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Discovering forgeries of modern art by the ^{14}C Bomb Peak

L. Caforio[1,2], M.E. Fedi[2,a], P.A. Mandò[1,2], F. Minarelli[3], E. Peccenini[4,5], V. Pellicori[4], F.C. Petrucci[4,5,6], P. Schwartzbaum[7], and F. Taccetti[2]

[1] Dipartimento di Fisica e Astronomia, Università di Firenze, Italy
[2] INFN, Sezione di Firenze, Italy
[3] Leonardo S.r.l. - Analysis and Restauration, Bologna, Italy
[4] Dipartimento di Fisica e Scienze della Terra, Università di Ferrara, Italy
[5] Laboratorio TekneHub, Tecnopolo di Ferrara, Italy
[6] INFN, Sezione di Ferrara, Italy
[7] Solomon R. Guggenheim Foundation, New York, USA

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Abstract. Exploiting the anomalous behaviour of the atmospheric radiocarbon concentration in the years after 1955 (so-called "Bomb Peak"), an alleged painting by Fernard Léger was unambiguously proven to be a fake just by dating the canvas support. Some art historians had questioned the authenticity of the painting, and their suspicions were fuelled by some scientific examinations of the paint materials (X-ray radiography, SEM-EDS), compared to those of another work unquestionably attributed to Léger. The decisive argument to prove that it was a fake was provided by the radiocarbon date obtained from a sample of canvas of the painting, using Accelerator Mass Spectrometry at the INFN-Labec laboratory in Florence. Beyond any doubt, the cotton plant from which the canvas was produced was cut no earlier than 1959, *i.e.* four years after Léger's death, thus definitely confirming the concerns of a fake.

Introduction

One of the most important "ideal" assumptions, on which radiocarbon dating is based, is the constancy of ^{14}C concentration in the atmosphere over time. However, this is well known to be only an approximation, and changes of the ^{14}C atmospheric concentration have been carefully measured. This has allowed the radiocarbon community to set up a calibration curve, which is used to correct the inaccuracy of the ideal assumption. This curve is periodically updated including new data and, by now, it covers the period from about 50000 years ago [1] to present days. The most recent times, *i.e.* the decades since the mid-1950s, have been characterized by very large variations of the radiocarbon concentration, as a result of the massive nuclear tests in the atmosphere. In fact, during the late 1950s and the early 1960s, testing nuclear weapons in the air caused the release of a large amount of neutrons, which in turn resulted in a sudden increase of the production rate of ^{14}C nuclei. The effect was roughly the doubling of the radiocarbon concentration in the atmosphere (and in all living organisms in equilibrium with the atmosphere) in just a short period of about ten years. The maximum value of ^{14}C concentration was reached in 1963–1965. Afterwards, the Nuclear Test Ban Treaty put an end to the nuclear tests in the atmosphere and the ^{14}C concentration started to decrease owing to the exchanges between the atmosphere itself and the other natural carbon reservoirs, first of all the oceans, in which the excess radiocarbon progressively diluted. The behaviour of the radiocarbon concentration in these years is so peculiar that the community typically refers to it by using the expression Bomb Peak [2]. The Bomb Peak has found many applications thanks to the fact that it allows us to date samples with a very high precision, typically of the order of one year, or few years at most, just owing to the large variations of ^{14}C atmospheric concentration from one year to another. This feature has been exploited in forensic sciences and in biology, to determine, *e.g.*, the year of death of humans [3], the cells turnover times [4], fakes and forgeries in archaeology [5] and food industry [6].

[a] e-mail: fedi@fi.infn.it

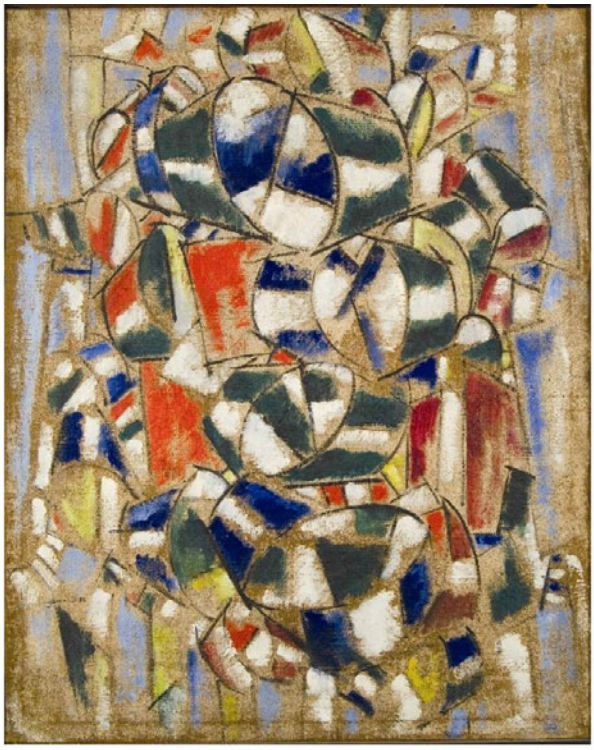

Fig. 1. *Contraste de formes*, oil on canvas, 92 × 73 cm, Peggy Guggenheim Collection, Venice.

The possibility of using the Bomb Peak for contemporary art issues has been investigated as well. Recent measurements performed on paper and canvas samples [7] have clearly shown that, although an accurate dating of an artwork is not really feasible on this basis, the Bomb Peak can be used as a powerful tool to detect recent forgeries of artworks claimed instead to have been manufactured in the first half of the 20th century or before.

Here we present a first application of the use of the radiocarbon Bomb Peak to unquestionably establish the forgery of an artwork supposed to be realised by the French painter Fernand Léger (1881–1955) in 1913. The painting is pertaining to the series of *Contrastes de formes* and belongs to the Peggy Guggenheim Collection in Venice (see fig. 1).

The *Contraste de formes* of the Peggy Guggenheim Collection

This painting has been considered a part of the large series *Contrastes de formes*, painted by Léger in the period from the late summer of 1913 to August 1914. It was bought by Peggy Guggenheim during the late 1960s, from the Berggruen Gallery in San Francisco, on commission from the Galerie Louise Leiris in Paris. According to Maurice Jardot, one of the directors of the Galerie Louise Leiris, the gallery had acquired the painting from Mr. G. Fourcade in 1966. Further previous property transfers can be safely traced back to the second half of the 1950s. In the 1970s, however, as Peggy Guggenheim herself remembered, the art critic and collector Douglas Cooper questioned the authenticity of the painting, so that she decided to give it back to the Galerie Louise Leiris, also asking for a refund. Meanwhile, in 1975, the Italian government inserted the Peggy Guggenheim Collection in the list of National Treasures, thus forbidding the alienation of any artwork —including *Contraste de formes*— from the Venice collection. Since then, the painting has not been exhibited anymore.

Following the first doubts concerning the authenticity of the painting, some scientific investigations have contributed to add some clues about this issue and a comparison of the results has been carried out between this *Contraste de formes* (indicated as PGC in the following) with another painting of the same series, definitely attributed to Léger, the *Contraste de formes* (see fig. 2) owned by the Solomon R. Guggenheim Foundation, New York (SRGF in the following)[1].

[1] Scientific investigations were performed and kindly provided by Gillian McMillan, associate chief conservator SRGF, New York.

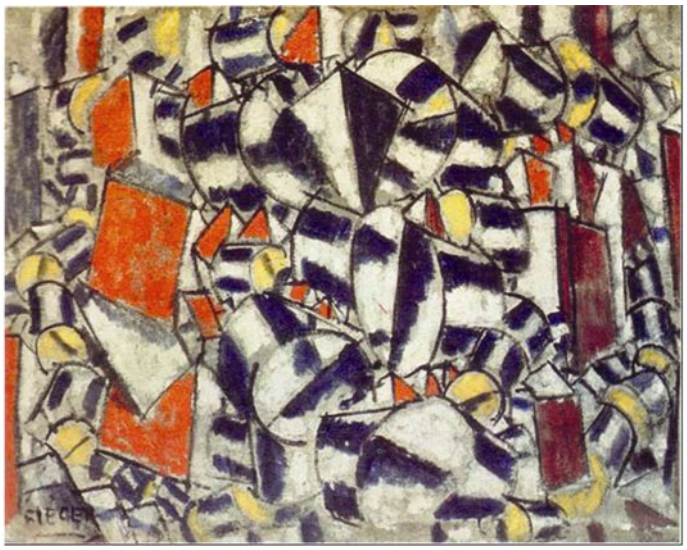

Fig. 2. *Contraste de formes*, 1913, oil on canvas, 98.8 × 125 cm, Solomon R. Guggenheim Foundation, New York.

Fig. 3. Detail of the canvas sample from PGC under the optical microscope.

We can briefly summarize the key points here.

- Canvas fibres of PGF consist of cotton, while those of SRGF are of linen.
- In some cases, different pigments were used for the same colour, as can be inferred from SEM-EDS measurements[2]. For example, lithopone ($ZnS + BaSO_4$) was used as a white pigment in PGF, while white lead was used in SRGF. Moreover, for most of the other colours (*e.g.*, red and yellow areas), the absence of large radio-opaque zones in the radiography of PGF suggests the use of organic pigments, at most mixed with some lithopone, while in SRGF vermillion (HgS) and cadmium yellow (CdS) are used for red and yellow, respectively. Moreover, no green colour is present in the SRGF palette, contrary to the case of PGF.

However, no decisive proof against authenticity could be established using image diagnostics and SEM techniques, because no historical anachronism in terms of pigments was found. It is just in this framework that we decided to perform the radiocarbon measurement of the canvas.

Sampling and experimental methods

For radiocarbon dating, we collected a sample of canvas (about 1 cm^2) from the rear of the painting, taking it from the fabric in excess around the frame. Before the pre-treatment, we examined it under the optical microscope to identify possible materials unrelated to the canvas fibres (*e.g.*, glue, oil, preparation), which obviously had to be removed. Figure 3 shows the sample as being basically clean and in a good state of preservation. Some threads were then extracted using a scalpel and washed in ultrasonic bath. The baths, 15 minutes each, were repeated three times. In

[2] By Alberto Conventi and Lorenzo Lazzarini, LAMA, Università IUAV di Venezia.

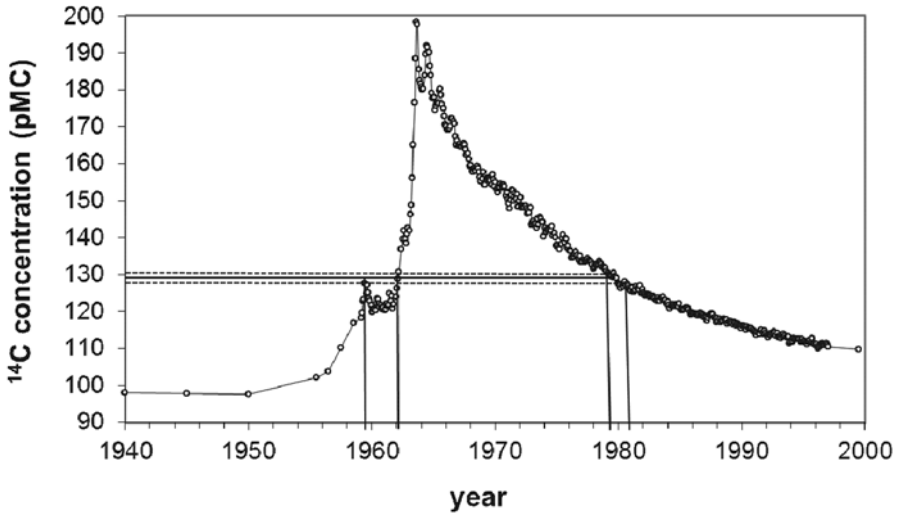

Fig. 4. Calibration of the measured ^{14}C concentration, (129.05±0.68) pMC: the radiocarbon concentration with its experimental error (reported as 2 sigma with dotted lines) is projected onto the Bomb NH1 curve. The Bomb Peak data are taken from the literature [2].

the first bath, the sample was soaked in a solution of ultra-pure water and acetone (1:1). In the second and third bath, ultra-pure water was used. After drying the sample in oven under vacuum at 100 °C for 5 hours, the so-called ABA (acid-basic-acid) protocol was applied to eliminate carbonates and humic traces. Finally, the cleaned and dried sample was combusted and graphitised. Combustion was achieved using a CHN elemental analyser (Thermo FlashEA 1112), directly coupled to the graphitisation line where the CO_2 from the sample was converted to solid C by reacting with hydrogen, at a temperature of about 600 °C, in the presence of iron as a catalyst [8]. The obtained graphite was pressed into a pellet to be then measured by Accelerator Mass Spectrometry (AMS). Given the small mass of the prepared sample (some hundreds of μg), AMS is the only technique allowing us to measure rare isotopes abundance with an adequate sensitivity.

AMS measurements were performed at the dedicated beam line installed at the 3 MV Tandetron accelerator of INFN-LABEC in Florence [9]. The $^{14}C/^{12}C$ isotopic ratio measured in the unknown sample was corrected for the background —estimated by measuring blank samples (nominally with no ^{14}C)— and for isotopic fractionation, evaluated by the $^{13}C/^{12}C$ ratio simultaneously measured in the accelerator beam line. Finally the $^{14}C/^{12}C$ isotopic ratio was normalized by comparison to a set of standard samples (NIST Oxalic Acid II, 134.06 pMC —percent of Modern Carbon), measured during the same batch of AMS runs.

Results and discussion

The data from AMS (^{14}C concentration and isotopic fractionation δ^{13}C) can be summarized as follows:

- ^{14}C concentration = (129.05 ± 0.68) pMC;
- $\delta^{13}C = -(24.70 \pm 0.09)‰$.

The measured radiocarbon concentration is indeed conclusive in our case: any concentration larger than 100 pMC is a clear indication that the organic component of the sample "died" after 1955, when the effects of the bomb explosions started to increase atmospheric radiocarbon concentration, as already mentioned in the introduction. More specifically, an estimate of the real age of the dated sample can be obtained by the comparison of the measured radiocarbon concentration to the Bomb Peak calibration curve. In particular, we took for comparison the so-called Bomb NH1 curve, where NH1 identifies the area from about 40 °N of latitude to the North Pole [2]. The application of the simple intercept method can be adequate in this case (see fig. 4): three possible time intervals are identified at 95% confidence level:

- 1959;
- 1962;
- 1979-1980.

The latter time interval can be excluded, since in those years the painting already belonged to the Peggy Guggenheim Collection. Thus, we can conclude that the canvas used by the painter was manufactured with plants cut either in 1959 or in 1962. 1959 is therefore a definite *terminus post quem* for the production of the painting, clearly indicating that it cannot be an original artwork by Léger, who died in 1955.

In conclusion, radiocarbon dating turned out to be a crucial tool in proving the forgery of the Léger painting, made in the late 1950s, providing objective evidence to the doubts of the art experts.

Although the measurement of radiocarbon concentration is destructive, with the use of AMS the quantity of material sampled is anyway very small. For instance, in the case of a painting on canvas, such as reported in this paper, a small amount of material can always be taken from the revers of the canvas itself wrapped around its wood stretcher. Therefore, we believe that such measurements can be safely done without fears of harming the integrity of the artwork to be dated; they would be thus well worth to be applied to the identification of forgeries, made after 1955, of paintings claimed to be older.

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