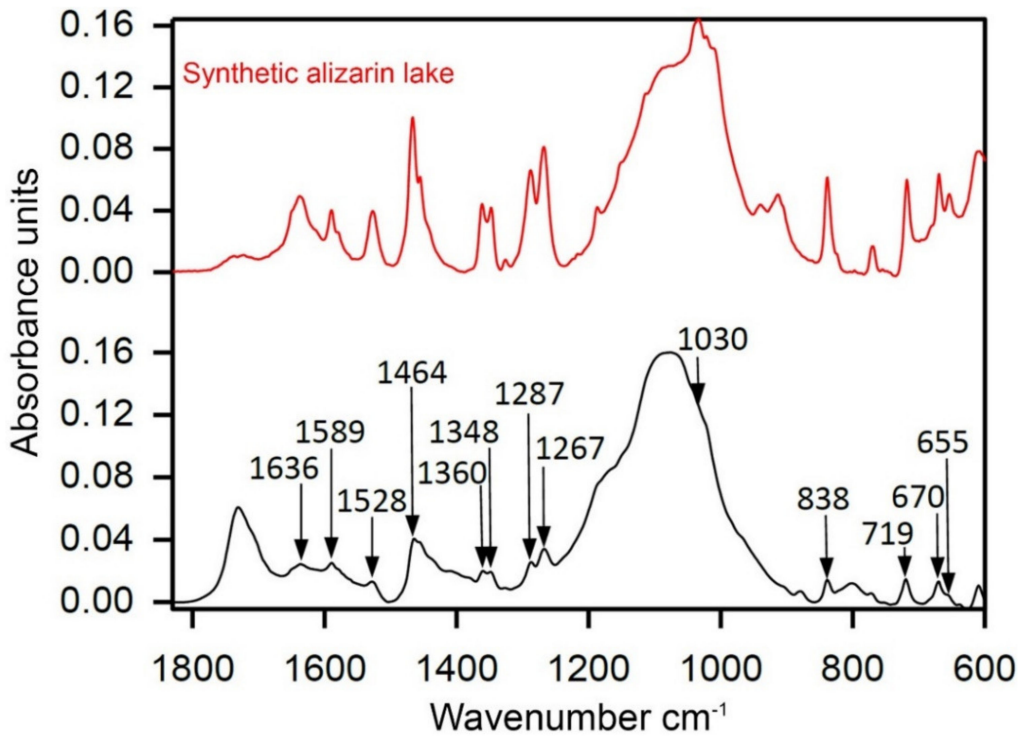

Figure 10. ATR-FTIR spectra of the red paint of sample 2 extracted from *Nude* (1992), with labelled marker peaks of synthetic alizarin lake and reference spectra of the same pigment.

3.1.5. Nude (1995)

The colour of the skin of the model on the left (sample 6) was obtained by mixing yellow and red iron-containing earth pigments with titanium and zinc whites and chalk; however, that paint mixture was modified for the skin colour of the opposite model (sample 7) by adding cobalt blue (PB29), observed with PLM (isotropic particles with a high refractive index that appear red with Chelsea filter) and by detection of concomitant Co and Al elements (Figure 11a,b). Cool mid-tones of the carnations were made with violet paint (sample 12) obtained with ultramarine mixed with red iron-containing earth and synthetic alizarin lake on Al-based substrate. The synthetic alizarin lake was suspected by its characteristic absorption bands at 1465, 1361, 1288, 1266, 1026, 840, 802, 771, 719 and 681 cm^{-1} [42,45]. The intensity of the violet paint was modified with bone black as well as white pigments such as lithopone and/or barium white and zinc white, chalk and some titanium white. Brown outlines were obtained by mixing yellow iron-containing earth pigment with some bone black, titanium and zinc whites (sample 10). For painting strokes of the black hair of the left-hand side model, the artist incorporated bone black, ultramarine, yellow iron-containing earth pigment with white paint made of lithopone and/or barium white and zinc white admixed with titanium white and chalk (sample 11).

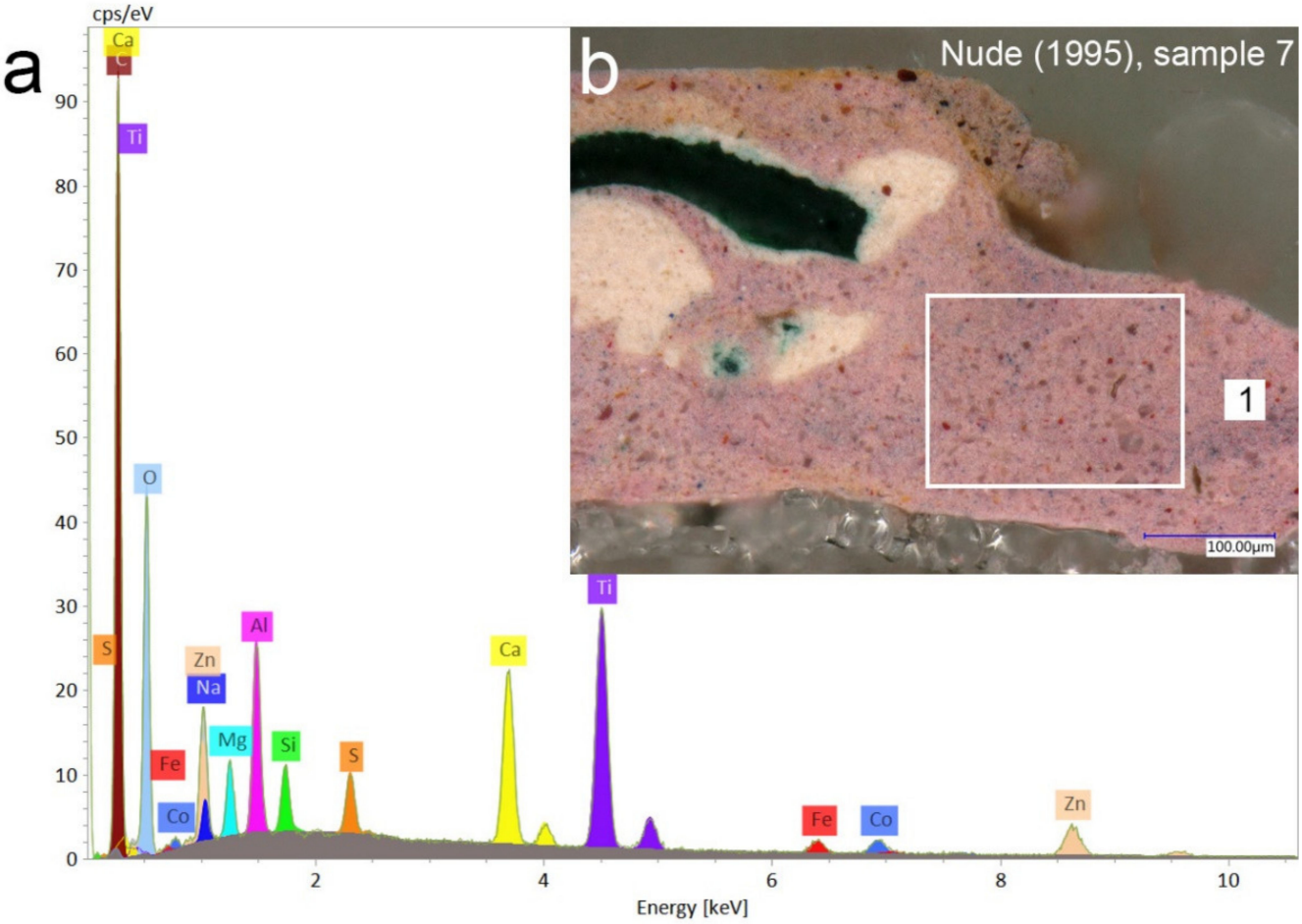

Figure 11. (**a**) SEM-EDS spectra of the pink paint from layer 1 of sample 7 extracted from *Nude* (1995); (**b**) optical microscopy image of the cross-section of the sample at 200× magnification, with marked area of analyses.

The dark blue background (sample 4) is made of cobalt blue with some lithopone and/or barium and zinc whites, chalk and trace presence of titanium white. Although a strong IR absorption band at 643 cm^{-1} was not sufficient to pinpoint cobalt blue, a combined PLM observation and SEM-EDS analysis enabled us to suspect this blue pigment [26]. The FTIR detection of absorption peaks at 1060 and 800 cm^{-1} combined with PLM and SEM-EDS analyses of a green paint from the green backdrop (sample 3) seem to point to viridian as the main component [36]. This pigment was admixed with yellow iron-containing earth pigment, cadmium yellow or its variant, bone black and a common type of white paint already characterised earlier. A concomitant presence of viridian and cadmium yellow may also be attributed to commercially prepared cadmium green. Red paint touches from the green backdrop (sample 8) contain a mixture of red iron-rich earth, organic red on Al-based substrate, bone black and traces of Cr-containing yellow(s) with frequently occurring white paint composition. The other red (sample 9) is a mixture of two different red paints applied wet-on-wet. The upper layer predominantly consists of the red iron-containing earth in combination with synthetic alizarin lake on Al-based substrate. FTIR provided the positive detection of the synthetic alizarin lake by absorption peaks at 1590, 1465, 1362, 1350, 1288, 1187, 1154, 1025, 839, 797, 771, 745, 719 and 671 cm^{-1}, which are consistent with the reference spectra [42,45]. Moreover, the investigated paint contains some admixtures of cadmium yellow or its variant, bone black and frequently occurring white paint composition. The bottom layer is composed mainly of red azo pigment naphthol red AS-D (PR112), identified by the absorption peaks at 3277, 3238, 3189, 3127, 3076, 3028, 1668, 1604, 1593, 1545, 1493, 1478, 1447, 1384, 1363, 1324, 1279, 1257, 1237, 1197, 1154, 1109,

1083, 1037, 1012, 964, 905, 890, 863, 749, 696 and 664 cm^{-1}, and red iron-rich earth. The SEM-EDS detection of strong Cl- and Sn-signals could be linked with another organic red on Sn-substrate [46,47] however, FTIR did not validate this presumption. In addition, the mixture of pigments was brightened with commonly used white paint.

3.1.6. Two Nudes (1996)

The analyses of sample 1 extracted from the pink coloured skin indicate the presence of red iron-rich earth pigment. The principal component of the red painterly contours of the shapes (sample 2) is naphthol red AS-D confirmed based on the absorption peaks in the FTIR spectrum at 3274, 3235, 3186, 3124, 3075, 3027, 1667, 1603, 1594, 1544, 1493, 1478, 1447, 1386, 1364, 1324, 1279, 1258, 1238, 1197, 1154, 1112, 1084, 1046, 1013, 964, 905, 890, 862, 748, 697 and 666 cm^{-1} (Figure 12) [48]. A detection of strong Cl- and Sn-signals may be ascribed to organic red on Sn-containing substrate; however, FTIR measurement did not confirm its presence. Therefore, a precise identification of the constituents of the investigated red paint would require the application of Raman spectroscopy or chromatography. Trace admixtures of red iron oxide, bone black, titanium white, chalk, lithopone and/or barium and zinc whites were also assumed. The paint sample from the uniform brown-red background (sample 3) was found to have the same constituents as sample 2; however, they were mixed in a different ratio, and red iron-containing earth is a prevailing pigment.

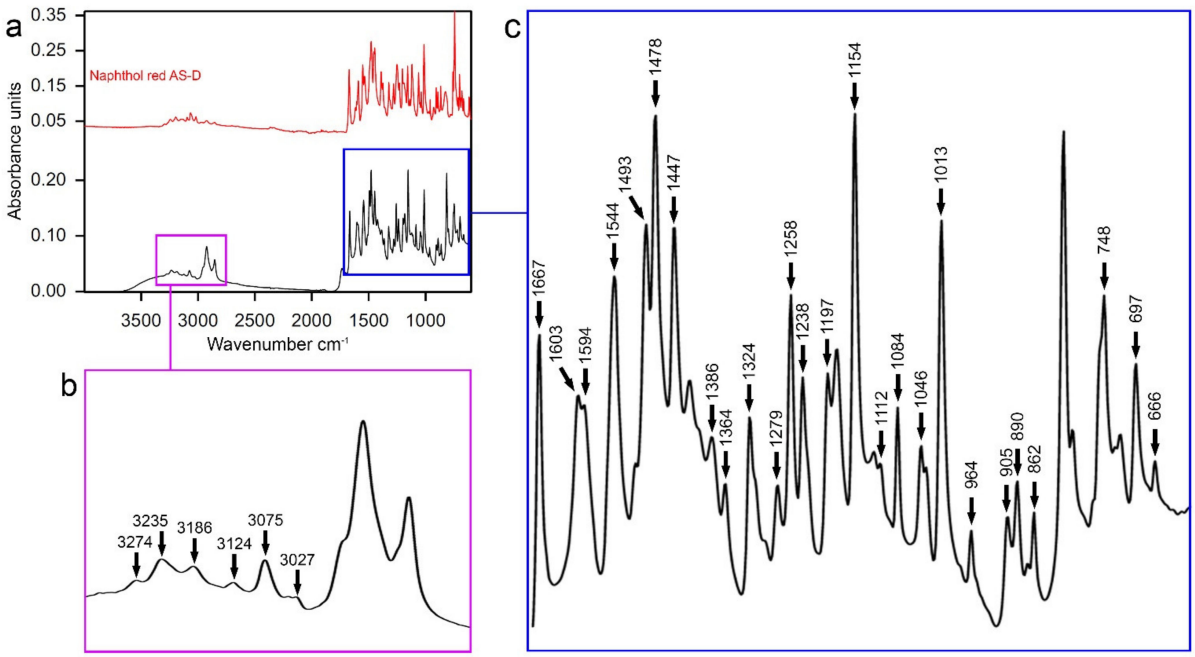

Figure 12. (**a**) ATR-FTIR spectra of the pink paint of sample 2 extracted from *Two nudes* (1996), with labelled marker peaks of naphthol red AS-D and reference spectra of the same pigment; (**b**) a scale expansion of the spectra of the sample from 2700 to 3300 cm^{-1}; (**c**) a scale expansion of the spectra of the sample from 600 to 1700 cm^{-1}.

3.1.7. Beauties at Rest II (1998)

The skin colours of the two models are determined by a predominant use of orange and red paints. The orange paint (sample 9) was found to be primarily made of yellow iron-containing earth pigment and cadmium yellow or its variant light cadmium yellow, based on the detection of Zn, Fe, Cd and S elements (Figure 13a,b). The elemental analyses of the red paint (sample 10) indicated a concomitant presence of Cd, Ba, S and Se, whereas the FTIR measurement exhibited characteristic absorption bands for lithopone or barium sulfate at 1174, 1104, 1065, 983, 635 and 606 cm^{-1}. This outcome seemed to point to cadmium orange and/or cadmium red co-precipitates with barium sulfate (PO20:1 or PR108:1) known as

cadmium orange/red lithopones [40,49,50] (Figure 13c,d). Moreover, the PLM and SEM-EDS analyses seem to suggest an admixture of organic red on Al-based substrate and a trace presence of red iron-containing earth pigment, which together contribute to the intense red hue of the investigated pigment mixture. Randomly applied green paint brushstrokes found on the orange model are probably composed of Cr- or Co-containing green based on its purple appearance in IRFC. The black paint used for depicting the models' hair (sample 13) was achieved by mixing bone black with blue pigments such as ultramarine and phthalocyanine blue (PB15). Although, the FTIR measurements provided the peculiar IR absorption peak at 1024 cm^{-1} (overlapping stretching band for Si-O-Si and Si-O-Al), which is insufficient to declare the identification of ultramarine, the additional PLM and SEM-EDS analyses contributed to the detection of this blue pigment. Phthalocyanine blue was detected by peaks at 1605, 1591, 1508, 1419, 1334, 1287, 1166, 1119, 1090, 900, 872, 769, 754 and 720 cm^{-1} as well as SEM-EDS detection of a Cu-signal (Figure 14a) [51–54].

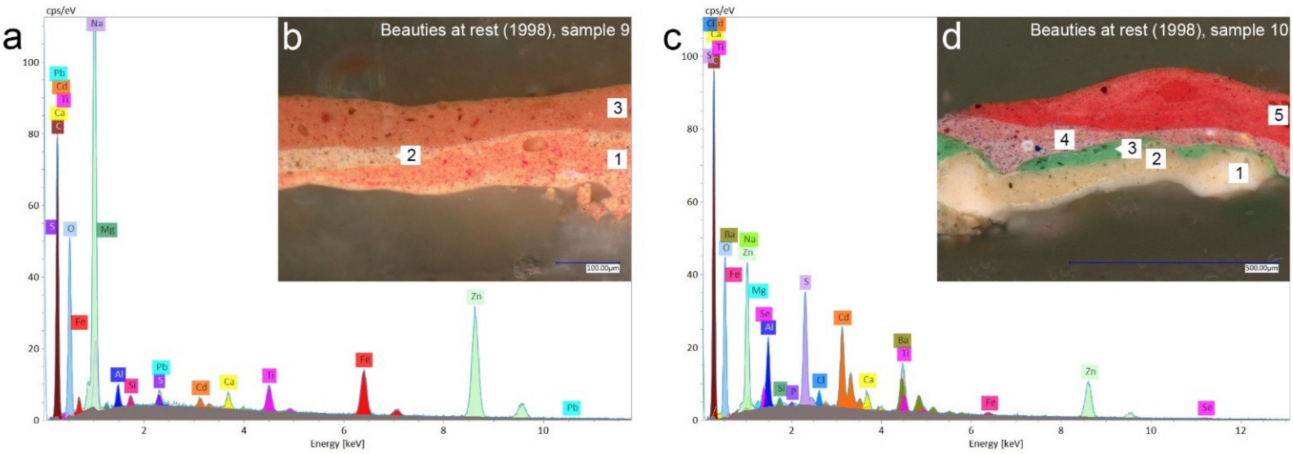

Figure 13. (**a**) SEM-EDS spectra of the orange paint from layer 3 of sample 9 extracted from *Beauties at rest II* (1998); (**b**) corresponding optical microscopy image of the cross-section of the sample at 200× magnification; (**c**) SEM-EDS spectra of the red paint from layer 5 of sample 10 extracted from *Beauties at rest* (1998); (**d**) corresponding optical microscopy image of the cross-section of the sample at 200× magnification.

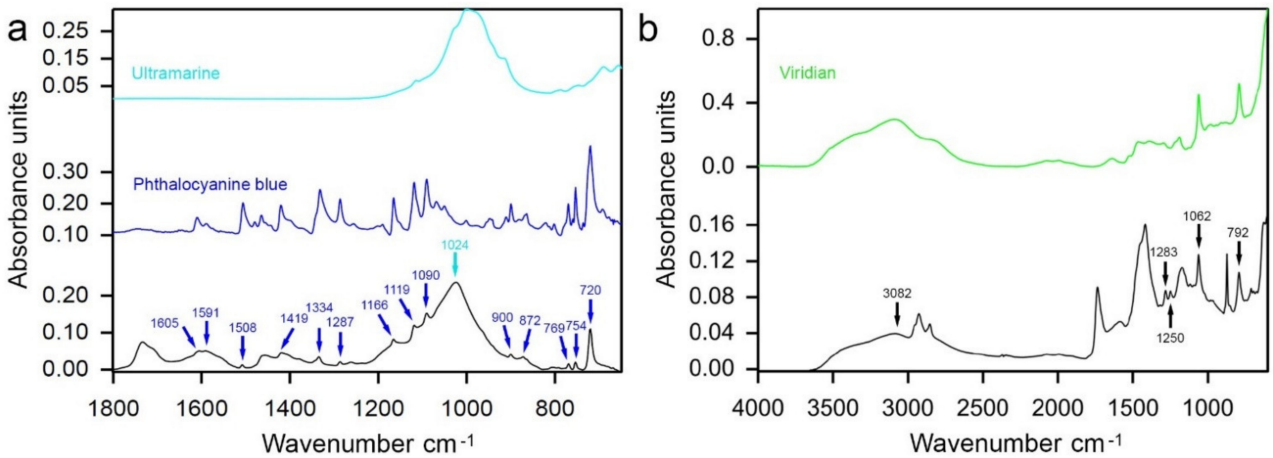

Figure 14. (**a**) ATR-FTIR spectra of the black paint of sample 13 extracted from *Beauties at rest II* (1998), with labelled (dark blue) marker peaks of phthalocyanine blue and ultramarine (light blue) and reference spectra of the same pigments; (**b**) ATR-FTIR spectra of the green paint of sample 3 extracted from *Beauties at rest II* (1998), with labelled marker peaks of viridian and reference spectra of the same pigment.

The principal pigment of the green paint (sample 3) extracted from the vertical stripe of the background is viridian confirmed with FTIR by absorption bands at 3082, 1283, 1250, 1062 and 792 cm^{-1} (Figure 14b) [36]. A blue carpet involved two hues of blue composed of different ingredients as visualised in IRFC imaging (Figure 15). Light blue (sample 11) applied with a palette knife was prepared by mixing ultramarine with Prussian blue (PB27). The latter was identified by PLM observation (dark blue isotropic particles, which appear dark green under a Chelsea filter and have a low refractive index), SEM-EDS detection of an Fe-signal and FTIR absorption peak at 2081 cm^{-1} (C≡N stretching). A trace presence of cadmium yellow or its variant is considered here as contamination. The analyses of the pigment mixture are consistent with dark violet imaging of the sampling area in IRFC, as the resultant colour is determined by the dark blue representation of Prussian blue combined with a purple representation of ultramarine. Dark blue (sample 6) was dabbed with a small brush over the lighter hue. The detection of Cu and IR absorption peaks at 1506, 1420, 1336, 1165, 1118, 1088, 901, 878, 770, 754 and 722 cm^{-1} permitted phthalocyanine blue attribution [51–54]. In addition, the artist added some ultramarine to modify the hue. Ultramarine was confirmed by absorption bands at 1022 and 680 cm^{-1} [41]. This outcome is consistent with the red appearance of the sampling area in IRFC as both phthalocyanine blue and ultramarine turn red. The brown paint used to characterise the floor panels (sample 8) is a mixture of ultramarine, synthetic alizarin lake on Al-containing substrate, red iron-rich earth, bone black, trace presence of cadmium yellow or its variant and Cr-containing yellow or green pigment(s). White paint extracted from the pillow (sample 7) is a combination of titanium white, lithopone and/or barium and zinc whites as well as chalk. Some contamination with red iron-containing earth, viridian and ultramarine were also detected. Nevertheless, the major constituents of the analysed white paint appear consistently in all pigment mixtures discussed here, probably as the artist's addition.

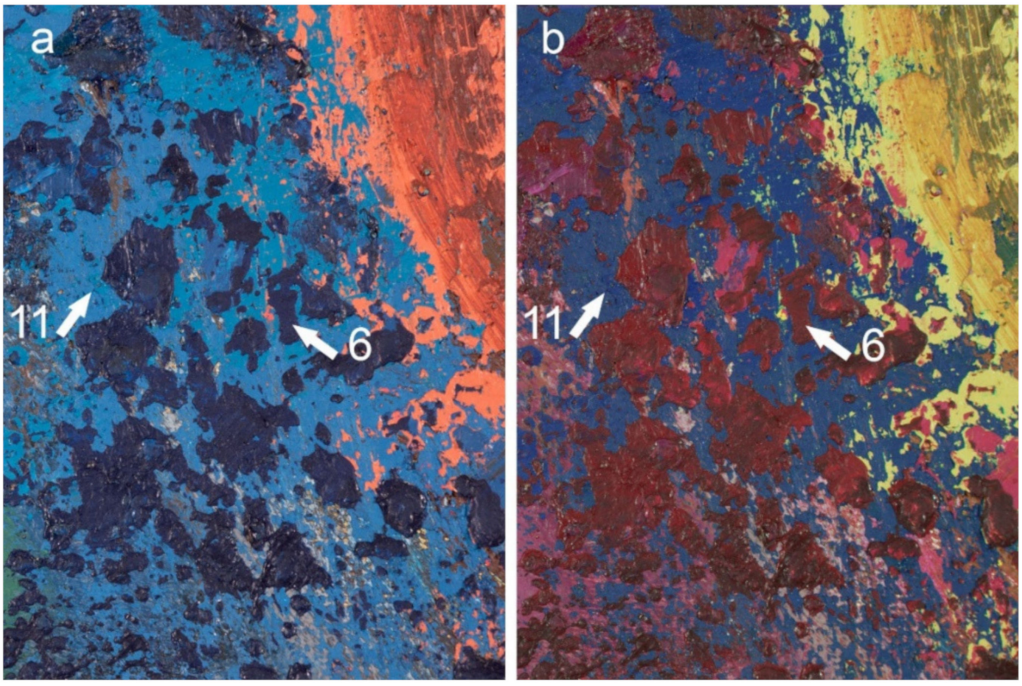

Figure 15. Detail of *Beauties at rest II* (1998), imaged in VIS (**a**) and IRFC (**b**). The arrows indicate the sampling spots of two different blues.

3.1.8. In Conversation (1999)

The female bodies were executed by the pointillist application of complementary colours. Thus, the yellow paint brushstrokes (sample 7) are rich in yellow iron-containing earth. Red (sample 6) contains red iron-containing earth in combination with Cr-based yellow pigment(s) and probably organic red on Al-based substrate. Unfortunately, the

overlapping intensive signals for chalk and oil hampered the FTIR identification of the organic red. Blue (sample 11) is composed of ultramarine and some Prussian blue confirmed with FTIR by the absorption peak at 2093 cm^{-1}.

The green background is composed predominantly of viridian (sample 9), while blue paint used for the foreground is composed of ultramarine and phthalocyanine blue (sample 3, 4). However, a small concentration of Fe, Cr, P and Ca elements recorded with SEM-EDS and combined with PLM observation of sample 3 suggest minor admixture or contamination with Prussian blue, viridian and bone black. A light tint of this blue mixture was achieved with the abundance of titanium white, probably admixed with chalk, lithopone and/or barium white and zinc white.

3.1.9. Binders and Other Identified Compounds

The binder for all identified pigment mixtures is drying oil, as confirmed with FTIR analyses and reported in Appendix A, Table A1. This spectroscopic technique enabled the detection of typical IR absorption peaks at 2923, 2853, 1738, 1460, 1375, 1235, 1160, 1098 and 720 cm^{-1} in most of the investigated paint samples [55,56]. Another important result of this study is the detection of zinc soaps in the paint samples extracted from six paintings, by FTIR absorption band at 1540 cm^{-1} [57,58]. They had likely formed as products of the chemical reaction between the saturated fatty acids of the lipid-based binder and the metal ions of the zinc-containing pigments present in the paint layers. The formation of metal soaps appears to be a common feature of Liu Kang's paintings [2,18,19]; however, no deterioration signs linked to the metal soaps have been observed. Nevertheless, special attention should be paid when designing display and storage conditions as well as conservation treatments of Liu Kang's paintings as high humidity promotes the formation of the soaps [59–63].

3.2. Preparatory Underdrawings and Sketching Studies

VIS examination of *Two nudes* (1996) revealed a preparatory drawing executed with thin and fluid red and blue crayon lines over the pink underpaint, then refined with the painterly bold and red contours in the following step (Figure 16). The examination of the remaining seven paintings did not evidence the preparatory underdrawings in VIS or NIR. This observation converges with the authors' research that focused on Liu Kang's earlier artistic periods, where only a few instances of sketches over the prepared ground layer were found in the paintings from the 1950s [19]. Hence, Liu Kang's practice of making preparatory underdrawings remains relatively unknown. The possible explanation could be that the underdrawings must have been very simple and below NIR detection, or the artist laid out the general composition with rough brushstrokes and subsequently blended them into the painted surface. Such an approach to this initial artistic process finds confirmation in a revealing description given by the artist's son, Liu Thai Ker: "After he decides on the subject matter, he studies the various on-location sketches and re-organises the composition of these sketches with more sketch studies to suit his artistic intention. When he gets something he is satisfied with, the image is transferred in broad simple lines on to the canvas" [5]. Hence, more information on the development of the compositions of nudes can be gathered from the artist's sketches on paper.

A signed and dated (1992) pen drawing of two nudes was probably used as a reference for *Nude* (1995) (Figure 17a,b). The drawing reveals that the model on the left was initially semi-reclining, whereas the final painting shows the model in a seated pose. That change enabled the artist to avoid placing any resting structure behind her back, hence resulting in a simpler composition. The pose of the second model from the drawing remains unchanged in the painted version.

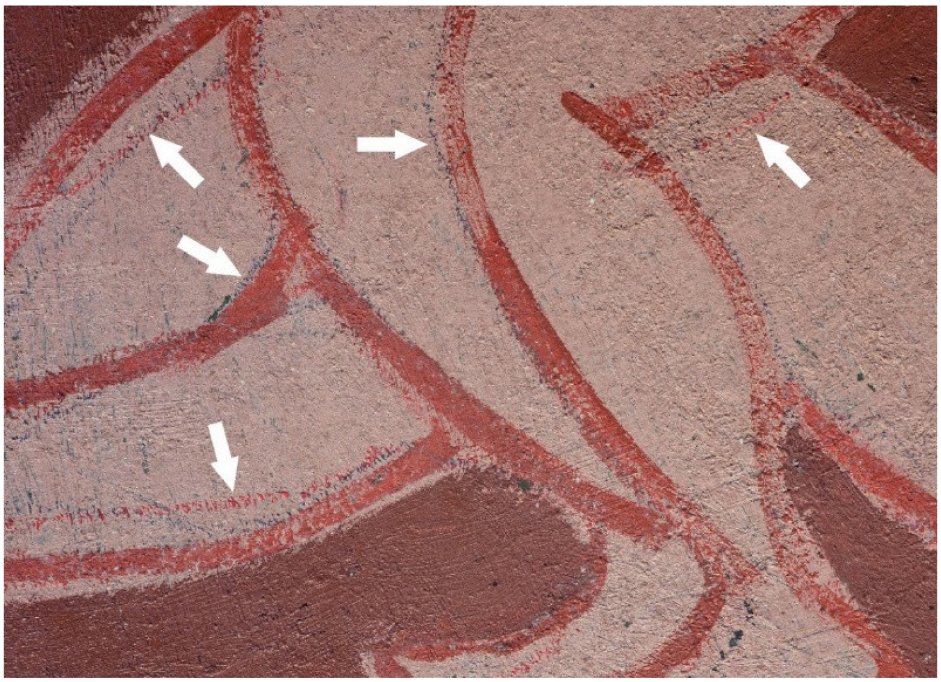

Figure 16. Detail of *Two nudes* (1996) indicating the preparatory drawing executed with red and blue crayon lines over the pink underpaint.

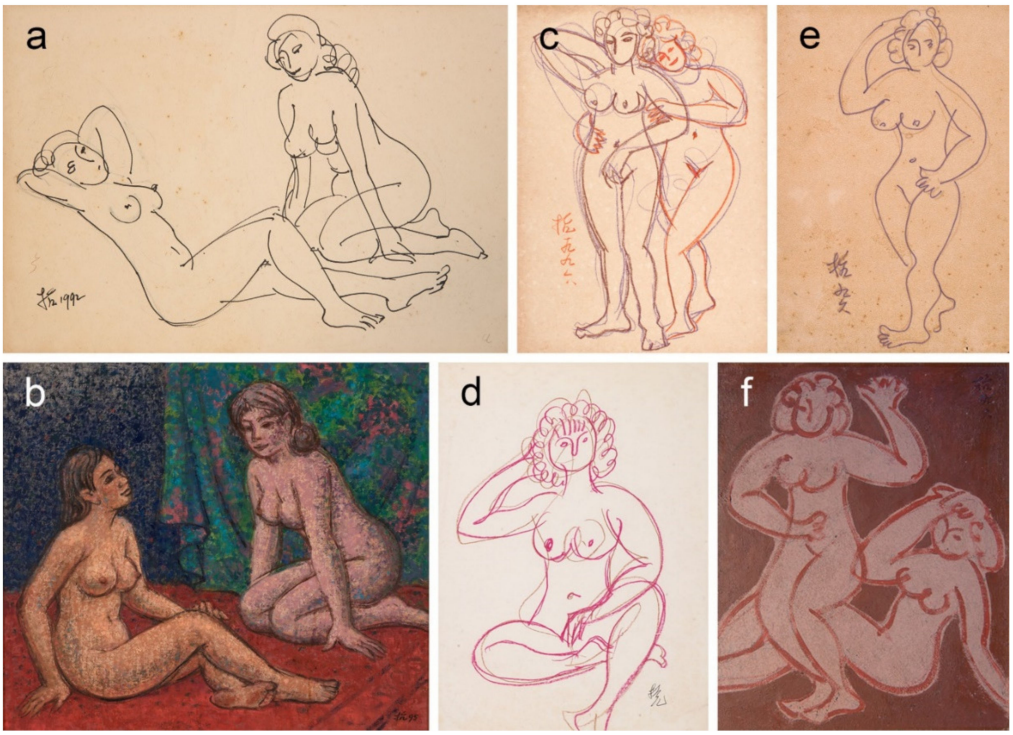

Figure 17. (**a**) Liu Kang, *Nude*, 1992, pen on paper, 26.5 × 38.5 cm. Liu Kang family collection. Image courtesy of Liu family. (**b**) Liu Kang, *Nude*, 1995, oil on canvas, 66 × 76 cm. (**c**) Liu Kang, *Nude*, 1996, crayon on paper, 37 × 27 cm. (**d**) Liu Kang, *Nude*, undated, crayon on paper, 24.5 × 17.5 cm. (**e**) Liu Kang, *Nude*, 1996, pen on paper, 34 × 23.5 cm. (**f**) Liu Kang, *Two nudes*, 1996, oil on board, 43 × 36 cm. Images (**c**–**e**) are gifts of the artist's family. Collection of National Gallery Singapore.

In three crayon sketches from 1996 (Figure 17c–e), the artist explored the theme of nudes in a unique expression characterised by distorted forms, radical reduction of detail and reliance on intricate and fluid lines, which subsequently were adopted for the

preparatory underdrawing of *Two nudes* (1996) (Figures 16 and 17f). The style of the sketches suggests that the artist strove to depict the figures in a way that evokes Matisse's drawing series of models from 1941 [64].

A series of four sketches executed with crayon and pencil, exploring reclining models in playful poses, reveals the artist's attempt to establish the general composition of the scene and determine the best poses of figures for the painting *Beauties at rest II* (1998) (Figure 18a–e). A date, 1982, on one of the sketches (Figure 18a) suggests that the initial conceptualisation work was carried out 16 years before the painting was created. Moreover, the archival date-stamped photograph from 1993 shows an unknown but seemingly similar painted version of two female nudes (Figure 18f), allowing us to infer that the artist was very satisfied with the achieved composition, which resulted in different versions of the painted scene.

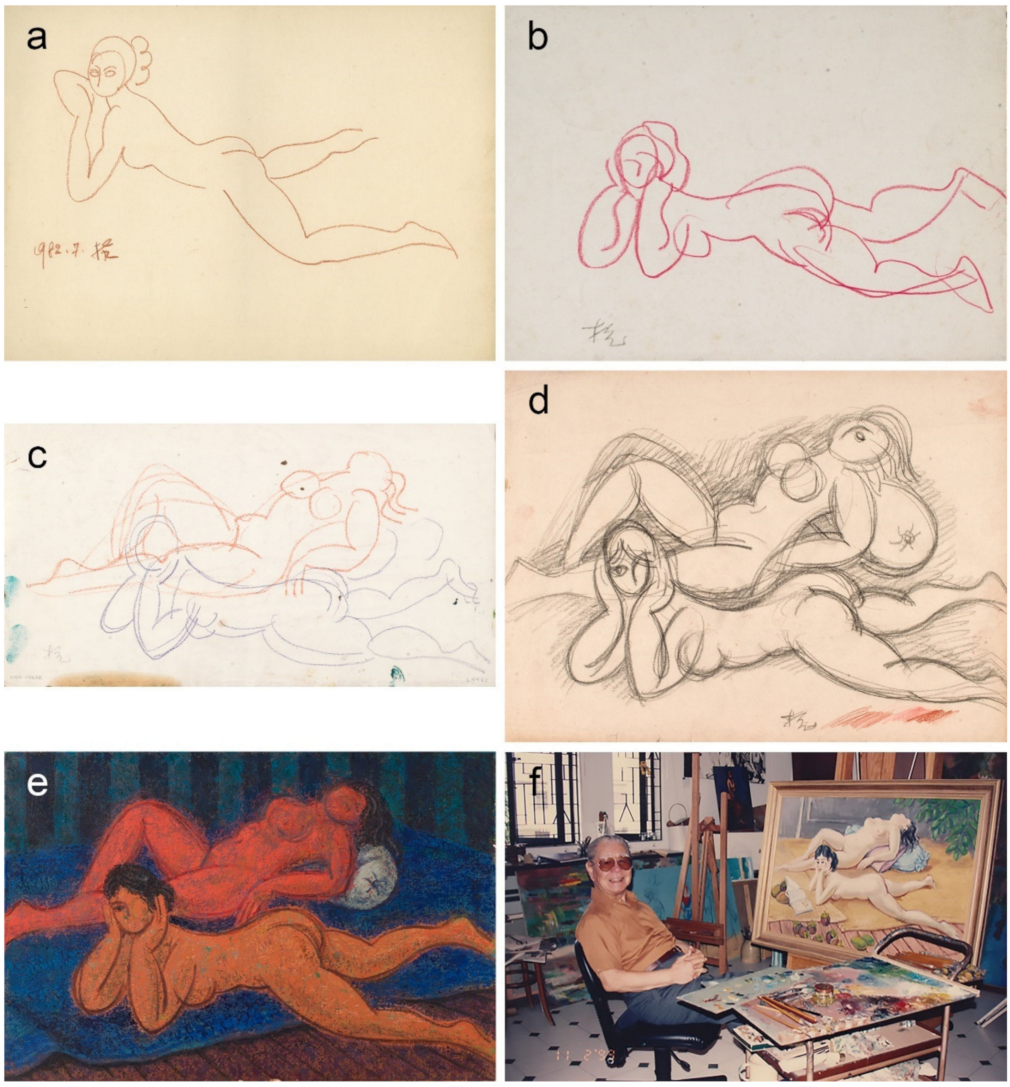

Figure 18. (**a**) Liu Kang, *Nude*, 1982, crayon on paper, 37 × 27.5 cm. Liu Kang family collection. Image courtesy of Liu family. (**b**) Liu Kang, *Nude*, undated, crayon on paper, 15.1 × 21 cm. (**c**) Liu Kang, *Beauties at rest (sketch study)*, undated, crayon on paper, 19 × 34.5 cm. (**d**) Liu Kang, *Beauties at rest III (sketch study)*, undated, crayon on paper, 27 × 36.7 cm. Images (**b**–**d**) are gifts of the artist's family. Collection of National Gallery Singapore. (**e**) Liu Kang, *Beauties at rest II*, 1998, oil on canvas, 85 × 127 cm. (**f**) The 1993 archival photograph of the artist at his earlier version of the nude painting. Liu Kang family collection. Image courtesy of Liu family.

The painting *In conversation* (1999) was inspired by an undated black and red crayon sketch of two female nudes depicted in relaxed sitting positions (Figure 19). A comparison of that initial idea recorded on the paper with the final painting reveals a minor alteration of the distance between the figures and some changes in their gestures. A sense of the depth of the painted composition was enhanced by enlarging the model on the left.

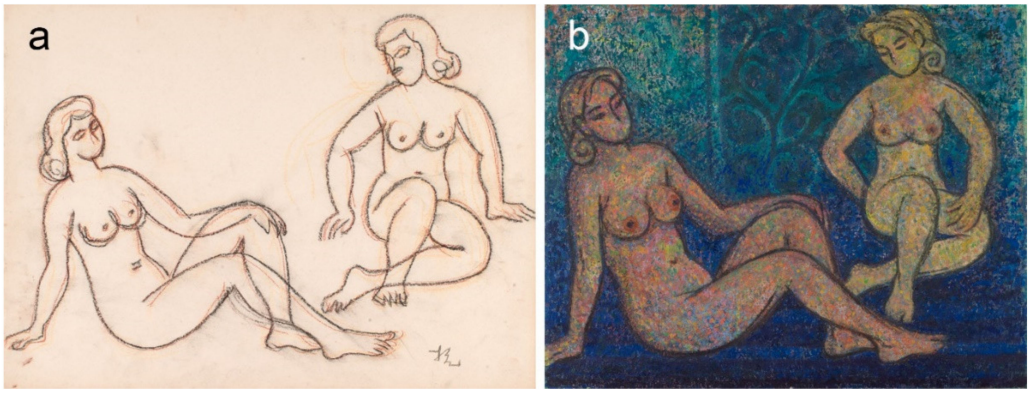

Figure 19. (**a**) Liu Kang, *Nudes*, undated, crayon on paper, 27 × 37 cm. Gift of the artist's family. Collection of National Gallery Singapore. (**b**) *In conversation*, 1999, oil on canvas, 61 × 76 cm.

3.3. Execution of the Paintings

The model in *Nude* (1927) was depicted in a classical way, without any exaggeration of forms or colours. The artist attempted to capture the charm and dimensionality of her body by using suggestive light effects and avoiding strong outlines. Based on the archival photograph taken on the day when the artwork was created, during a live nude painting class at Xinhua Arts Academy in Shanghai, Liu Kang used small and medium-sized brushes that required complex manipulation of the paint, resulting in the creation of the substantial texture (Figure 20a–d). This visible aspect of the painting correlates with the OM of the paint's cross-section (sample 7), exposing a wet-on-wet execution (Figure 7).

A thick and vigorous brushwork of *Nude* (1934) reflects Modernists' influences as it was created after Liu Kang's return from Paris (Figures 2b and 20e). The paint layer was applied with bigger brushes, showing the quality and confidence of the paint strokes that render light effects on the model's body.

That modernist trend can be observed in *Nude* (1940), which is another bold step forward in the evolution of the painterly depiction of the subject (Figure 2c). The composition is characterised by reduced light effects negating the illusion of depth. Hence, the artist rendered the setting with strong colour block division to differentiate the planes of the composition. The incorporation of broad and dark contours to enhance the forms seems justified. However, judging from Liu Kang's strong connection to Chinese tradition, the bold contours can represent inspiration with Chinese ink painting.

Liu Kang's return to the subject of nudity in the 1990s reflects an accomplished artist who enjoyed new painting approaches and tried to make up for lost time. In *Nude* (1992), he departed from the conventional depiction of a model in a realistic setting and adopted an expressionist style, by reducing unnecessary detail to allow the viewer an uninterrupted contemplation of the female's beauty (Figure 2e). Such an idealised approach can be elucidated from his 1989 interview: "The human body is the most beautiful object in nature . . . its form, shape and texture of the skin. It is intricate yet complete and is very difficult to represent" [65]. An apple held by the model creates a strong visual and symbolic accent. The circle or sphere symbolises the perfect form in the art; therefore, the artist might have incorporated the apple to underscore his idea of beauty.

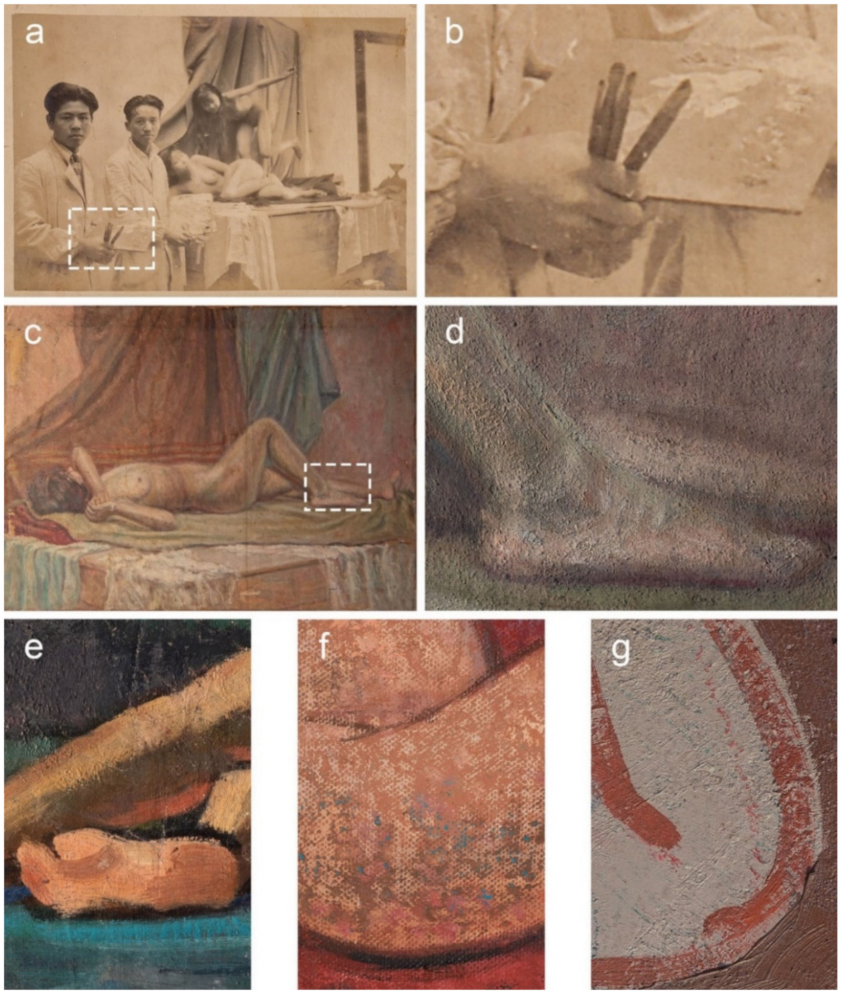

Figure 20. (**a**) The 1927 archival photograph of the artist during a live nude painting class at Xinhua Arts Academy in Shanghai. Liu Kang family collection. Image courtesy of Liu family. (**b**) Detail of the photograph showing the small and medium-sized brushes the artist used probably for the painting of *Nude* (1927) (**c**). (**d**) Corresponding detail of *Nude* (1927), showing the texture of the paint layer. Details of *Nude* (1934) (**e**), *Nude* (1995) (**f**) and *Two Nudes* (1996) (**g**), showing the artist's painting technique for depiction of the models' bodies.

The paint layer in *Nude* (1992) is characterised by broad and decisive brushstrokes that convey a sense of the rapid execution of the composition. However, by the undefined occupation of space by the model and incorporation of fluid contour lines, the style of the painting reflects some influences of Chinese literati painting [66,67], which Liu Kang highly respected as a part of his cultural inheritance [68].

Nude (1995) strikes with a different approach not seen in earlier paintings discussed here (Figure 2d). Instead of one model, the artist depicted two young females sitting and facing each other. The execution of the entire scene was achieved by dragging a thick paint across the textured ground with a stiff brush, thus creating an effect of randomly broken paint flow. This technique is clearly evident in the execution of figures where the skin colour results from layered dashes of tinted paint juxtaposed with the exposed ground layer, assisting in the effect of optical vibration, resembling a pointillist style (Figure 20f). Thus, the artist decisively moved away from the previously employed paint modelling. Bold, sensuous and effortlessly executed strokes of brown paint enhance the shapes of the figures, expressing the artist's notion of beauty. Overall, a new painting approach indicates the artist's willingness to experiment despite his age.

His interest in the form and shape of the female body was translated into the stylised *Two nudes* (1996) (Figure 3a). The colouristic scheme was drastically reduced to three tints of red. The artist employed a palette knife for the flat application of the pink skin colour of the models (Figure 20g). The figures are defined by red fluid brush lines which, together with the intentionally exposed crayon underdrawing contours (Figure 16) and dark background, rapidly executed with brushes, play a significant role in the final aesthetics of the painting.

In conceiving *Beauties at rest II* (1998), Liu Kang followed the original concept reflected in the sketch and depicted the models with limited facial expression (Figure 18a–e). However, most importantly, the artist focused on creating an idealised and eroticised image of the female body by reducing the figures to universal shapes. The realistic skin tones known from the 1993 version of reclining models (Figure 18f) gave way to an expressionistic use of orange and red, which contrasted with the intense green and blue of the setting, revealing a radical interpretation of this composition. Such an approach could have been a result of Liu Kang's deteriorating eyesight. In a 1989 interview, he gave a brief account of his condition after an apparently unsuccessful cornea surgery in 1986: "Of course, there is a difference. The colours are different. I used too much blue and green and my children would point it out to me. I can't paint for periods now. Before, I could paint through the whole day. Now, I get tired. It is a problem" [69]. That unusual painting convention could also have reflected Liu Kang's temperament and susceptibility to varying moods, which dominated his artistic expression [17]. Hence, it is conceivable that this factor could have caused Liu Kang to reject the 1993 version of the composition and reuse it for *Beauties at rest II* (1998). Detailed photography of the latter pointed out that the exposed colour scheme corresponds to the 1993 version of the scene (Figure 21).

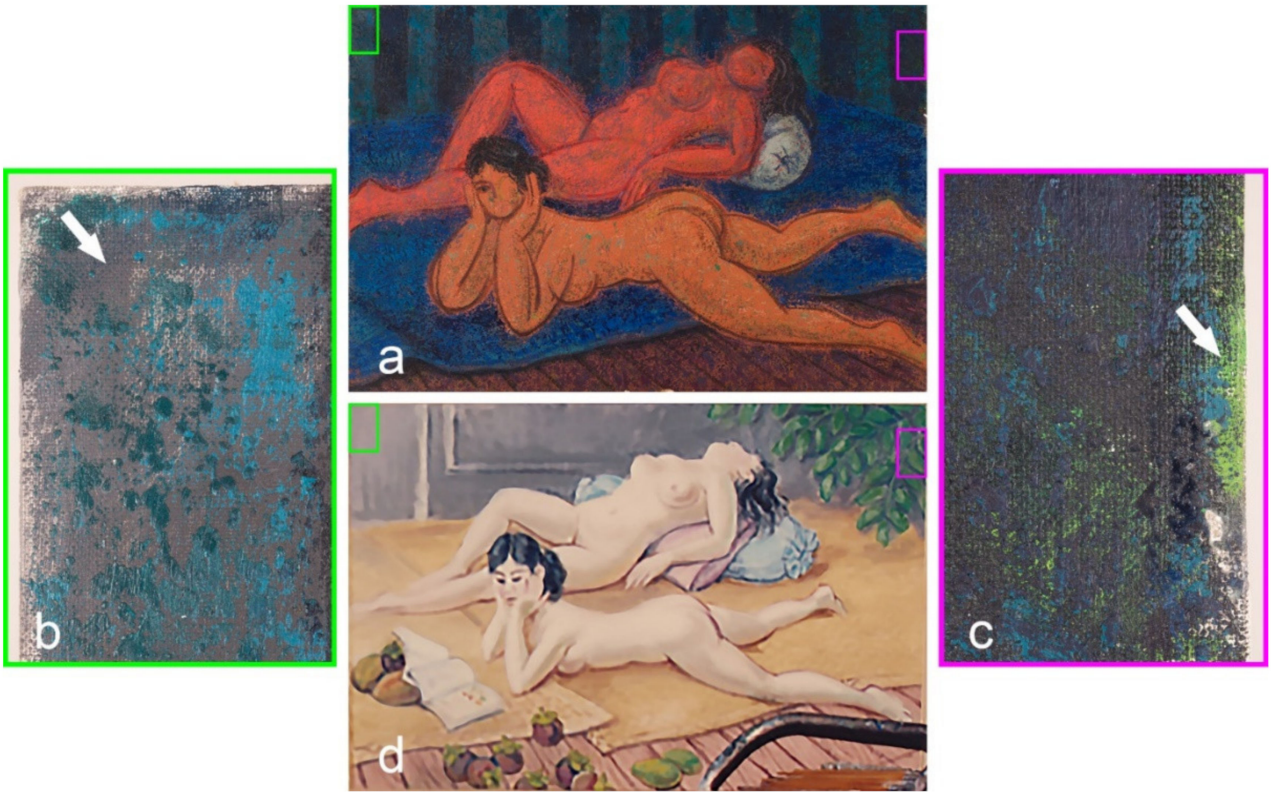

Figure 21. (**a**) *Beauties at rest II* (1998), showing the areas of the exposed colour scheme of the 1993 hidden painted composition (green and pink rectangles). (**b**,**c**) Corresponding details of *Beauties at rest II* (1998) indicating paint of the earlier composition: grey paint (green rectangle) and green paint of (pink rectangle). (**d**) Nude painting from the 1993 archival photograph cropped and transformed with the perspective and distortion control tools of Adobe Photoshop CC. The selected areas show the same colours as found in *Beauties at rest II* (1998) (**b**,**c**).

Subsequent transmitted NIR imaging carried out with the camera facing the front of the painting followed by the XRR, unveiled paint features resembling the leaves of the plant seen in the top-right corner of the 1993 version of the composition (Figure 22a–d). Moreover, the XRR of the bottom-right corner of *Beauties at rest II* (1998) depicted the model in the foreground with an additional pair of legs that could relate to a compositional change made by the artist during the painting process or a hidden nude painting seen in the 1993 photograph. The comparison of the XRR image of *Beauties at rest II* (1998) with VIS of the same painting and the corresponding area of the painting from the 1993 photograph permitted us to distinguish between the legs of the model from both compositions (Figure 22e–g). Thus, the model's right leg from the 1993 photograph depicted with a sense of perspective as much shorter than the left one is clearly seen on the XRR image (Figure 22f).

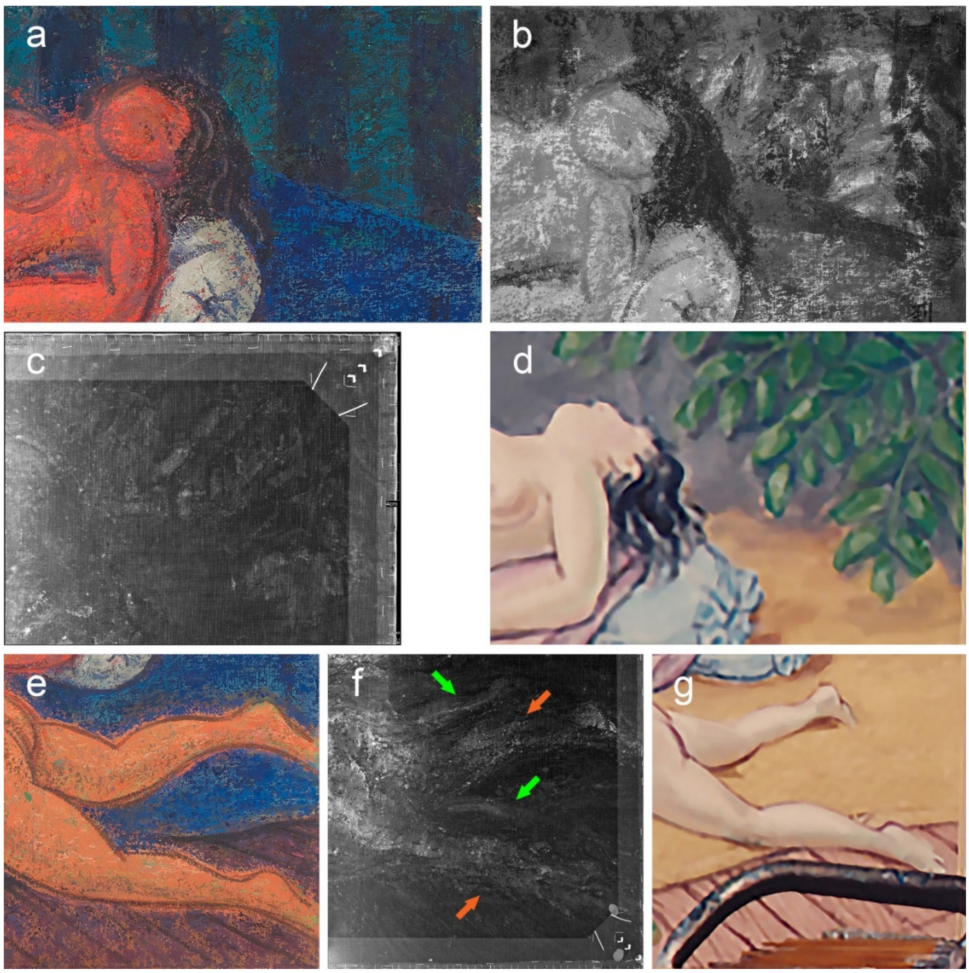

Figure 22. Detail of *Beauties at rest II* (1998) photographed in VIS (**a**) and corresponding transmitted NIR (**b**) and XRR (**c**) images of the same area. The NIR and XRR images reveal the features resembling the leaves of the plant seen in the same area of nude painting from the 1993 archival photograph (**d**). Detail of *Beauties at rest II* (1998) photographed in VIS (**e**) and corresponding XRR image of the same area (**f**). The XRR image reveals the model's legs from *Beauties at rest II* (1998), indicated with the orange arrows, and an additional pair of legs, indicated with green arrows, relating to the figure from the 1993 archival photograph (**g**).

The results of the imaging techniques are additionally supported by the undated archival photograph of the nude painting (Figure 23a), which appears to be an early phase of the overpainting process of the artwork from the 1993. The photograph reveals two features not completely covered with the current painting: vertical divisions of the wall in the top-left corner and obliterated leaves of the plant in the top-right corner. The red colour

of the pillow was covered with white paint in the final version from the 1998; however, its traces are still visible through the paint losses (Figure 23b,c).

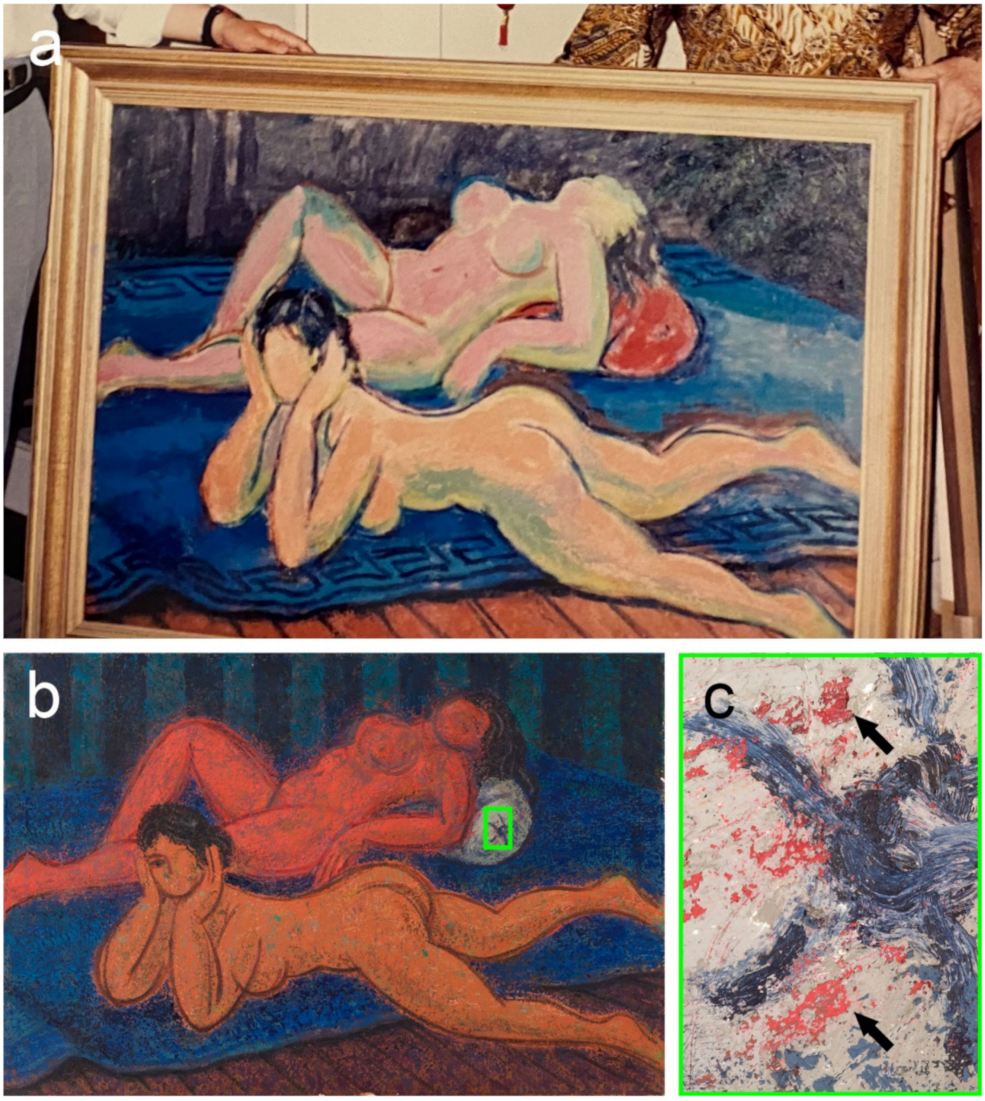

Figure 23. (**a**) Nude painting from the undated archival photograph. Liu Kang Collection, National Library Singapore. (**b**) *Beauties at rest II* (1998), showing the area of the white pillow (green rectangle). (**c**) Corresponding detail of *Beauties at rest II* (1998) showing traces of red paint scheme beneath white finish indicated with the black arrows.

Hence, the obtained findings lead us to believe that the underlying painting could be the one documented in the 1993 casual photograph of the artist in his studio. Although the previous research demonstrated that possible financial constraints [2,18,70] and scarcity of the painting materials [71] motivated Liu Kang's earlier practice of reusing unwanted paintings, these reasons are not convincing in unravelling the case discussed here. Judging from the fact that Liu Kang was already a successful and renowned artist in the 1990s, he did not have to be concerned about access to painting materials and to resort to reusing earlier compositions. Therefore, it is conceivable that rejecting the completed and framed painting from 1993 and reusing it for *Beauties at rest II* (1998), which represents a different style, was a radical move more likely governed by a strong artistic self-criticism or emotions of a great magnitude. At first glance, the paint application technique in *Beauties at rest II* (1998) resembles the approach known from *Nude* (1995). However, contrary to *Nude* (1995),

traces of a palette knife application are visible underneath chaotic brushstrokes resulting in the accumulation of thick impastos (Figure 24a).

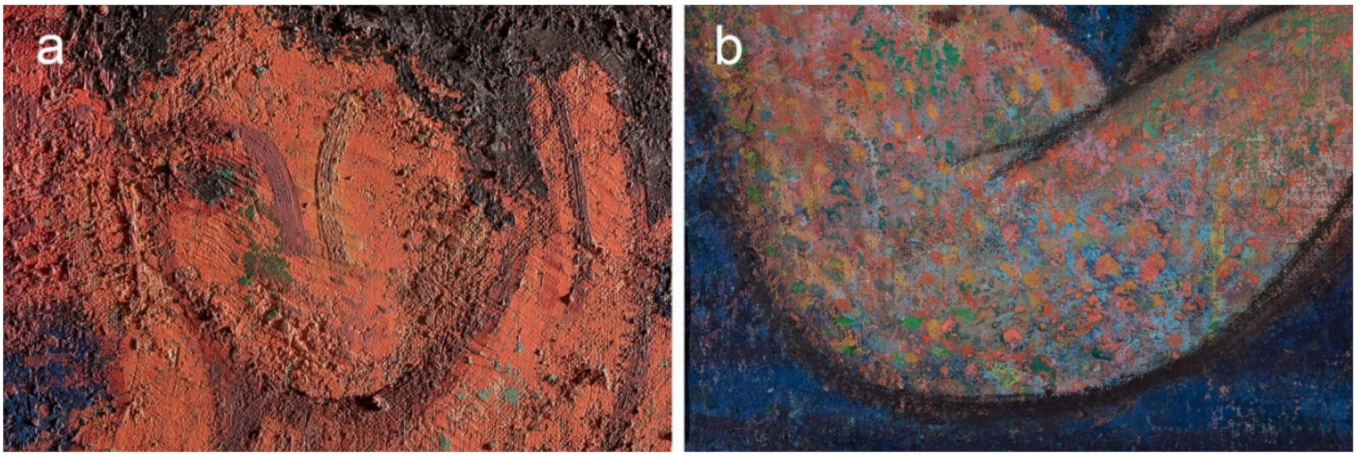

Figure 24. (**a**) Detail of *Beauties at rest II* (1998), indicating traces of a palette knife application underneath thick impastos produced with brush. (**b**) Detail of *In conversation* (1999), showing a pointillist brush application of complementary colours.

In conversation (1999), as one of the latest compositions by Liu Kang in the NGS collection, represents the apogee of his lifelong exploration of the subject of nudes (Figure 3c). It also demonstrates the artist's continuous ability to experiment with new approaches to painting. Although this artwork, alongside *Nude* (1995) and *Beauties at rest II* (1998), reflects a specific painting convention, its execution and optical effects differ from two other examples. Instead of manipulating tinted paint as in *Nude* (1995), the artist made a step forward and incorporated a range of yellow, green, blue and red hues to depict skin colours. His best paint application and interplay of complementary colours can be seen in the mid-tones of the model on the left (Figure 24b). The artist used different size brushes for a pointillist style and the contrasting application of complementary pairs in a near impressionistic fashion.

3.4. Brands of the Painting Materials Used by Liu Kang

In providing technical information about the identified painting materials, the question about the artists' colourmen brand(s) used by Liu Kang is raised. As his final nudes were created in the 1990s, one would expect the existence of visual or written information about Liu Kang's painting materials. Unfortunately, none of Liu Kang's paint tubes were preserved, and the authors did not find any written sources pointing to the brands of the materials he used during his artistic career. However, the archival search allowed the identification of several paint tubes on the photographs of the artist for his 1997 and 1998 exhibition catalogues (Figure 25a,b) [17,72]. The comparison of detailed images of these paint tubes with the authors' reference materials (Figure 25d, e, g) enabled the identification of Royal Talens oil paints (Rembrandt series). Another photograph, which, according to the artist's family, was taken in the 1990s, shows Liu Kang behind a well-stocked painting trolley with the paint tube box sets, which, when compared with the authors' references, appear to be from Royal Talens and Rowney (Georgian series) (Figure 25c,f,h,i). Hence, it could be said that the artist used both brands independently or mixed them during his painting in the 1990s. Moreover, these photographs lead us to believe that the Liu Kang was convinced about using these brands and probably preferred bulk purchase to prevent interruption to the artistic process. This finding is a major step towards expanding the knowledge of Liu Kang's painting materials, as little is known about his art material supplies from earlier artistic periods.

Figure 25. Archival photographs of Liu Kang for his 1997 (**a**) and 1998 exhibition catalogues (**b**) and undated photograph, probably from the 1990s (**c**), showing the artist's paint tubes (blue and red rectangles) and paint tube box sets (green rectangle). Liu Kang family collection. Image courtesy of Liu family. Corresponding details of the photographs showing the: (**d**,**e**) paint tubes from Royal Talens (Rembrandt series); (**f**) the paint tube box sets, from Royal Talens and Rowney (Georgian series). Authors reference paint materials from the 1990s of the: (**g**) Royal Talens (Rembrandt series) oil paint tubes; (**h**) Royal Talens (Rembrandt series) paint tube box set; (**i**) Rowney (Georgian series) paint tube box set.

4. Conclusions

The interdisciplinary study of Liu Kang's female nude paintings is a first attempt to comprehensively analyse and discuss the artist's approach to the theme. The particular aspects of that investigation include the role of the drawing in the final painted composition as well as the evolution of the artist's pigment choices and painting technique for the execution of female bodies.

In terms of the conceptualisation work, Liu Kang relied on drawing and sketching as the primary stage for the development of ideas. However, his further stage of the artistic creation—preparatory underdrawing—was evidenced only in *Two nudes* (1996). Nevertheless, it is conceivable that, once satisfied with the concept, the artist translated his drawing and sketching studies through simple brushstrokes to establish the general composition.

All investigated paint samples contain drying oil as a binder. The characterisation of the pigment mixtures from nude models revealed that the artist consistently employed different tints of yellow iron-rich earth pigments as a principal paint for bright skin tones. Some modifications of that base paint were achieved by replacing yellow iron-containing earths with a mixture of umber, organic red and bone black in *Nude* (1992) or admixing yellow and red iron-containing earth pigments with cobalt blue in *Nude* (1995). In *Two nudes* (1996), the artist moved away from realistic skin tones and depicted figures using a pink colour, achieved with red iron-based earth pigment. This approach continues in *Beauties at rest II* (1998), where alongside the yellow and red iron-based earths, the artist used cadmium yellow, cadmium orange and/or cadmium red or their variants, and organic red on Al-containing substrate. *In conversation* (1999) confirms the experimental nature of the artist by means of the successful use of contrasting and complementary colours. Thus, as well as the yellow and red iron-rich earth pigments and the organic red on Al-based substrate, the artist engaged Cr-containing yellow pigment(s), ultramarine and Prussian blue.

Although the mid-tones were not employed frequently, their tentative VIS and IRFC assessment in *Nude* (1927) and *Nude* (1934) suggested that the artist could have considered emerald green, Cr- or Co-containing green, ultramarine or cobalt blue, organic red and yellow iron-containing earth pigment. In *Nude* (1992), the mid-tone was achieved by mixing synthetic alizarin lake, red iron-containing earth pigment with cadmium yellow or its variant and bone black, while in *Nude* (1995), ultramarine, red iron-containing earth, synthetic alizarin lake on Al-containing substrate and bone black played an important role in obtaining a violet hue of cool mid-tone.

Regarding the dark outlines of the shapes, the analyses of three samples extracted from the paintings created in 1940, 1995 and 1996 revealed a consistent use of yellow or red iron-based earth pigment and bone black. The prevailing use of naphthol red AS-D in combination with red iron oxide and probably an organic red on Sn-containing substrate is suggested in the dark contours in *Two nudes* (1996).

As for the models' black hair, bone black is the prevailing pigment, and it frequently appears with ultramarine. This pair was admixed with a phthalocyanine blue in *Beauties at rest II* (1998). An organic red on Al-containing substrate was added to achieve a warm and deep hue in *Nude* (1927), while the admixture of umber appears in *Nude* (1992). The intensity of black was modified primarily with white paints; however, yellow iron-rich earth pigment and cadmium yellow or its variant were used in *Nude* (1940).

Although 62 paint samples were analysed, the areas of nude figures are not sufficiently represented in the research materials due to sampling limitations. Hence, the analyses of the paint samples from the drapery settings of the compositions supported a tentative assessment of the pigment mixtures used for achieving the skin colours of nude figures.

VIS and digital microscopy played a crucial role in studying the evolution of the painting technique for the execution of nude figures. The earliest *Nude* (1927) represents a realistic style and strong attention to detail, the latter achieved with small brushes. This approach was replaced with a subjective observation resembling Modernist influences, seen in *Nude* from 1934 and 1940. Both paintings demonstrate confident and rapid execution and a gradual reduction in detail and light effects. Liu Kang's return to the theme of nudes in

the 1990s is accompanied by an eruption of new concepts and techniques. The repertoire of different sized brushes was extended by the use of palette knifes. The theme of nudity was employed as a platform for the unconventional artist's expression. In *Nude* (1992) and *Two nudes* (1996), he reduced the figures to lines and universal shapes using a limited palette of colours. In *Nude* (1995) and *Beauties at rest II* (1998), he underscored the role of colour and experimented with the optical vibration of different colour values by adopting an almost pointillist paint application technique. This unique technique evolved into an intuitive use of contrasting and complementary colours in *In conversation* (1999).

As well as the technical aspects, the study revealed an earlier painted version of two reclining nudes underneath *Beauties at rest II* (1998). The visual evidence supports the notion that the hidden composition could be the painting documented in the 1993 photograph taken in the artist's studio. This information contributes to our knowledge of Liu Kang's working practice by evidencing a strong sense of artistic self-criticism that governed his decision about rejecting and repainting a former artwork. Moreover, the photograph enabled us to see that the reused painting, which was framed, was completed and satisfactory.

With regard to painting materials, this study provides, for the first time, photographic evidence of Liu Kang using Royal Talens and Rowney (Georgian series) oil paint tubes in the 1990s. This important information may assist researchers and conservators in future monitoring of the deterioration processes of the paint layers from the 1990s. To conclude, the yield data can be used as a reference for any future investigation of Liu Kang's working process. Moreover, the investigation of the commercial oil paints used by Singapore and Western artists in the 1990s can also benefit from the characterisation of pigment mixtures in this study.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Summary of the materials detected in the paint samples obtained from the examined paintings.

Title and Inventory Number	Date	Colour	Sample	SEM-EDS * Detected Elements	PLM, SEM-EDS Tentative Assignments	FTIR Identification
Nude	1927	Green	4	**C**, **O**, **Pb**, Ba, Zn, As, Cr, Cu, Al, Ca, (S, Na, Si, Fe)	Lead white, lithopone and/or barium white and zinc white, emerald green, viridian, ultramarine	Lead white, lithopone and/or barium white and zinc white, emerald green, oil
			8	**O**, **C**, **Cr**, **Ba**, Pb, Ca, S, Zn, (Ti, Na, Si, Al, Cl)	Viridian, lithopone and/or barium white and zinc white, lead white, chalk, titanium white, ultramarine	Lead white, lithopone and/or barium white and zinc white, chalk, viridian, oil
		Yellow	7	**Pb**, **C**, **O**, Zn, Ba, Na, (As, Ti, Ca, Al, Cl)	Lead white, lithopone and/or barium white and zinc white, emerald green, titanium white, chalk	Lead white, lithopone and or/barium white and zinc white, oil
		Red	6	**C**, **O**, Al, Pb, Zn, P, S, Ba, (Ca, Si, Br, Cr, Mg, Ti, Cl)	Organic red on Al-containing substrate, lead white, lithopone and/or barium white and zinc white, bone black, chalk, Cr-containing green and/or yellow(s)	Lead white, lithopone and/or barium white and zinc white, oil
		Brown	2	**C**, **O**, **Pb**, Ba, Al, Zn, Cr, Ca, S, (As, Si, Ti, Fe, Cu, P)	Lead white, lithopone and/or barium white and zinc white, organic red, viridian, emerald green, titanium white, yellow iron-containing earth pigment, bone black	
		Black	10, upper layer	**O**, **C**, Ba, Al, Pb, S, Si, Cr, As, Ca, (Cu, Zn, Fe, P)	Lithopone and/or barium white and zinc white, lead white, organic red on Al-containing substrate, Cr-containing green(s) and/or yellow(s), emerald green, bone black, iron-containing earth pigment	Lithopone and/or barium white and zinc white, bone black and/or iron-containing earth pigment, oil
		Black	10, bottom layer	**O**, **C**, Fe, Ca, Si, Pb, Mn, Al, (Na, As, Mg, S, P, K, Cu)	Umber, bone black, lead white, ultramarine, emerald green	Bone black, iron-containing earth pigment, oil
		White	9	**Pb**, **O**, **C**, Zn, Ba, As, Na, (Cu)	Lead white, lithopone and/or barium white and zinc white, emerald green	Lead white, lithopone and/or barium white and zinc white, oil
Nude	1934	Blue	6	**C**, **O**, **Ba**, S, Zn, Cr, Ca, Na, Ti, (Si, Al, Pb, Sr)	Lithopone and/or barium white and zinc white, viridian, ultramarine, titanium white, lead white	Lithopone and/or barium white and zinc white, chalk, ultramarine, viridian, oil
			7	**C**, **O**, **Ba**, Cr, S, Ca, Zn, Na, Si, Al, Ti, (Pb, Sr, Cl, K)	Lithopone and/or barium white and zinc white, viridian, ultramarine, titanium white, lead white	

Table A1. *Cont.*

Title and Inventory Number	Date	Colour	Sample	SEM-EDS * Detected Elements	PLM, SEM-EDS Tentative Assignments	FTIR Identification
			8	**O**, **C**, **Ba**, S, Cr, Zn, Ca, Na, Si, Al, (Ti, Pb, K, Cl, Fe)	Lithopone and/or barium white and zinc white, viridian, ultramarine, titanium white, lead white	
		Green	4	**C**, **O**, Zn, Fe, Si, Na, Ba, Ca, Al, S, (Mg, Ti, Cl, Pb, Sr)	Lithopone, and/or barium white and zinc white, yellow iron-containing earth pigment, chalk, ultramarine, titanium white	Lithopone and/or barium white and zinc white, yellow iron-containing earth pigment, oil, zinc soap
		Yellow	12	**C**, **Ba**, **O**, S, Zn, Ca, Ti, Na, (Sr, Fe, Si, Pb, Al, Cl)	Lithopone and/or barium white and zinc white, chalk, titanium white, yellow iron-containing earth pigment	
		Brown	11	**C**, **O**, **Ba**, S, Zn, Ca, Fe, Si, Ti, (Na, Al, Sr, Pb)	Lithopone and/or barium white and zinc white, yellow iron-containing earth pigment, titanium white,	Lithopone and/or barium white and zinc white, chalk, yellow ochre, oil
		Black	10	**C**, **O**, Ba, Ca, S, (Fe, Zn, Si, Al, Ti, Na, Mg, Pb)	Lithopone and/or barium white and zinc white, carbon black, ultramarine, titanium white	
		White	9	**C**, **O**, **Ba**, S, Zn, Ca, Ti, Na, (Si, Sr, Pb, Fe, Cr, Al, P)	Lithopone and/or barium white and zinc white, chalk, titanium white, yellow iron oxide, viridian, ultramarine	
Nude	1940	Blue	14	**O**, **C**, **Zn**, **Na**, Al, Si, S, (Sr, Mg, K, Ca, Pb, Fe, P, Cl)	Zinc white, ultramarine, bone black, Prussian blue, lead white	
		Green	2	**O**, **C**, Zn, Al, Na, Ca, Cl, Ti, S, Si, Pb, Fe, (Ba, Mg, Sr, K, P, Cr)	Lithopone and/or barium white and zinc white, ultramarine, titanium white, lead white, yellow iron-containing earth pigment, bone black, viridian	Lithopone and/or barium white and zinc white, yellow iron-containing earth pigment, oil
			3	**C**, **O**, Zn, Ca, Fe, Ti, Mg, Al, Na, Cl, (Si, S)	Zinc white, chalk, yellow iron-containing earth pigment, ultramarine	Lithopone and/or barium white and zinc white, chalk, yellow iron-containing earth pigment, oil
		Yellow	4	**C**, **O**, Fe Ca, Zn, Mg, Ti, (Na, Al, Si, Pb, S)	Yellow iron-containing earth pigment, chalk, zinc white, titanium white, lead white	
			6	**C**, **O**, **Ba**, **Cd**, S, Al, Ti, Zn, (Na, Si, Pb, Ca, Cl, Sr)	Lithopone and/or barium white and zinc white, cadmium yellow or its variant, titanium white, lead white, chalk	Lithopone and/or barium white and zinc white, oil

Table A1. *Cont.*

Title and Inventory Number	Date	Colour	Sample	SEM-EDS * Detected Elements	PLM, SEM-EDS Tentative Assignments	FTIR Identification
			7	**C**, **O**, Ca, Fe, Zn, Mg, Ti, Al, Na, (Si, S)	Chalk, yellow iron-containing earth pigment, zinc white, titanium white	
		Orange	5	**O**, **C**, **Ba**, Cd, S, Al, Ti, (Zn, Na, Sr, Se, Cl, Si)	Lithopone and/or barium white and zinc white, cadmium orange or its variant, organic red on Al-containing substrate	Lithopone and/or barium white and zinc white, oil
		Red	15	**C**, **Zn**, **O**, Na, Al, Fe, Ti, (Si, Ca, S, Mg)	Zinc white, ultramarine, yellow iron-containing earth pigment, organic red on Al-containing substrate, titanium white	Ultramarine, yellow ochre, oil, zinc soap
		Brown	10	**C**, **O**, **Fe**, **Ba**, S, Zn, Al, Ca, (Ti, Si, P, Pb, Mn, Cr, Cl)	Umber, lithopone and/or barium white and zinc white, bone black, titanium white, lead white, Cr-containing yellow(s)	
			11	**C**, **O**, **Ba**, **Zn**, S, Ca, Na, Ti, (Fe, Sr, Pb, Al, Si, Cl)	Lithopone and/or barium white and zinc white, chalk, titanium white, yellow iron-containing earth pigment, lead white	
			12	**C**, **O**, **Ba**, S, Zn, Fe, Ca, Ti, Na, (Al, Sr, Si)	Lithopone and/or barium white and zinc white, yellow iron-containing earth pigment, chalk, titanium white	Lithopone and/or barium white and zinc white, yellow iron-containing earth pigment. oil
		Black	9	**C**, **O**, **Ca**, P, Ba, Fe, (S, Zn, Si, Al, Na, Cd, Mg, Ti, Sr)	Bone black, lithopone and/or barium white and zinc white, yellow iron-containing earth pigment, ultramarine, cadmium yellow or its variant, titanium white	
		White	8	**C**, **O**, **Ba**, S, Zn, Ca, Ti, Na, (Sr, Pb, Al, Si, Cl)	Lithopone and/or barium white and zinc white, chalk, titanium white, lead white	
Nude, 2003-03259	1992	Yellow	4	**Cd**, **C**, **O**, **S**, Ti, Zn, Ba, Si, (Ca, Na, Fe, Al, Se, P, Mg)	Cadmium yellow and/or orange or their variants, titanium white, lithopone and/or barium white and zinc white, chalk, yellow iron-containing earth pigment, bone black	Lithopone and/or barium white and zinc white, synthetic alizarin lake, oil
			5	**C**, **O**, Ti, Zn, Fe, Ca, Al, Mg, Na, (S, Si, Pb, Sr, Mn, P)	Titanium white, zinc white, chalk, umber, organic red on Al-containing substrate, lead white, bone black	Iron-containing earth, oil, zinc soap

Table A1. *Cont.*

Title and Inventory Number	Date	Colour	Sample	SEM-EDS * Detected Elements	PLM, SEM-EDS Tentative Assignments	FTIR Identification
		Red	2	**C**, **O**, **Cd**, S, Ca, Ba, Zn, Ti, Al, (Fe, Na, P, Mg, Pb, Cl)	Cadmium yellow or its variant, lithopone and/or barium white and zinc white, titanium white, chalk, red iron-rich earth pigment, bone black, lead white, organic red on Al-containing substrate	Lithopone and/or barium white and zinc white, synthetic alizarin lake, bone black, red iron-rich earth pigment, chalk, oil, zinc soap
			6	**C**, **O**, Ti, Zn, Fe, Ca, Al, Na, Mg, (Si, S, Pb, Ba, Cl, P, Cd, Sr)	Titanium white, lithopone and/or barium white and zinc white, chalk, organic red on Al-containing substrate, red iron-containing earth pigment, chalk, lead white, bone black, cadmium yellow or its variant	Synthetic alizarin lake, oil, zinc soap
		Brown	1	**C**, **O**, **Fe**, Ti, Ca, Zn, Si, Al, Na, (Mg, S, K, P, Sr, Pb, Cl)	Red iron-rich earth pigment, titanium white, chalk, zinc white, lead white, bone black	
			8	**C**, **O**, Ti, Ca, Fe, Zn, (Na, Al, Si, P, Mg, S)	Titanium white, chalk, red iron-rich earth pigment, zinc white, bone black	
		Black	7	**C**, **O**, Ca, Fe, Zn, Ti, Mg, Si, (S, Ba, Al, Na, Pb, Mn, Sr, P)	Bone black, umber, titanium white, lithopone, and/or barium white and zinc white	
Nude, 2003-03265	1995	Blue	4	**C**, **O**, Al, Co, Ca, Zn, Si, Ba, (S, Mg, Na, Ti)	Cobalt blue, chalk, lithopone and/or barium white and zinc white, titanium white	Chalk, lithopone and/or barium white and zinc white, cobalt blue, oil
		Violet	12	**C**, **Zn**, **O**, Na, (Al, Ca, Ba, Fe, Ti, S, Mg, P, Si)	Lithopone and/or barium white and zinc white, chalk, organic red on Al-containing substrate, red iron-containing earth pigment, ultramarine, titanium white, bone black	Lithopone and/or barium white and zinc white, synthetic alizarin lake, oil
		Green	3	**C**, **O**, Ca, Zn, Al, Ti, Cr, Na, (Ba, S, Fe, Cl, Cd, Si, Mg, P)	Chalk, lithopone and/or barium white and zinc white, titanium white, viridian, yellow iron-containing earth pigment, cadmium yellow or its variant, bone black	Chalk, lithopone and/or barium white and zinc white, yellow iron-containing earth pigment, viridian, oil, zinc soap
		Yellow	6	**C**, **O**, Ti, Zn, Fe, Ca, Al, Na, Mg, Si, (S, Sr, K)	Titanium white, zinc white, yellow and red iron-containing earth pigments, chalk	
		Pink	7	**C**, **O**, Ti, Zn, Ca, Al, Mg, (Na, Co, Si, Fe, S)	Titanium white, zinc white, chalk, cobalt blue, yellow and red iron oxide	

Table A1. *Cont.*

Title and Inventory Number	Date	Colour	Sample	SEM-EDS * Detected Elements	PLM, SEM-EDS Tentative Assignments	FTIR Identification
		Red	8	**C**, **Zn**, **O**, Na, Fe, (Al, Ba, Ca, S, Pb, P, Si, Cl, Cr, Ti)	Lithopone and/or barium white and zinc white, red iron-containing earth, organic red, lead white, bone black, Cr-containing yellow(s), titanium white	
			9, upper cluster	**C**, **O**, **Zn**, Fe, Na, Ba, Ca, Al, (S, Cl, P, Ti, Si, Pb, Mg, Cd)	Lithopone and/or barium white and zinc white, red iron-containing earth, chalk, organic red on Al-containing substrate, bone black, titanium white, lead white, cadmium yellow or its variant	Lithopone and/or barium white and zinc white, iron oxide, synthetic alizarin lake, oil
			9, bottom cluster	**C**, **O**, Fe, Cl, Al, Ti, Zn, Ca, Si, (S, Sn, Mg, Ba, Na, Sr, Pb, K)	Red iron-containing earth, organic red on Sn-containing substrate, titanium white, lithopone and/or barium white and zinc white, chalk, lead white	Naphthol red AS-D, lithopone and/or barium white and zinc white, oil
		Brown	10	**C**, **O**, Fe, Zn, Ca, Na, (P, Ti, Al, Si, S, Mg, Cl)	Yellow iron-containing earth pigment, zinc white, bone black, titanium white	
		Black	11	**C**, **O**, Zn, Fe, Ca, Na, (Si, Al, P, Ti, S, Mg, Ba, Sr)	Lithopone and/or barium white and zinc white, chalk, yellow iron-containing earth pigment, ultramarine, bone black, titanium white	
Two nudes	1996	Red	1	**C**, **O**, *Ti*, Zn, Ca, Fe, Al, Mg, (Na, Si, S, Pb, K)	Titanium white, zinc white, chalk, red iron-containing earth pigment, lead white	Chalk, red iron-containing earth pigment, oil
			2	**C**, **O**, **Cl**, Sn, Ca, Mg, Si, (S, Fe, Ti, Zn, Al, Ba, P, Pb)	Organic red on Sn-containing substrate, lithopone and/or barium white and zinc white, chalk, red iron-containing earth pigment, titanium white, bone black, lead white	Naphthol red AS-D, oil
		Brown	3	**C**, **O**, **Ti**, Fe, Cl, Zn, Sn, Ca, (Ba, Mg, Al, S, Si, Na, P, Pb)	Titanium white, red iron-containing earth pigment, organic red on Sn-containing substrate, lithopone and/or barium white and zinc white, lead white, bone black	Naphthol red AS-D, oil
Beauties at rest II, 2003-03470	1998	Blue	6	**C**, **O**, **Zn**, Si, Ti, Al, Na, (Ca, Ba, Mg, Cu, Cl, S, Fe, P)	Lithopone and/or barium white and zinc white, titanium white, ultramarine, phthalocyanine blue, Prussian blue, bone black	Ultramarine, phthalocyanine blue, oil, zinc soap

Table A1. *Cont.*

Title and Inventory Number	Date	Colour	Sample	SEM-EDS * Detected Elements	PLM, SEM-EDS Tentative Assignments	FTIR Identification
			11	**C**, **O**, **Zn**, Ti, Ca, Na, Fe, Al, Mg, (Cl, S, Cd, Si)	Zinc white, titanium white, chalk, Prussian blue, ultramarine, cadmium yellow	Prussian blue
		Green	3	**C**, **O**, **Cr**, Ca, Ba, (Ti, Mg, S, Zn, Si, Cl, Al, Sr)	Viridian, chalk, lithopone and/or barium white and zinc white, titanium white	Lithopone and/or barium white and zinc white, chalk, viridian, oil
		Orange	9	**C**, **Zn**, **O**, Fe, Na, Ti, (Al, Cd, Ca, Mg, S, Si, Pb)	Zinc white, yellow iron-containing earth pigment, titanium white, cadmium yellow or its variant, chalk, lead white	
		Red	10	**C**, **O**, Zn, Cd, Ba, S, Al, Ti, (Na, Se, Ca, Cl, Mg, Fe, Si, P)	Lithopone and/or barium white and zinc white, cadmium orange and/or red lithopone, organic red on Al-containing substrate, titanium white, chalk, red iron-containing earth pigment, bone black	Cadmium orange and/or red lithopone, red iron-containing earth pigment, oil
		Brown	8	**C**, **O**, Zn, Al, Ca, Ti, S, Na, Si, (Fe, Mg, P, Ba, Cr, Cd)	Lithopone and/or barium white and zinc white, chalk, titanium white, organic red on Al-containing substrate, red iron-containing earth pigment oxide, bone black, Cr-containing yellow and/or green, cadmium yellow or its variant	Lithopone and/or barium white and zinc white, chalk, synthetic alizarin lake, oil
		Black	13	**C**, **O**, Zn, Ca, Si, Na, Al, P, (Cu, Sr, S, Mg, Fe, Ba, Cr, Cl)	Lithopone and/or barium white and zinc white, bone black, ultramarine, phthalocyanine blue	Ultramarine, phthalocyanine blue, chalk, oil
		White	7	**C**, **O**, Ti, Zn, Ba, Ca, Mg, Al, Fe, (Cr, Na, Si, S)	Titanium white, lithopone and/or barium white and zinc white, chalk, red iron-containing earth pigment, viridian, ultramarine	
In conversation, 2003-03305	1999	Blue	3	**C**, **O**, Ti, Si, Ca, Zn, Al, Ba, (Na, Cu, Cl, Fe, Cr, Mg, P, Pb, S)	Titanium white, ultramarine, chalk, lithopone and/or barium white and zinc white, phthalocyanine blue, Prussian blue, viridian, lead white, bone black	
			4	**C**, **O**, Si, Ca, Al, (Cu, Na, P, Zn, Ti, Ba, S, Cl)	Ultramarine, chalk, phthalocyanine blue, titanium white, lithopone and/or barium white and zinc white	Ultramarine, phthalocyanine blue, oil
			11	**C**, **O**, **Ti**, Zn, Ca, Na, (Al, Fe, Mg, Si, S, Pb, Cl, K)	Titanium white, zinc white, chalk, ultramarine, Prussian blue, lead white	Prussian blue

Table A1. *Cont.*

Title and Inventory Number	Date	Colour	Sample	SEM-EDS * Detected Elements	PLM, SEM-EDS Tentative Assignments	FTIR Identification
		Green	9	**C**, **O**, **Cr**, Ca, Ba, Mg, (S, Zn, Cl, Ti, Al, Na, Si)	Viridian, chalk, lithopone and/or barium white and zinc white, titanium white, ultramarine	
		Yellow	7	**C**, **O**, **Fe**, Ca, Ti, Zn, (Al, Ba, S, Si, Na, Mg, Cl)	Yellow iron-containing earth pigment, chalk, titanium white, lithopone and/or barium white and zinc white	
		Red	6	**C**, **O**, **Ca**, Zn, Ti, (Ba, Mg, Cl, Pb, Al, Fe, Na, Si, Cr, S)	Chalk, lithopone and/or barium white and zinc white, titanium white, lead white, red iron-containing earth pigment, Cr-containing yellow(s), organic red on Al-containing substrate	Chalk, zinc soap, oil

* Major elements are given in bold, minor elements in plain type and trace elements in brackets.

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