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Detecting recent forgeries of Impressionist and Pointillist paintings with high-precision radiocarbon dating

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Abstract

We report on the capacity of AMS radiocarbon dating to play a decisive role in fighting against the illicit trade in art. In the framework of a current police investigation, where previously unseen paintings were discovered in a restorer's workshop by the French Central Office for the Fight against Illicit Trafficking in Cultural Property (OCBC), we demonstrated that two paintings alleged to be by Impressionist and Pointillist artists had in fact been painted recently. Our results were based on the excess of ^{14}C derived from atmospheric nuclear tests detected in the fibers used to make the canvas. By combining AMS ^{14}C absolute dating and the fine precision of the post-bomb atmospheric calibration curve, we established a clear chronological context for the production of these forgeries. ^{14}C content of the fibers revealed that the canvases were manufactured in 1956-1957 or, more likely, after 2000. As a result, absolute dating proves unambiguously that the Impressionist and Pointillist paintings are forgeries since they were not painted at the beginning of the 20th century by the alleged artists, who died in the 1940s.

Keywords: Radiocarbon (^{14}C) dating, painting, art forgeries, forensics

1. Introduction

Recently, hundreds of paintings were discovered in a private restorer's workshop by the French Central Office for the Fight against Illicit Trafficking in Cultural Property (OCBC). A part of them was seized and many masterpieces attributed to two Impressionist and Pointillist artists of the end of the 19th and the beginning of the 20th centuries were found. However, doubts as to their authenticity were expressed soon after the start of the investigation. One of the two alleged artists was close to the great Impressionist painter Claude Monet while the other is known for his Pointillist technique depicting views of ports painted between 1920 and 1940. These two artists are becoming attractive on the European and US art markets with prices achieved at auction reaching up to US\$ 200 000. As the police investigation is still in progress, it is not possible to provide more details about the paintings involved and alleged artists.

Along with police investigations, scientific techniques and forensics are tools that help in the detection of art forgeries, by proving that the art in question could not have been made by the purported artist. The prevalent scientific methodology to determine the authenticity of paintings is based on imaging techniques such as X-radiography, multispectral imaging and chemical analysis of the paint components in order to look for anachronisms or contentious materials [1-6]. This methodology can provide useful evidence for authenticity and attribution studies by providing evidence for or against an association with the alleged artist, but does not provide an absolute date of creation. Long considered too invasive or not precise enough, the radiocarbon dating method was not included in the authentication toolkit for paintings. However, recent publications have pointed out the potential role of this absolute method to date pigment such as lead white [7-9] and to uncover forgeries by directly dating organic medium [10], canvas [11,12] or paint [12]. For example, Caforio et al. (2014) confirmed that an alleged Fernand Léger cubist painting was definitely a fake [11], and more recently, Hendriks et al. demonstrated the power of ^{14}C dating using a known modern paint forgery, dated 1866 but created in the 1980s [12].

Here, we present a study undertaken in this forensic context, without museum documentation or previous studies available to support the present research. The

research was conducted taking into account the on-going investigation, with time and sampling limitations, as well as confidentiality. In order to address the question of the authenticity of these paintings, we relied on the radioactive carbon isotope ^{14}C released into the atmosphere by the nuclear tests performed in the 20th century [13]. The anomalous excess of ^{14}C started in 1955 and reached a peak in 1964. After the partial nuclear test ban, levels of artificially produced ^{14}C started to decrease by dilution in the atmosphere to the present level. The ^{14}C concentration is well documented and can be used to date recent events based on the calibration curves available from 1950 up to now [13-15]. For this study, we also included data on the natural ^{14}C activity for the last ten years in France, by measuring ^{14}C content of nut fruits, and we implemented the resulting calibration curve with our data in the OxCal calibration program [16]. The ^{14}C concentration is now well documented up to 2020 with a very high resolution and a precision of a few years, providing a tool of choice for authenticating paintings or proving recent forgeries.

2. Material and methods

Four paintings of different styles were selected by the French Central Office for the Fight against Illicit Trafficking in Cultural Property (OCBC). The study of two paintings - one Impressionist and one Pointillist - is presented here. For each painting, different materials were sampled (Table 1). Samples of canvas fiber (labeled Fiber I (Fig. 1.a) and Fiber P (Fig.1.b)) were taken from the paintings for radiocarbon dating. Even if it is known that stretchers are commonly replaced or recycled, samples of wood (labeled Wood I and Wood P) were also taken for comparison. For the Impressionist painting, white paint (Paint I) was scraped from the edge of the artwork (Fig.1.c) for chemical analysis and dating. The paint layer is composed of particles of pigment(s) in a binder; both can be radiocarbon dated if they derive from natural organic components such as organic pigment and oil medium [10-12] or if they incorporate organic CO_2 as it has been recently demonstrated for lead white [7,8 17-19]. For the Pointillist painting, a small piece of fiber (5 mm long) coated on the varnish layer and found during the investigation

was taken for radiocarbon dating (Fig.1.d). This fiber may come from the brush used for varnishing.

Painting	Painting constituent	Materials	Sample reference	Sample mass (mg)
Impressionist	Stretcher	Wood	Wood I	2.7
	Canvas	Fiber	Fiber I	7.0
	White paint layer	Pigment Binder	Paint I	6.6
Pointillist	Stretcher	Wood	Wood P	4.2
	Canvas	Fiber	Fiber P1	16.2
	Isolated fiber at the surface of the varnish layer	Fiber	Fiber P2	4.6

Table 1. Description of the samples taken from the Impressionist and Pointillist paintings for radiocarbon dating

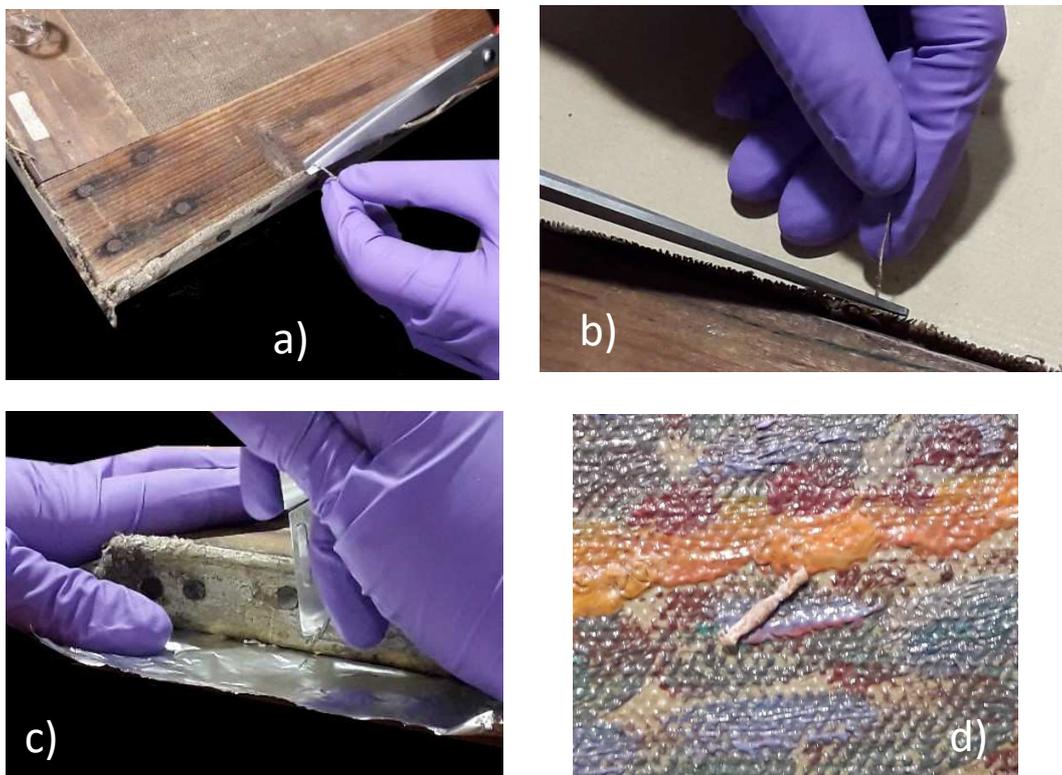


Figure 1. Sampling of the Impressionist (a) and c) on the left) and the Pointillist (b) and d) on the right) paintings: a) and b) canvas fibers taken from the turnover edge, c) white paint, d) small fiber (5 mm long) coated at the surface of the painting.

The pigment of the paint sample was characterized by X-ray Diffraction (XRD), using a RU-200B (Rigaku) rotating anode X-Ray generator equipped with a Mo anode. Mo radiations are monochromatised around the $K\alpha$ emission lines ($\lambda = 0.7093 \text{ \AA}$) using a FOX-2D (Xenocs) toroidal mirror. The beam was focalized on the sample with a beam size of $100 \mu\text{m}$ and a photon flux of about $2 \cdot 10^7 \text{ ph/s}$. XRD data were collected on a Pilatus 300K (Dectris) hybrid pixel detector in transmission mode. 2D images were circularly integrated using the fit2D software and phase identification was carried out with Diffrac-EVA software (Bruker) integrating a reference database from ICDD.

The canvas fibers were separated and observed in longitudinal view using a polarized light microscope at 200x magnification. The observation was necessary to detect the potential presence of synthetic fiber which is not suitable for radiocarbon dating due to the absence of ^{14}C in petroleum-based compounds.

All the samples collected for radiocarbon dating – except the paint sample - were subjected to a series of acid and basic washes (HCl-NaOH- HCl) to eliminate potential contaminants, rinsed with ultra-pure water, dried (60°C under 0.1 mbar) and then combusted in the presence of copper oxide (400–500 mg) and silver (1-cm wire) at 835°C for 5 hours in order to produce carbon dioxide [20]. No solvent wash was used to pre-treatment the fibers but their aspect was clean and satisfactory after the acid and basic washes. After checking the absence of calcium carbonate by XRD, the paint sample was washed with water and then directly converted to carbon dioxide by combustion.

CO₂ gas was reduced by hydrogen at 600°C in the presence of iron powder to form graphite. Once compacted into aluminum targets, carbon isotopes of the samples were measured with the AMS LMC14/ARTEMIS facility (Saclay, France) [21]. Oxalic acid II was used for normalization, and international intercomparison samples (FIRI H and FIRI I) for validation [22].

The ¹⁴C contents were converted into calendar years with the OxCal calibration program [16] using the Intcal20 atmospheric curve [23] for pre-bomb ages (i.e. before 1950) and the Bomb 13 NH1 post-bomb atmospheric curve for the most recent decades (i.e. after 1950) with our data up to 2020 which were taken in France to be closer to this case study.

3. Results and discussion

3.1 The Impressionist painting

Three samples of the Impressionist painting were dated: two from the support – one from the wooden stretcher and another from the canvas – and one from the white paint of the ground preparation, taken along the edge of the painting. X-ray diffraction analysis of the white paint identified pure zinc oxide (ZnO) (Fig. 2). ZnO is the component of the zinc white pigment. Combined XRF measurement confirms that no other white pigment such as titanium white, lead white, lithopone is present in that layer. The paint layer contains also an organic binder, not identified here.

Zinc white was suggested as a substitute for lead white as early as the end of the 18th century, but was produced on a large scale only from 1835 on [24]. Industrial production

began in 1845 near Paris, followed shortly afterwards by the rest of Europe as well as by the United States. As zinc white was widely used by the Impressionists (e. g. Monet, Cézanne, etc.), the presence of this pigment is consistent with the purported date of the painting.

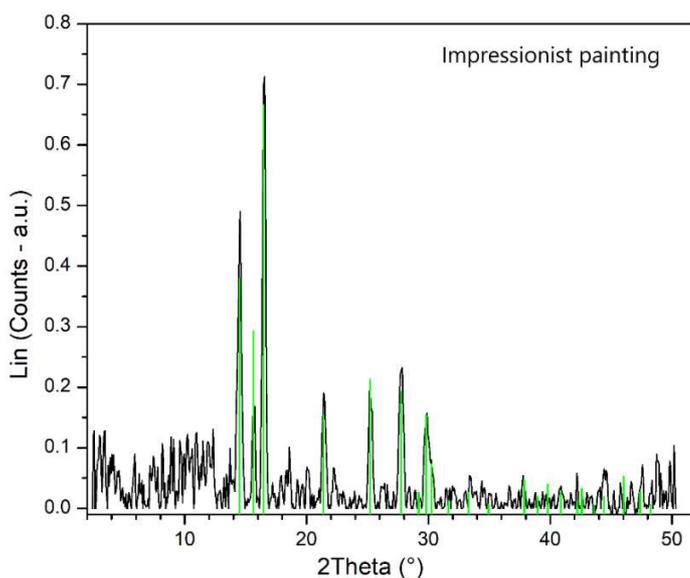


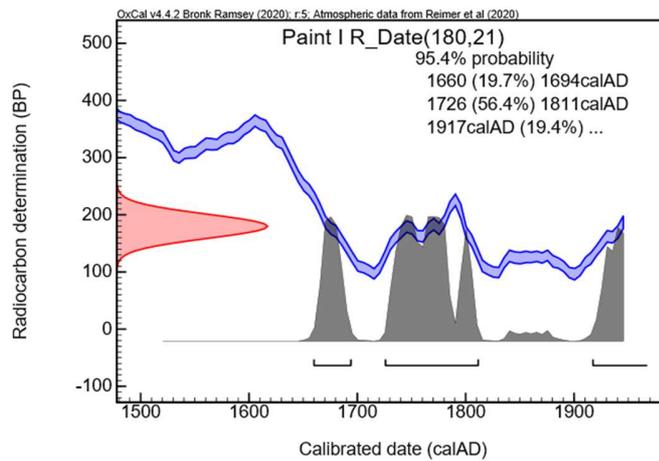
Figure 2. X-ray diffractogram (in black) of the white paint sample of the Impressionist painting showing the presence of zinc white. The green lines indicates the diffraction peak positions for ZnO.

Radiocarbon dating of the white paint showed a pre-bomb age of 180 ± 21 BP (Table 2). This result, obtained for the binder fraction of the paint, corresponds after calibration to a wide distribution of calendar dates from 1660 to 1950 with three intervals (Fig. 3a): 1630-1694 (19.7%), 1726-1811 (56.4%) and 1917-... (19.4%).

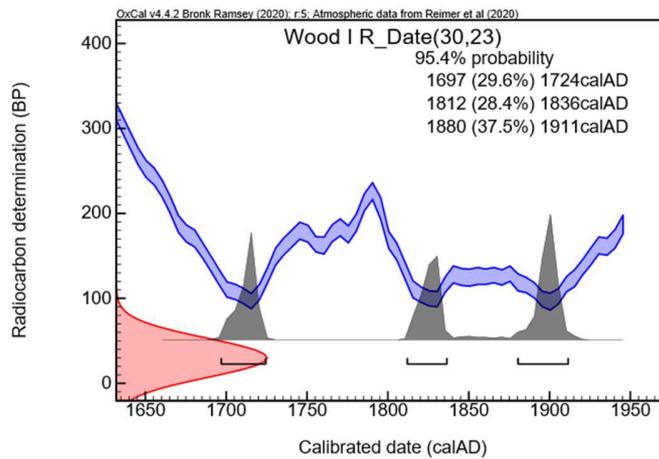
A close result was obtained on the wooden stretcher with a radiocarbon age of 30 ± 23 BP (Table 2). Even if the relative uncertainty on the measurement is larger than that for the paint, the calendar dates seem to be better determined as they correspond to a better resolved part of the calibration curve. Three possible intervals with equivalent probabilities 1697-1724 (29.6%), 1812-1836 (28.4%) and 1880-1911 (37.5%) were found after calibration (Fig. 3b).

AMS lab code SacA	Sample reference	Constituent	Mass of extracted carbon (mg)	Percentage of Modern Carbon (pMC)	Age in year BP for pMC<100 or after 1950 for pMC>100
57274	Paint I	White paint layer	0.96	97.77 ± 0.26	180 ± 21
57262	Wood I	Stretcher	1.01	99.62 ± 0.29	30 ± 23
57263	Fiber I	Canvas	1.09	108.59 ± 0.27	after 1950

Table 2. Uncalibrated radiocarbon results for the constituents of the Impressionist painting



a)



b)

Figure 3. Calibrated ^{14}C results for (a) the white paint (Paint I - SacA 57274) and (b) the stretcher (Wood I - SacA 57262) of the Impressionist painting.

The dating of the white paint and the stretcher provided similar results, i.e. pre-bomb ^{14}C content materials with the most recent interval of the distribution in agreement with the active period of the alleged artist. However, the interpretation of the results is not straightforward, due to several factors. First, dating samples from the end of the 19th – beginning of the 20th century is quite challenging due to the shape of the calibration curve. Many fluctuations on a flat plateau are observed from the end of the 17th century to the beginning of the 20th century, strongly limiting the resolution of ^{14}C dating in this range. Second, old materials can be used and former supports can be recycled by the artist him/herself, as did Picasso and Van Gogh [25-26], or be intentionally selected by forgers to mimic ancient stretchers [5]. The wooden stretcher of the Impressionist painting could originate from old trees or from other 19th artworks reused on purpose.

The paint sample contains zinc white in an organic binder. As zinc white is composed of pure zinc oxide and as no other pigment was detected, the ^{14}C signature of the paint layer should be uniquely carried by the organic oil binder. However, external contamination by dust or other compounds due to the degraded conditions of storage in the workshop and by possible varnish drips has to be considered since the white paint was taken at the edge of the painting on the canvas surface (Fig. 1c). Water washing was used to remove dust particles but the presence of varnish residues in the dated sample cannot be excluded. The contribution of the varnish to the paint date is difficult to estimate as varnish can be applied by the artist or later by a restorer after removing a previous deteriorated film. Removing and reapplying varnish is one of the most common procedures in painting conservation and can occur several times at different periods. As a result, natural or synthetic resins can be present and alter the paint layer dating. A synthetic resin depleted in ^{14}C would imply apparent older ages whereas past and modern restorations with natural resins would produce various ages that are difficult to interpret. In the case of this Impressionist painting, the radiocarbon dating of the binder

appears to be inconclusive due to the lack of resolution of the calibration curve as well as possible contamination.

For the same painting, fibers of the canvas were easily accessible. Sampling canvas has the advantage of not altering the pictorial layers. Natural bast fibers, characterized by the presence of X-shaped dislocation (Fig. 4.a) were identified, indicating that natural plants such as flax, hemp or jute were processed to make the canvas fabric. Linen fabric is a traditional support for oil paintings covered with gesso (CaSO_4) or less commonly with calcium carbonates (CaCO_3). The fiber sample was pretreated to eliminate possible fossil carbonates depleted in ^{14}C . The ^{14}C measurement of the fiber, 108.56 ± 0.27 pMC (Table 2), shows a clear post-bomb ^{14}C content with a value higher than 100 percent of Modern Carbon (pMC) corresponding to the year 1950. After calibration using the NH1 curve [13], two dates or intervals are proposed due to the shape of the “bomb peak”: 1957 and 2000-2003 (Fig. 4.b). Both solutions are posterior to the death in the 1940s of the artist whose signature features on the painting. No evidence of restoration treatments of the support by a lining canvas (i.e. a second canvas attached to the back of the original) was observed, rejecting possible later modification. As a result, we can conclude that the Impressionist painting was not executed between 1880 and 1900 which corresponds to the active period of the artist and therefore was not created by the hand of the artist her/himself. A completion date can be proposed based on the 2000-2003 interval, which seems to be the most probable according to other observations made during the police investigation. This interval of dates relates to the harvesting of the plants used for the canvas fibers. Previous studies [27] demonstrated that a time lag of 2-5 years may occur between the harvesting of the flax used to make linen and the completion of the piece for modern paintings. This estimation was based on authentic paintings kept in museums and reflects the time necessary to process the fibers, to make and sell the supports. Storage in the artist’s workshop and the time required to finish the work also have to be taken into consideration, but they are very variable from one artist or forger to another. Taking into account this time sequence, we can state that the Impressionist painting was forged after 2000 and more likely between 2002 and 2008.

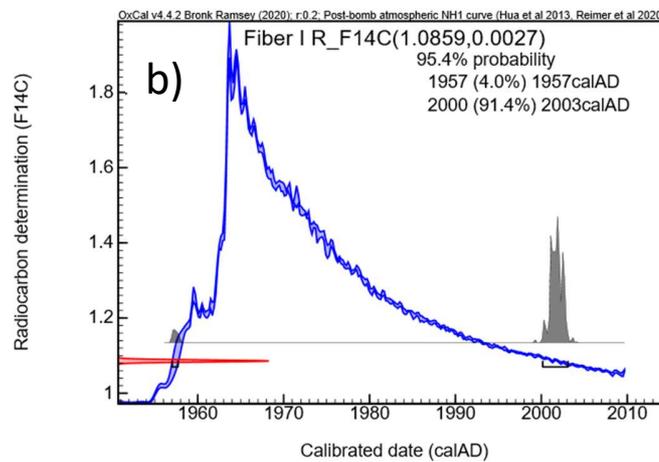


Figure 4. Impressionist painting canvas: (a) Observation of the canvas fiber under polarized light microscope 200x (white scale = 0.05 mm), identified as natural bast fibers, (b) calibrated ^{14}C results for the canvas (Fiber I - SacA 57263) showing that the plant producing the fabric fibers was harvested in 1957 or between 2000 and 2003.

3.2 The Pointillist painting

The wood stretcher and the canvas of the Pointillist painting were dated as well as a small piece of fiber coated at the surface of the paint layer. The radiocarbon dating of the wooden stretcher showed a pre-bomb age of 135 ± 21 BP (Table 3), corresponding, after calibration, to a wide distribution of calendar dates from 1676 to 1941 (Fig. 5) which

is in agreement with the active period of the alleged artist. However, not only is the result not precise due to the plateau of the calibration curve, but also as discussed above, old wood or a second-hand stretcher could have been used to mimic old artworks.

AMS lab code SacA	Sample reference	Constituent	Mass of extracted carbon (mg)	Percentage of Modern Carbon (pMC)	Age in year BP for pMC<100 or after 1950 for pMC>100
57264	Wood P	Stretcher	1.06	98.33 ± 0.26	135 ± 23
57265	Fiber P1	Fiber	1.01	105.60 ± 0.27	after 1950
57266	Fiber P2	Isolated fiber at the surface	0.60	104.23 ± 0.27	after 1950

Table 3. Uncalibrated radiocarbon results for the constituents of the Pointillist painting

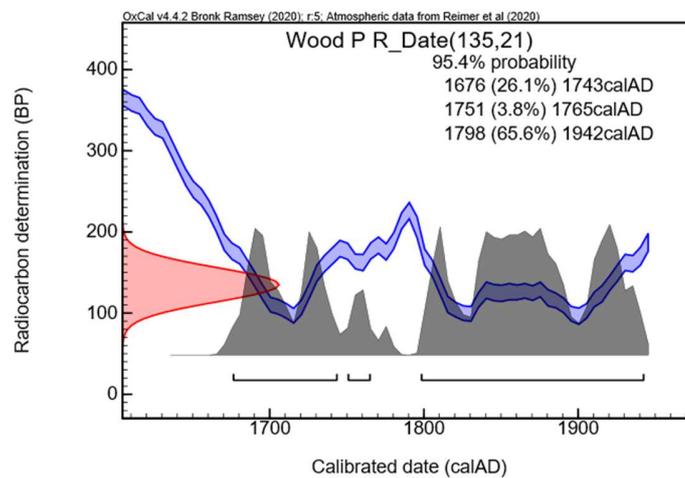


Figure 5. Calibrated ¹⁴C results for the stretcher (Wood P - SacA 57264) of the Pointillist painting

Two different textile fibers were also radiocarbon dated. The first fiber comes from the canvas (Fig. 1b) and was identified as flax (Fig. 6a). The second fiber was taken from the surface of the painting (Fig. 1d). This fiber probably comes from the brush used to apply the varnish in the final stage of creating the painting. The ^{14}C measurements were 105.60 ± 0.27 pMC and 104.23 ± 0.27 pMC for the two fibers (Table 3), showing post-bomb ^{14}C content. After calibration, using the upgraded version of the post-bomb atmospheric calibration curve developed for this study, two dates or intervals were proposed: 1956-1957 and 2004-2010 for the canvas fiber and 1956-1957 and 2008-2012 for the brush fiber (Fig. 6b and 6c). All the results are posterior to the death at the beginning of the 1940s of the alleged artist. As for the Impressionist painting, no evidence of restoration treatments of the support such as a lining canvas was observed, rejecting possible later modification. Even if the date obtained for the brush fiber could be related to a later varnishing, the date of the canvas fiber is evidence of a support manufactured after 1956. We can conclude that this Pointillist painting was not executed during the life of the alleged artist, but later in the 1950s or after 2004. Taking into account the typical time lag of 2-5 years [27] between harvesting of the flax and completion of the work, the painting could have been forged at the end of the 1950s or more probably between 2006 and 2014.

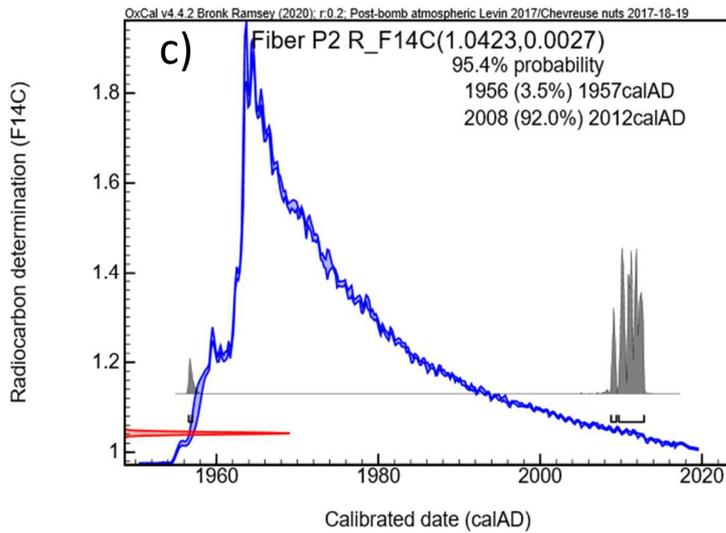
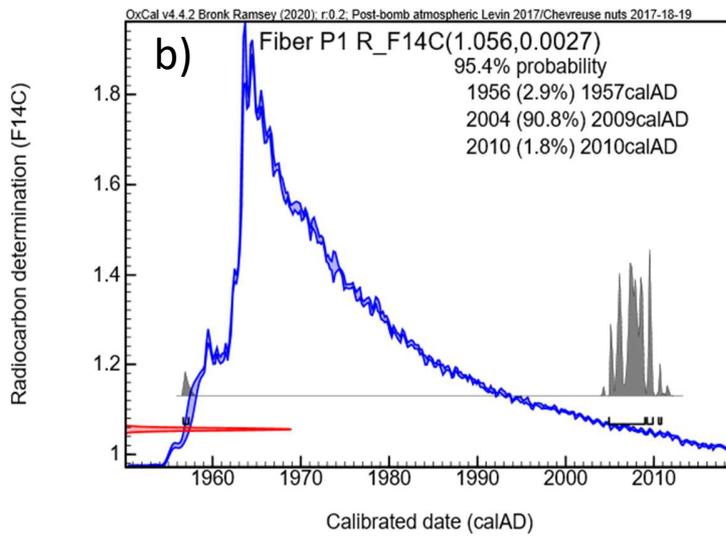
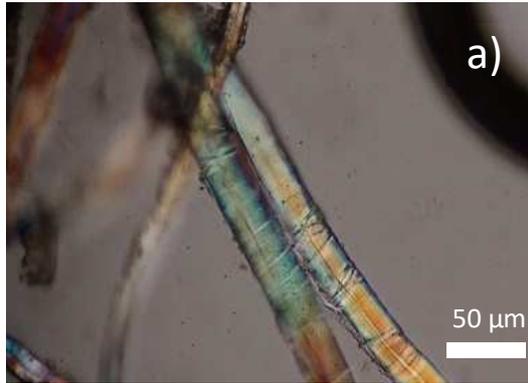


Figure 6. Pointillist painting: (a) Observation of the canvas fiber under polarized light microscope 200x (white scale = 0.05 mm), identified as natural bast fibers, (b) calibrated ^{14}C results for the canvas (Fiber P1- SacA 57265), c) calibrated ^{14}C results for the fiber coated at the surface of the painting (Fiber P2- SacA 57266). The results show that the plants that produced the fibers were cut in 1956-1957 or between 2004 and 2010 for the canvas and in 1956-1957 or between 2008 and 2012 for the isolated fiber (Length of the fiber = 5mm, mass = 4.6 mg)

4. Conclusion

AMS radiocarbon dating can play a crucial role in the fight against art counterfeiting and in the protection of Cultural Heritage [28]. This study shows that ^{14}C measurements provide absolute ages for most of the painting constituents. Due to the skill of the forgers, it is necessary to explore more than one constituent to unmask fraud. As forgers recycle old materials, select the pigment composition according to the active period of the artists or artificially age the forged works, attention must be paid to all the materials as far as possible. Pigments, medium and supports have to be carefully examined for analysis and dating. In this study, the forger(s) used a white pigment available at the beginning of the 20th century and wood coming from trees felled before 1950 for the stretchers, which implies an intention to deceive the date. The canvases were made of linen, which is in agreement with their having been manufactured at the beginning of the 20th century. Furthermore, their aspect – slightly yellowed and quite damaged in places – also matched with a one-century-old support. However, radiocarbon dating of the fibers revealed that the canvases had been woven with fibers extracted from plants harvested in the years 1956-1957 or more recently between 2000 and 2010. As a result, absolute dating proved unambiguously that the Impressionist and Pointillist paintings were not painted at the beginning of the 20th century and not by the alleged artists, who died in the 1940s.

Despite the two possible solutions of the calibration curve, the results obtained in this investigation confirm that the “ ^{14}C bomb peak” provides an efficient tool to uncover modern forgeries. The combination of different calibration curves reinforces the robustness of the method to determine the period of production with a precision of a few

years, which is helpful for the police investigation and contributes to protecting the art market and museums.

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