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Indian Yellow and Titanium White – A Material-centred Perspective on the Pigments Used by Artists Helene Schjerfbeck and Akseli Gallen-Kallela in the 1920s

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This article presents the results of material studies focused on identifying and comparing the contents of the pigment palettes of two notable Finnish painters, Helene Schjerfbeck (1862–1946) and Akseli Gallen-Kallela (1865–1931). The research methods used comprise energy-dispersive X-ray fluorescence spectrometry (EDXRF) and polarised light microscopy (PLM). In addition, certain pigments have been identified in colour areas of the works using specular reflection FT-infrared spectrometry (FTIR) and Raman spectrometry.[1] To support the results gathered using scientific analytical methods, archival research has been conducted in order to find notes and references to the pigments made by the artists themselves.

Prior to the research, the main composition of Akseli Gallen-Kallela's pigment palette was identified using the first two of the aforementioned analytical methods. The results of the research study in question were presented in the online journal of the Society for Art History in Finland *Tahiti,* published in March 2020.[2] A similar research project began in the autumn of 2020 in order to identify the composition of Helene Schjerfbeck's pigment palette. The research is ongoing and the results will be published over the coming years.

Research background

Helene Schjerfbeck and Akseli Gallen-Kallela are internationally the most significant Finnish artists from the turn of the 19th and 20th centuries. Both were regarded as highly talented at a very early age and gained considerable popularity on the Finnish art scene in their own lifetimes. They were both educated in Helsinki at the Drawing School of the Finnish Art Society and also as private students of elder masters. Both also travelled to Paris to access the most

1 All the methods used are non-invasive and/or non-destructive.

2 Hanne Tikkala and Seppo Hornytzkyj. 'Luonnontieteellisin analyysimenetelmin tunnistettu Akseli Gallen-Kallelan väripaletti', *Tahiti*, *10*(1), 5–55, https://doi.org/10.23995/tht.90554 (accessed 7 June 2022).

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Fig. 1. Helene Schjerfbeck, *The Convalescent*, 1888, oil on canvas, 92cm x 107cm Finnish National Gallery / Ateneum Art Museum (A I 223)
Photo: Finnish National Gallery / Yehia Eweis

Fig 2. Akseli Gallen-Kallela, *Aino Myth*, Triptych, 1891, oil on canvas, 200cm x 413cm Finnish National Gallery / Ateneum Art Museum (A I 518)
Photo: Finnish National Gallery / Hannu Aaltonen

modern education of the period. Schjerfbeck studied at the Académie Trélat and Académie Colarossi, and Gallen-Kallela at the Académie Julian.[3]

During her long career Helene Schjerfbeck's art evolved from historical themes and French-influenced realism to delicate, minimalistic and in some cases colourful portraits and still-lifes. Her works, *The Convalescent* (1887) (Fig. 1), *Self-Portrait, Black Background* (1915*), Red Apples* (1915) and *Self-Portrait with Red Dot* (1944) are well known to virtually all Finns.

Akseli Gallen-Kallela in turn acted as vital influencer in Finnish nationalist circles at the turn of the century. His art developed from using a precise academic painting technique towards an expressive style, with brave brushwork and a distinctive tone.[4] He is known as the illustrator of the Finnish common people, landscapes and *The Kalevala,* the Finnish national

3 Riitta Konttinen. 'Schjerfbeck, Helene' (http://urn.fi/urn:nbn:fi:sks-kbg-004115) and Aimo Reitala. 'Gallen-Kallela, Akseli' (http://urn.fi/urn:nbn:fi:sks-kbg-003194), in *The National Biography of Finland*, online publication. Helsinki: Finnish Literature Society, 1997– (accessed 3 June 2022).

4 Katariina Johde and Hanne Tikkala. 'Observations on the Painting Technique and the Materials in the Painting of *Lake View*, by Akseli Gallen-Kallela', *FNG Research*, 3/2021, 11, https://research.fng.fi/wp-content/uploads/2022/01/fngr_2021-3_johde_katariina_tikkala_hanne_article1.pdf (accessed 7 February 2022).

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epos. Gallen-Kallela's most notable works include *Boy with a Crow* (1884), *Aino Myth, Triptych* (1891) (Fig. 2) and *Lake Keitele* (1905).

During the 1920s, Helene Schjerfbeck lived in Hyvinkää and Tammisaari, Finland, while Akseli Gallen-Kallela resided in Finland in Ruovesi, Porvoo, and Espoo, and between 1923–26, in the US, in Chicago and in the artist collective in Taos, New Mexico. During the 1920s, a new pigment, titanium white, which is significant from a present-day perspective, entered the art supplies market. At the same time, the use of some historical, widely used pigments, such as emerald green[5], began to decline.[6] The objective of this research study is to examine trends in the use of painting materials by these artists. The research questions were: Did Helene Schjerfbeck and Akseli Gallen-Kallela use pigments that had recently entered the market and how do the pigment palettes they used in the 1920s differ from one another?

While the identification of pigments used in individual works over an artist's entire oeuvre serves as an important tool for research into attribution and authentication, the findings serve an equally significant role as part of the procedures related to preventive conservation and the occupational safety of conservators.[7] Identifying the colour areas with pigments susceptible to fading or changing colour in artworks makes it possible to implement protective measures for the works in an increasingly targeted manner and to limit exposure to light during exhibitions when necessary. Correspondingly, if pigments containing arsenic have been identified in the work, the conservator working on the object is able to take this into consideration while performing procedures involving surface cleaning or varnish removal.

The identification of pigments is challenging because of the layered structure and heterogeneous mixtures of pigment particles in paints. This is the case in the painting techniques of both Helene Schjerfbeck and Akseli Gallen-Kallela, who used different mixtures of paints, and especially of Schjerfbeck who reworked her paintings several times and used multi-layered structures. The colour areas to be studied usually contain several pigments and fillers, each revealing its own information and yet sometimes covering the information provided by another material. In fact, the results are often the sum of several separate results from which the researcher must identify the relevant characteristics of different pigments. Another challenge for the research involves whether the research can be undertaken entirely non-invasively or whether small samples can be taken.

Research data

In all, the research material comprises 70 oil and tempera paintings spanning 1920–30, most of which are either on canvas or on panel. Of these paintings, 27 are by Helene Schjerfbeck and 43 by Akseli Gallen-Kallela. Of Gallen-Kallela's production from the period in question, the pigments in 27 works have been identified with an EDXRF spectrometer and a polarised light microscope over the course of the previous research. The results of further studies on the pigments used in these works are presented here, as well as the first findings regarding 16 works not previously examined.

The works are part of the collections of the Finnish National Gallery, the Gösta Serlachius Fine Arts Foundation, the Gallen-Kallela Museum, the Mannerheim Museum, the Signe and Ane Gyllenberg Foundation and the Didrichsen Art Museum. All museums are in Finland. Some works belong to private collections (Tables 1 and 2).

As a method supporting the research results, the archives and correspondence of the painters have been surveyed for references to and notes on the pigments they used. In

5 In this research the term emerald green is used when referred to a pigment containing copper and arsenic (copper acetoarsenite), and not viridian, which is hydrated chromium oxide.

6 The authors have observed this phenomenon when studying Finnish paintings dated to the turn of the 19th and 20th century.

7 Katrien Keune, Jennifer Mass, Apruva Mehta, Jonathan Church and Florian Meier. 'Analytical imaging studies of the migration of degraded orpiment, realgar and emerald green pigments in historic paintings and related conservation issues', *Heritage Science* 4:10, 2016, https://doi.org/10.1186/s40494-016-0078-1 (accessed 25 February 2022).

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x = EDXRF
p = PLM
ir = FTIR-reflection
uv-f = UV fluorescence seen with bare eye
uv (m) = UV fluorescence seen through microscope
x^{Br} = Bromium in spectrum, possible eosin
? = identification not sure
x = main white
* inofficial translation

Year	Title	Collection/Museum	Size (cm)	cobalt blue	synthetic ultramarine	prussian blue	cerulean blue	emerald green	malachite	arsenic in red, black or brown	chromium green / viridian	chromium yellow	cadmium yellow	neaples yellow	indian yellow	red lead	vermilion	organic red	geranium lake	cobalt violet	iron oxide pigments	lead white	zinc white	titanium white	bone black	iron oxide black	$BaSO_4$/litophone	$CaCO_3$ / $CaSO_4$
1919–20	Einar Reuter III	Finnish National Gallery (A-1998-498)	34 x 28	x, p		p		x		x					p						x, p	x	x					x
1923	Annuli Reading	Finnish National Gallery (A-2005-132)	37 x 30,5	x, p	p				x, p		x, p						x	p, uv (m)			x, p	x	x				x	x
1924–25	Robber at the Gate of Paradise	Gösta Serlachius Fine Arts Foundation (GSTS-2156)	84 x 62,5	x																	x	x	x				x	x
1925	Blonde Woman	Finnish National Gallery (A-2005-136)	50,5 x 35,5	x		p							x				x				x, p	x	x				x	x
1925–27	La dame au chapeau bleu, d'après Constantin Guys / Lady with a Blue Hat, after Constantin Guys	Signe and Ane Gyllenberg Foundation (G-2011-165)	65,5 x 50,5	x									x					uv (m)			x, p	x	x				x	x
1926	The Fortune-Teller	Finnish National Gallery (A-2005-114)	65,5 x 51	x, p								x, p	x		p						x, p	x	x				x	x
1926	Angel Fragment, after El Greco	Finnish National Gallery (A-2002-453)	74 x 54	x															x^{Br}		x	x	x				x	x
1926	The Gardberg Buildings	Gösta Serlachius Fine Arts Foundation GSTS-2465	44,5 x 48,5	x, p	p													p, uv (m)			x, p	x	x					
1926–28	Karin (Girl with Red Cheeks)	Didrichsen Art Museum (DAM1067)	49,3 x 37,4	x																	x	x	x					x
1926–27	Portrait of Matti Kiianlinna	Gösta Serlachius Fine Arts Foundation (GSTS-2367)	64 x 51	x						x											x	x	x		x		x	x
1927	Park Seat (Shadow on the Wall)	Didrichsen Art Museum (DAM1121)	47 x 40	x	p	p				x	x, p		x					p			x, p	x	x				x	x
1927	The Seamstress, Half-Length Portrait (The Working Woman)	Finnish National Gallery (A-2005-111)	67 x 49,5	x						x			x					p			x, p	x	x		x		x	x
1927	Girl from Eydtkuhne II	Finnish National Gallery (A-2005-110)	70 x 54,5	x		p							x, p					p			x, p	x	x				x	x
1927	Sjundby Manor	Finnish National Gallery (A-2005-135)	79,5 x 94	x, p				x			x,p		x, p				x				x, p	x	x		?		x	x
1927	The Death of Wilhelm von Schwerin	Gösta Serlachius Fine Arts Foundation (GSTS-1545)	80 x 62	x							x										x	x	x				x	x
1927	Rosy-Cheeked Girl	Gösta Serlachius Fine Arts Foundation (GSTS-160)	37,5 x 36,5	x																	x	x	x		x		x	x
~1928	Elegant Lady (Dora)	Signe and Ane Gyllenberg Foundation (G-2011-167)	37,5 x 38,5	x							x										x	x	x		x		x	x
1928	Modern Schoolgirl	Finnish National Gallery (A-2002-456)	66,5 x 50	x				x, p									x				x	x	x				x	x
1928	The Applegirl	Didrichsen Art Museum (DAM1068)	32 x 34,2	x				x													x	x	x					x
1928	Shadow on the Wall II (Green Bench)	Finnish National Gallery (A-2002-454)	64 x 51,4	x, p	p						x, p		x					p			x, p	x	x			x		x
1928	The Landlord II (Profile of a Man)	Finnish National Gallery (A-2005-112)	48 x 38,5	x, p									x	x			x				x, p	x	x					x
1928 /-29	Crucifixion	Signe and Ane Gyllenberg Foundation (G-2011-168)	62,0 x 75,5	x													x				x	x	x				x	x
1929	Dark Lady	Signe and Ane Gyllenberg Foundation (G-2011-169)	53,5 x 41,5	x													x	uv-f			x	x	x		x		x	x
1929	The Motorist (Måns Schjerfbeck)	Gösta Serlachius Fine Arts Foundation (GSTS-164)	55 x 47	x	p	p		x			x							p, uv (m)			x	x	x				x	x
1929	Girl from the Islands	Finnish National Gallery (A-2005-113)	45 x 30,5	x, p		p											x	p, uv-f			x, p	x	x		x		x	x
1930	Måns Schjerfbeck	Finnish National Gallery (TA-2005-9)	50,5 x 35,5	x		p, ir						x									x, p	x	x				x	x
~1930	Still Life in Green	Finnish National Gallery (A IV 3382)	33,5 x 50	x, p	p						x, p		x, p		p			p, uv-f			x, p	x	x		x		x	x

Table 1. Paintings by Helene Schjerfbeck researched for 'Indian Yellow and Titanium White – A Material-centred Perspective on the Pigments Used by Artists Helene Schjerfbeck and Akseli Gallen-Kallela in the 1920s'

x = EDXRF
p = PLM
r = Raman
ir = FTIR-reflection
uv-f = UV fluorescence seen with bare eye
? = identification not sure
x = main white
** results published 2020
*** results published 2020 and in-depth research conducted 2021
* inofficial translation

Year	Title	Collection / Museum	Size (cm)	cobalt blue	synthetic ultramarine	prussian blue	cerulean blue	emerald green	malachite	arsenic in red, black or brown	chromium green / viridian	chromium yellow	cadmium yellow	neaples yellow	indian yellow	lead red	vermilion	organic red	geranium lake	cobalt violet	iron oxide pigments	lead white	zinc white	titanium white	bone black	iron oxide black	$BaSO_4$/litophone	$CaCO_3$ / $CaSO_4$
~1920	View from the Window at Linudd**	Private collection	36,5 x 28,5	x							x		x				x			x	x	x	x				x	x
1920	First Snow in Ruovesi**	Gallen-Kallela Museum (GKM-7378)	30 x 52	x							x		x				x				x	x	x				x	x
1924	Mrs Margaret Lippo Hecht and Daughter Margareta, double portrait, sketch**	Gösta Serlachius Fine Arts Foundation (GSTS618)	48,5 x 56	x							x		x				x	uv-f			x	x	x	x			x	x
1924	Mrs Hecht, portrait, sketch***	Gallen-Kallela Museum (GKM-313)	27 x 19	x							x		x				x	uv-f		?	x	x	x	x	x		x	x
1924	Mrs Hecht	Private collection	68 x 51,5	x			x				x		x				x	uv-f			x	x	x	x			x	x
1924	Portrait of Elmer Forsberg	Gallen-Kallela Museum (GKM-734)	23 x 30	x							x						x	uv-f			x	x	x	x	x		x	x
1924	View from the Window in Chicago*, ***	Gallen-Kallela Museum (GKM-314)	29 x 26,5	x	?	?					x		x				x				x	x	x				x	x
1924	A Rocky Landscape in New Mexico**	Gösta Serlachius Foundation (GSTS288)	20 x 14,5	x			x				x						x				x	x	x					x
1924	Portrait of Mr Heyskar, sketch*	Private collection	31 x 31	x							x		x				x	uv-f		x	x	x	x	x			x	x
1924	Portrait of Kirsti, in Taos*, **	Private collection	29 x 37	x	?	?							x				x	uv-f			x	x	x	x			x	x
1925	Gate in Taos***	Finnish National Gallery (A III 2156)	30 x 16,5	x, p							x, p		x				x	p, uv-f			x	x	x	x			x	x
1925	Taos Home in Sunlight***	Finnish National Gallery (A III 2158)	35 x 29,5	x, p	p		x, p				x, p		x, p				x	p, uv-f			x,p	x	x	x			x	x
1925	Taos Home in Moonlight***	Finnish National Gallery (A III 2157)	20,5 x 32,5	x, p	p						x, p		x, p				x	p, uv-f			x, p	x	x				x	x
1925	View from the Taos Mountains, Horses***	Private collection	26,5 x 21	x							x		x				x	uv-f			x	x	x				x	x
1925	View from the Taos Mountains (green blanket and horses*)	Private collection	29 x 29	x							x		x				x	uv-f			x	x	x		x			
1925	View from the Taos Mountains**	Private collection	20 x 26	x			x				x		x				x	uv-f			x	x	x					x
1925	Home in Taos**	Private collection	30 x 33	x							x		x				x	uv-f			x	x	x				x	x
1925	Horse and Sheep***	Gallen-Kallela Museum (GKM-733)	20 x 25	x							x		?				x	uv-f			x	x	x		x		x	x
1925	View to Taos Mountains, Home*,***	Private collection	32 x 35	x							x		x				x				x	x	x					x
1925	Shed in the Taos Mountains**	Finnish National Gallery (A III 2162)	20,5 x 26	x							x		x				x	uv-f			x	x	x		x		x	x
1925	Taos Mountains Shrouded in Clouds***	Finnish National Gallery (A III 2161)	28,5 x 38	x, p							x, p		x, p				x	p			x	x	x	x, r			x	x
1925	An Indian Woman in New Mexico**	Gösta Serlachius Fine Arts Foundation (GSTS 289)	25 x 19,5	x, p			x, p				x		x				x	uv-f			x, p	x	x					x
1925	Native American on Horseback in Snow***	Finnish National Gallery (A III 2160)	19,5 x 26	x							x		x				x			x, p	x	x	x	x, r			x	x
1925	Native American on Horseback***	Finnish National Gallery (A III 2159)	30 x 41,5	x, p	p						x, p		x				x	p, uv-f		x, p	x, p	x	x	x			x	
1925	Penitents Carrying Their Crosses*, ***	Private collection	14 x 20	x							x		x				x				x	x	x				x	x
1925	Native American in Snow Blizzard***	Private collection	50 x 59		?	?					x		x			?					x	x	x					x
1925	Crack Willow and Blue Bird in New Mexico**	Gösta Serlachius Fine Arts Foundation (GSTS 290)	25 x 19,5	x							x						x	uv-f			x	x	x					x
1925	Girl Carrying a Milk Jug in Taos*	Gallen-Kallela Museum (GKM-3469)	20 x 14,5	x							x		x				x			x	x	x	x	x			x	x
1925	Portrait of Dr Bergmans*	Gallen-Kallela Museum (GKM-3471)	26 x 20	x													x				x	x	x				x	x
1925	Native American in Green Cloak	Private collection	37,8 x 29 / 39 x 30	x							x		x				x				x	x	x		x		x	x
1925	Native Americans on Horseback*	Private collection	49,5 x 34,5	x							x		x				x	uv-f		?	x	x	x				x	x
not dated	Siu Ohutaa (Eagle Star)	Private collection	40 x 30	x			x				x						x	uv-f			x	x	x	x	x		x	x
not dated	View from the Taos Mountains (spiral column and dead horse*)***	Private collection	32 x 35	x							x		x				x			x	x	x	x					x
not dated	Landscape in the Rocky Mountains (red shoe*)	Private collection	29 x 39	x							x						x	uv-f		x	x	x	x	x	x		x	x
not dated	Taos Mountains, sketch*	Gallen-Kallela Museum (GKM-7391)	15 x 20	x							x		x				x				x	x	x				x	x
not dated	Portrait of Gustaf Mannerheim, sketch*	Gallen-Kallela Museum (GKM-309)	50 x 42	x							x		x				x	uv-f			x	x	x				x	x
not dated	Portrait of Carl Gustaf Mannerheim	Private collection	32 x 25,5	x							x		x				x	uv-f			x	x	x				x	x
1928	Portrait of Carl Gustaf Mannerheim, sketch*, ***	Private collection	39,5 x 34	x							x		x				x				x	x	x				x	x
1928	The Forging of the Sampo, sketch for fresco of KOP*	Gallen-Kallela Museum (GKM-3895)	20 x 69	x									x				x				x	x	x				x	x
1928	Sketch for Frescoes of the National Theatre	Gallen-Kallela Museum (GKM-3897)	24 x 41	x							x		x				x				x	x	x				x	x
1928	Sketch for Frescoes of the National Theatre	Gallen-Kallela Museum (GKM-3896)	24 x 68,5	x			x				x		x				x				x	x	x				x	x
1929	Portrait of Carl Gustaf Mannerheim, sketch*, ***	Private collection	55 x 45,5	x							x						x				x	x	x					x
1929	Portrait of Carl Gustaf Mannerheim**	Mannerheim Museum	113 x 73,5	x							x		x				x				x	x	x				x	x

Table 2. Paintings by Akseli Gallen-Kallela researched for 'Indian Yellow and Titanium White – A Material-centred Perspective on the Pigments Used by Artists Helene Schjerfbeck and Akseli Gallen-Kallela in the 1920s'

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Fig. 3. Beckmann's Syntonos-Colours sales catalogue. Akseli Gallen-Kallela Archive, Gallen-Kallela Museum, Espoo
Photo: Finnish National Gallery / Hanne Tikkala

the case of Helene Schjerfbeck, this research focuses on the correspondence with her 'sister artists' Ada Thilén, Maria Wiik and Helena Westermarck and a long-time friend, forester and artist Einar Reuter. The correspondence is located in the Åbo Akademi University Archives in Turku and in the Archives of the Society of Swedish Literature in Finland, in Helsinki.

The archival material research concerning Gallen-Kallela was conducted by searching the Gallen-Kallela Archive and home library in the Gallen-Kallela Museum, in Espoo. Gallen-Kallela described his pigments and the mixing techniques involved only to a very limited extent, which is why the background material concerning him mostly consists of supporting documentation of various kinds, such as purchase invoices and art supply merchants' catalogues. Especially interesting is a sales catalogue of Beckmann's Syntonos-Colours located in the Gallen-Kallela Archive. In this catalogue, presumably Gallen-Kallela himself has marked which of the oil-colour tubes was to be purchased.[8] (Fig. 3) In addition, his archive includes a notebook in which he reflects on Michel-Eugéne Chevreul's colour theory[9] and there is also a reference to Friedrich Wilhelm Ostwald's colour theory[10]. The colour theories, and their implementation, have been excluded from the scope of this study.

8 L. Auerbach & Co., Fuerth, Bavaria. *Sole manufacturers of Beckmann's Syntonos-Colours* (catalogue). Akseli Gallen-Kallela Archive. Gallen-Kallela Museum, Espoo.

9 Akseli Gallen-Kallela's notebook, GKM-7698. Akseli Gallen-Kallela Archive. Gallen-Kallela Museum, Espoo.

10 Receipt from A.B. Herman Lindell. Akseli Gallen-Kallela Archive, Gallen-Kallela Museum, Espoo. A.B. Herman Lindell Esplanadgatan 8, Helsingfors, 21. December 1928, when the item '1ast ostwaldsfärger' was purchased. This item could have been a box of crayons or a model showing Friedrich Ostwald's colour classification system, https://www.winsornewton.com/na/articles/art-history/ostwald-bauhaus-colour-system/ (accessed 19 March 2021) and https://varioppi.wordpress.com/oppihistoria/#Ostwald (accessed 20 March 2021).

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Research methods

The analytical methods used in this research follow the research protocol developed in the Finnish National Gallery's Conservation unit and Materials research laboratory. This protocol has been under pressure during the past decade, as the Finnish National Gallery has been obliged to participate in research to determine any art forgeries in Finland as a contributor to help the National Bureau of Investigation. The main factors affecting the development of this protocol and the analytical methods chosen are non-destructivity, effectiveness/performance and cost-effectiveness. All methods used in this research are commonly used in the field of pigment studies.[11]

First, the works were examined using a stereo microscope at 10–40X magnification. This resulted in findings on the structure of the colour areas: the colour and size of the pigment particles or particle aggregates in the colour surface of the work, as well as the way in which these were distributed. For example, during the examination, a purple area might have been found to contain either nothing but a purple pigment or different mixtures of blue and red pigments. This examination facilitated linking elements identified from paint surfaces to specific pigments. Subsequently, the work was illuminated using a Labino UVG3 2.0 UV-light (365 nm) and observations were made regarding the possible fluorescence caused by pigments in the work.

Following the preliminary research, XRF spectra were collected from different colour areas of the works using a hand-held Bruker Tracer 5g-spectrometer with a 3mm collimator, rhodium anode and SSD-detector. The multiple measuring parameters were 15 keV, 10 µA, no filter and 30 seconds, and 40 keV, 37 µA, Ti/Al-filter and 30 seconds. The XRF spectra were processed using Bruker Artax software.

Sometimes, simply identifying elements in colour areas is not enough to identify a pigment conclusively. For example, identifying blue pigments such as Prussian blue or ultramarine requires additional analytical methods. In this study polarised light microscopy was used as an additional analytical method.

For the study, a small pigment sample was removed under the stereomicroscope from the colour area of the work with a tungsten needle. In size, the sample was usually a few tens of micrometres. The sample was mounted in Meltmount (RI:1.662) between the microscope slide and the cover slip and examined using 100–400X magnification in plane-polarised and cross-polarised transmitted and/or reflected light. One sample was prepared as a cross-section sample. It was embedded in polystyrene resin and ground and polished using silicon carbide papers of 500, 1,000 and 4,000 grit.

The microscopes used were an Olympus BH-2 and a Leica DMRX polarised light microscope and a Leica MZ 12-stereomicroscope. The micrographs were taken with a Nikon Coolpix 4500 digital camera mounted on the Leica DMRX polarised light microscope.

In a few cases, a definitive identification of a pigment was impossible using the analytical methods described. In these cases, the pigment was identified using FTIR spectrometry or Raman spectrometry. In this study both applications were used non-destructively.

FTIR spectrometric analyses were performed in reflection mode on the colour surfaces using a Bruker Alpha FTIR-spectrometer with a DRIFTS-module. The measurements were carried out in the 4,000–400cm^{-1} range at a resolution of 4cm^{-1} using 60 scans and recorded by OPUS software.

Raman spectrometric analyses were performed with a Bruker Bravo Raman-spectrometer (1,064nm) and a DXR Smart Raman-spectrometer equipped with a Thermo Scientific DXR microscope with a laser wavelength of 780nm at 12mW of power. Spectra were collected under the microscope (50X objective) in the range of 60–1,800cm^{-1}. During

11 Walter McCrone. 'The Microscopical Identification of Artists' Pigments', *Journal of the International Institute of Conservation*, no 1 and 2, vol 7, 1982, 11–34; Chris McGlinchey. 'Handheld XRF for the examination of paintings: proper use and limitations', in Aaron N. Shugar and Jennifer L. Mass (eds.), *Studies in Archaeological Sciences. Handheld XRF for Art and Archaeology*. Leuven: Leuven University Press, 2012, 131–58.

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Fig 4. Akseli Gallen-Kallela, *Crack Willow and Blue Bird in New Mexico*, 1925, oil on canvas, mounted on cardboard, 25cm x 19.5cm
Gösta Serlachius Fine Arts Foundation, Mänttä (GSTS 290)
Photo: Gösta Serlachius Fine Arts Foundation / Hannu Miettinen

recording, a 10sec exposure time with 3 scans was used and the spectra were recorded by Omnic software.

Results

The following section deals with pigments and colour palettes used by the artists and is based on analytical results and archival sources. It should be taken into account that pigments in each painting are mainly identified using XRF spectrometry.

Blue pigments

The most common blue pigment identified in both artists' paintings is cobalt blue ($CoAl_2O_4$). All of Schjerfbeck's paintings and 42 of the 43 Gallen-Kallela paintings analysed contained cobalt blue. In Gallen-Kallela's painting *Crack Willow and Blue Bird in New Mexico* (1925) (Fig. 4) it was used to create a sunny blue sky and in Schjerfbeck's painting *Girl from Eydtkuhne II* (1927)[12] the green shades in the dress are a mixture of cobalt blue, iron-containing colours, cadmium yellow and whites, mainly zinc white but also lead white.

In a letter to her artist friend Ada Thilén, in 1902, Schjerfbeck asked her to buy some paints, including one tube of cobalt blue.[13] In her correspondence, she has often described the instability of pigments containing cobalt and its tendency to darken during the painting process. In a letter addressed to her friend Einar Reuter in 1928, she wrote that cobalt (in blue) is a dangerous pigment as it changes its colour to dark plum purée in the course of

12 Yrjö and Nanny Kaunisto Collection, Finnish National Gallery / Ateneum Art Museum (A-2005-110), https://www.kansallisgalleria.fi/en/object/547218 (accessed 24 February 2022).

13 Letter from Helene Schjerfbeck to Ada Thilén, 18 December 1902. Westermarck, Helena. Manuscript Collections, Åbo Akademi University Library, Turku.

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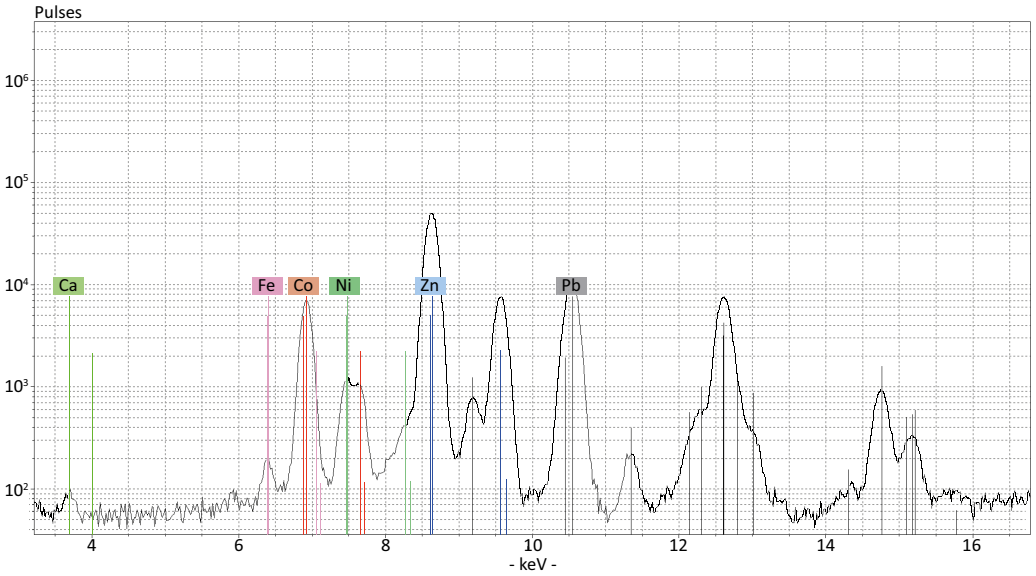

Spectrum 1. EDXRF spectrum measured from the blue area of Akseli Gallen-Kallela's painting *Portrait of Carl Gustaf Mannerheim*, sketch. Private collection
Figure: Finnish National Gallery / Materials research laboratory, Hanne Tikkala

time.[14] She also advised Maria Wiik to be careful with cobalt as it had a tendency to darken to a greenish-black with age.[15] Cobalt blue is known as a very stable and permanent pigment[16] and so it is likely that Schjerfbeck refers to some other cobalt-containing pigment in her letters. For example, smalt, a cobalt-containing potassium glass, has a tendency to fade but to date it has not been identified in her paintings. Another possibility is that the tube of paint supplied as cobalt blue contained synthetic organic compounds that tended to fade and therefore the hue of the painted surface changed during the course of time.

Two references to the use of cobalt blue were found in the Gallen-Kallela Archive and in the Collections of the Gallen-Kallela Museum.[17] Cobalt blue pigment was identified in three oil colour tubes named 'Cobalt blue'. The tubes were manufactured by H. Schmincke & Co, Dr. Fr. Schoenfield & Co and Weimarfarbe. Moreover, three oil colour tubes containing mixtures of pigments contained cobalt blue, together with synthetic ultramarine or cerulean blue and/or chromium colours and zinc and lead whites and barium sulphate/litophone.[18]

Cobalt blue was identified when peaks of cobalt (Co) were present in an XRF spectrum collected from a blue area. (Spectrum 1) Most cobalt blues dating to the beginning of the 20th century contain detectable amounts of nickel (Ni) by EDXRF and arsenic (As). These elements

14 'Om jag hade lagt bara Cobolt i Katharinas blå skuggor hade hon inom kort varit tennigt svart, Cobolt är farlig. Nu tror jag det blir "plommonsås" med tiden. En del konstverk åldras vackert, en del dö.' Letter from Helene Schjerfbeck to Einar Reuter, 2 January 1928. Schjerfbeck, Helene. Manuscript Collections, Åbo Akademi University Library, Turku.

15 'Ett råd i olja skall jag ge dig, spara på cobalt, jag vill använda det bästa och nu är allt mörkt svartgrönt i en kall tenning ton, såg nog hela tiden att det förändrades från en dag till en annan.' Letter from Helene Schjerfbeck to Maria Wiik, 26 December 1908. SLSA 1297 Letters from Helene Schjerfbeck to Maria Wiik (1907–1928). The Society of Swedish Literature in Finland, Helsinki.

16 A. H. Church. *The Chemistry of Paints and Painting*. London, Great Britain: Seeley, Service & Co. Limited, 1915, 234; Nicholas Eastaugh, Valentine Walsh, Tracey Chaplin and Ruth Siddall. *Pigment Compendium. Dictionary of Historical Pigments.* Burlington, US: Elsevier Butterworth-Heinemann, 2004, 113.

17 L. Auerbach & Co., Fuerth, Bavaria. *Sole manufacturers of Beckmann's Syntonos-Colours* (catalogue). Akseli Gallen-Kallela Archive. Gallen-Kallela Museum.

18 Tikkala and Hornytzkyj, 'Luonnontieteellisin analyysimenetelmin tunnistettu Akseli Gallen-Kallelan väripaletti', 53–55.

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are impurities in the pigment that have remained from the manufacturing process.[19] Smalt, a blue potash glass pigment containing cobalt, also includes detectable amounts of nickel and sometimes also arsenic but in addition a distinct peak of potassium (K) can be observed in the XRF spectrum.[20] In the case of degraded smalt the potassium peak is less intense.

In plane polarised light, the cobalt blue particles appeared translucent blue with a low relief. According to the literature, the refractive index is equal to or higher than that of the medium (RI ≥ 1.662).[21] However, the cobalt blue particles from both artists' paintings have a refractive index, which is lower than the medium (RI < 1.662). Cobalt blue has high red transmission and the particles appeared red when viewed with the Chelsea-filter. The particles of cobalt blue appeared isotropic under crossed polars and their size and morphology was typical of cobalt blue.

The other blue pigment that was identified from both artists' pigment palettes was synthetic ultramarine ($Na_7Ca(Al_6Si_6O_{24})(SO_4)(S_3)\cdot H_2O$). Unlike cobalt blue, it does not have a characteristic metallic element in its chemical composition, and its constituent elements are commonly found in extenders, as well as being poorly detected by an EDXRF spectrometer, so identification was not possible. That is why it was not possible to evaluate how common synthetic ultramarine is in the pigment palettes of these these two artists.

Synthetic ultramarine is present in Gallen-Kallela's painting *Native American on Horseback* (1925)[22] in the colourful rug on the Native American's horse. In Schjerfbeck's painting, *The Motorist*[23]*,* it has been mixed with emerald green in the man's jacket to form a vivid blue-green.

There are no indications in Schjerfbeck's letters of the use of synthetic ultramarine, but in the private archive of Gallen-Kallela references are found.[24] In addition, five oil-colour tubes named ultramarine belong to the Collections of the Gallen-Kallela Museum. The tubes are from W. Becker, v. Pereira and Weimarfarbe. In all, synthetic ultramarine was identified from eight oil-colour tubes belonging to the museum's collections. In some tubes, it was part of a colour mixture.[25]

In plane polarised light synthetic ultramarine appeared as evenly coloured translucent blue particles. These particles were rounded and small but coarser particles were also observed. The particles often aggregated, forming bigger clusters and that is why the individual particles were sometimes hard to distinguish. The refractive index was lower than that of the medium (RI < 1.662) and the relief was low. Synthetic ultramarine (as well as natural) has a high red transmission and it appeared red with the Chelsea-filter. Under crossed polars the synthetic ultramarine particles appeared isotropic.

Prussian blue, ferric ferrocyanide, is a pigment that was used only by Helene Schjerfbeck. It has been identified in four of her paintings. Schjerfbeck has noted the pigment

19 Muriel Geldof and Lise Steyn. 'Van Gogh's Cobalt Blue', in Marija Vellekoop, Muriel Geldof, Ella Hendriks, Leo Jansen and Alberto de Tagle (eds.), *Van Gogh's Studio Practice*. Brussels: Mercatorfonds, 2013, (256–67) 260–65.

20 Marika Spring, Veronika Kugler and Stewart Bean. 'Quantitative energy dispersive X-ray analysis of the blue pigment smalt', in Nigel Meeks, Caroline Cartwright, Andrew Meek and Aude Mongiatti (eds.), *Historical Technology, Materials and Conservation: SEM and microanalysis*. London: Archetype Publications in association with British Museum, 2012, (114–22) 117.

21 Nicholas Eastaugh, Valentine Walsh, Tracey Chaplin and Ruth Siddall. *Pigment Compendium. Optical Microscopy of Historical Pigments.* Burlington, US: Elsevier Butterworth-Heinemann, 2004, 35; Roy Ashok. 'Cobalt blue', in Barbara H. Berrie (ed.), *Artists' Pigments. A Handbook of Their History and Characteristics*. Volume 4. Washington: National Gallery of Art, 2007, (151–77) 155.

22 Finnish National Gallery / Ateneum Art Museum (A III 2159), https://www.kansallisgalleria.fi/en/object/440830 (accessed 24 February 2022).

23 Gösta Serlachius Fine Arts Foundation (GSTS-164), https://taide.art/teokset/rCrGcgGjW0S0nBHAKE-TwA/Autoilija-M%C3%A5ns-Schjerfbeck (accessed 27 June 2022).

24 L. Auerbach & Co., Fuerth, Bavaria. *Sole manufacturers of Beckmann's Syntonos-Colours* (catalogue). Akseli Gallen-Kallela Archive. Gallen-Kallela Museum, Espoo.

25 Tikkala and Hornytzkyj, 'Luonnontieteellisin analyysimenetelmin tunnistettu Akseli Gallen-Kallelan väripaletti', 53–55.

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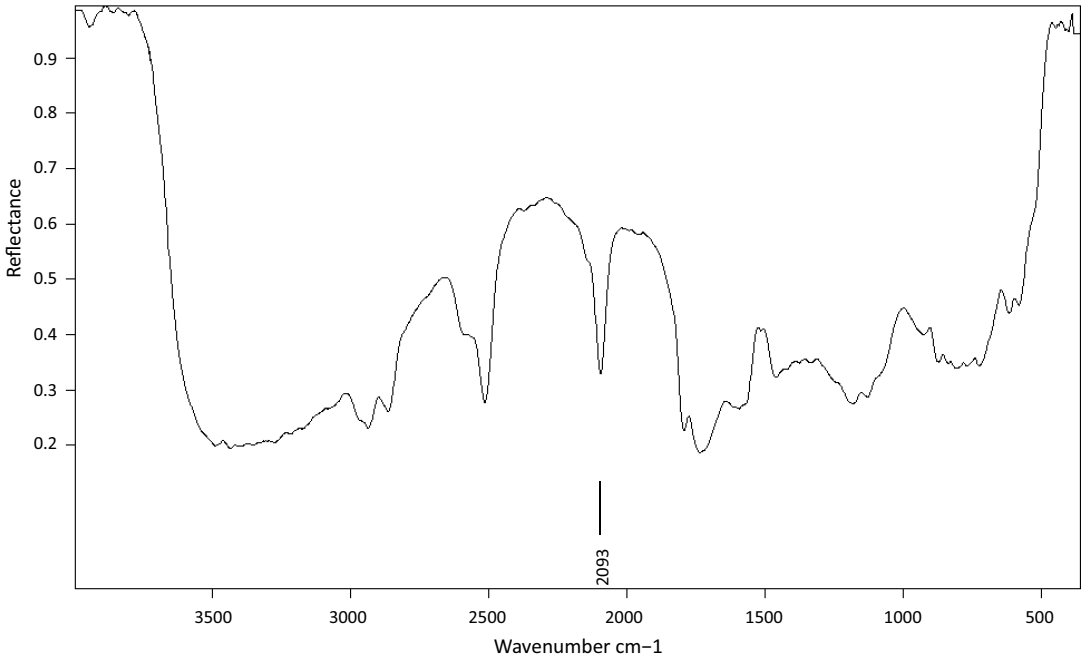
Fig. 5. Helene Schjerfbeck, *Portrait of Måns Schjerfbeck*, 1930, oil on canvas, 50.5cm x 35.5cm
Deposited at the Finnish National Gallery (TA-2005-9)
Photo: Finnish National Gallery / Yehia Eweis

and its darkening properties in her letters to Maria Wiik and to Einar Reuter.[26] In the Gallen-Kallela Archive, no references to the use of Prussian blue are found, but it has been identified in one of the oil-colour tubes which had unclear markings.[27] Nevertheless, in the early years of his career, Gallen-Kallela used Prussian blue but was left unconvinced about its properties. He has written on the back of one of his paintings that the Prussian blue he had used had faded and changed colour, to a black-greenish tone.[28]



Spectrum 2. Specular reflection FTIR spectrum measured from Helene Schjerfbeck's painting *Portrait of Måns Schjerfbeck*, deposited at the Finnish National Gallery (TA-2005-9)
Figure: Finnish National Gallery / Materials research laboratory, Hanne Tikkala

26 'I Kath. Bauman satte jag bleu de Prusse ett grand i panna och bykt, det mörknar efter en tid och det blir en gammal tavla, liten omväxling i glädjen.' Letter from Helene Schjerfbeck to Maria Wiik, 18 December 1927. SLSA 1297 Letters from Helene Schjerfbeck to Maria Wiik (1907–1928). The Society of Swedish Literature in Finland, Helsinki.

27 Tikkala and Hornytzkyj, 'Luonnontieteellisin analyysimenetelmin tunnistettu Akseli Gallen-Kallelan väripaletti', 54.

28 *Winter Scene in Jaatsi*, 1882 (GKM-355), Gallen-Kallela Museum, Espoo.

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Fig. 6. Akseli Gallen-Kallela, *Taos Home in Sunlight*, 1925, oil on canvas, mounted on plywood, 35cm x 29.5cm
Finnish National Gallery / Ateneum Art Museum (A III 2158)
Photo: Finnish National Gallery / Jenni Nurminen

In plane polarised light Prussian blue particles were very small, translucent and had an intense blue shade. The particles tended to aggregate and that is the reason why the clusters appeared opaque at times. The relief was low and the refractive index was lower than that of the medium (RI < 1.662). When viewed with the Chelsea-filter, the colour of the particles was unchanged. Under crossed polars the particles appeared isotropic.

In one of the Schjerfbeck paintings, *Portrait of Måns Schjerfbeck* (Fig. 5), Prussian blue was identified in the blue jacket of the model, using specular reflectance FTIR spectrometry. The Prussian blue particles formed agglomerates in combination with zinc white and this made characterisation of the particles difficult. In specular reflection FTIR spectrometry, Prussian blue was identified when a typical cyano group absorption band at around 2,100 cm^{-1} was present in the spectrum.[29] (Spectrum 2)

Cerulean blue ($CoSnO_3$) was used only by Gallen-Kallela during the 1920s. It was identified in seven of the 43 paintings analysed. For example, in the painting *Taos Home in Sunlight* (1925) (Fig. 6) it was used as a mixture with synthetic ultramarine and viridian in the blue-green sky area. Cerulean blue is not discussed by either of the artists, but it has been identified in two of Gallen-Kallela's oil-paint tubes. Both were manufactured by H. Schmincke. One was named 'Cölinblau' and the other 'Blaugrünoxyd no 103'.[30]

Cerulean blue was identified when peaks of cobalt (Co) and tin (Sn) were present in the XRF spectrum collected from a blue area of the painting. In plane polarised light, small rounded translucent blue-green particles were observed. The particle size was small, the relief was high and the refractive index was higher than that of the medium (> 1.662). Under crossed polars cerulean blue particles were isotropic.

Green and yellow pigments

In general, green and yellow chromium pigments are common in both artists' pigment palettes. There are many different types of pigments containing chromium and they were often used by artists during the latter half of the 19th century and at the beginning of the 20th

29 The efficiency of this method depends on the possible existence of a layer of lacquer on the surface of the painting and of its thickness. In this case such a layer either did not exist or was really thin and the characterisation of the pigment was possible. Because of the lacquer layer it is more common to characterise Prussian blue with polarised light microscopy.

30 Tikkala and Hornytzkyj, 'Luonnontieteellisin analyysimenetelmin tunnistettu Akseli Gallen-Kallelan väripaletti', 53–54.

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Fig. 7. Helene Schjerfbeck, *Sjundby Manor*, 1927, oil on canvas, 79.5cm x 94cm Yrjö and Nanny Kaunisto Collection, Finnish National Gallery / Ateneum Art Museum (A-2005-135)
Photo: Finnish National Gallery / Hannu Pakarinen

century. Identifying these is often challenging. Very often the elements chromium (Cr), lead (Pb), barium (Ba) and strontium (Sr) are detected in different colour areas in paintings with an XRF-spectrometer. The area containing these elements might include a green pigment, a mixture of blue and yellow pigment, a mixture of green and yellow pigment or a mixture of blue, green and yellow pigment. That is why the pigments containing chromium cannot be identified using XRF spectrometry alone, and so other analytical techniques are necessary.

In this research, the most common chromium-containing pigment identified was viridian, hydrated chromium oxide ($Cr_2O_3 \cdot 2H_2O$). For example, in Schjerfbeck's painting *Sjundby Manor* (Fig. 7) it forms different shades of green with emerald green and iron-containing pigments. In Gallen-Kallela's *Native American on Horseback*[31] the green colour in the blanket is viridian.

Viridian was identified in seven oil-colour tubes belonging to the Collections of the Gallen-Kallela Museum. It forms part of a colour mixture in three Fritz Behrendt tube colours named 'Behrendtgrün'. Wilh. Becker's oil-colour tube named 'Kromoxidgrönt', two Weimarfarbens 'Permanentgrün' tubes and one tube of J. Blockx Fils à Vieux-dieu called 'Vert compose' contained viridian. Gallen-Kallela has also marked a colour called 'Chrome oxid [sic] blue-green' in Beckmann's Syntonos-Colours catalogue.[32]

Helene Schjerfbeck mentioned chromium pigment just once, when she wrote to Maria Wiik in 1914 about the paintings she was working on. In her letter she noted that chromium

31 Finnish National Gallery / Ateneum Art Museum (A III 2159), https://www.kansallisgalleria.fi/en/object/440830 (accessed 27 June 2022).

32 L. Auerbach & Co., Fuerth (Bavaria). *Sole manufacturers of Beckmann's Syntonos-Colours* (catalogue). Akseli Gallen-Kallela Archive. Gallen-Kallela Museum.

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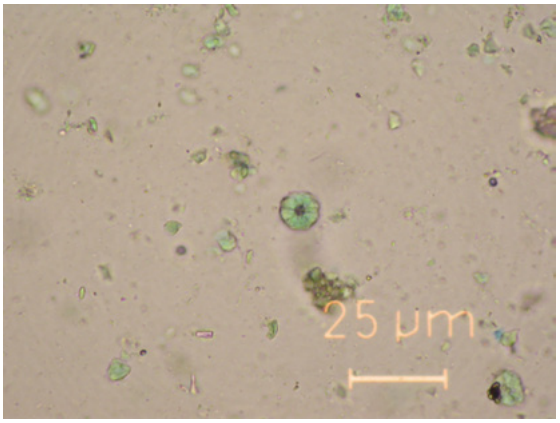

Fig. 8. Particles of emerald green pigment observed in plane polarised transmitted light. From Helene Schjerfbeck's painting *Modern Schoolgirl*, 1928
Ester and Jalo Sihtola Fine Arts Foundation Donation, Finnish National Gallery / Ateneum Art Museum (A-2002-456)
Photo: Finnish National Gallery / Materials research laboratory, Seppo Hornytzkyj

and cinnabar were dangerous, but no explanation to this comment was given.[33] She did not explain whether she meant viridian, chromium yellow or some other pigments containing chromium.

In plane polarised light, particles of viridian appeared translucent bright green. The relief was low and the refractive index was higher than that of the medium (RI > 1.662). The particle size showed a broad distribution. Under crossed polars the particles were anisotropic and had high birefringence that was masked by the bright blue-green body colour. Because the particles often occur as aggregates, sweeping extinction could be seen when the microscope table was turned.

Chrome yellow ($PbCrO_4$) was identified in one of the Schjerfbeck paintings – *The Fortune Teller* (1926)[34] – in the woman's yellow dress. As for Gallen-Kallela, chrome yellow was identified in one of the Wilh. Becker oil-colour tubes called 'Kromoxidgrönt' and in one of the Weimarfarbe oil-colour tubes called 'Permanentgrün'.[35]

Copper aceto arsenite ($Cu(C_2H_3O_2)_2{\cdot}3Cu(AsO_2)_2$), known as emerald green, and other pigments containing copper were not identified in Gallen-Kallela's researched paintings from the 1920s, but five of the 27 Schjerfbeck paintings analysed contained emerald green in green or brown colour areas. Copper aceto arsenite was identified, when intense peaks of copper (Cu) and arsenic (As) were present in the XRF spectrum. In *Modern Schoolgirl* (1928)[36] the green collar of the girl is painted with emerald green.

In plane polarised light copper aceto arsenite particles appeared as translucent green, finely fibrous spherulites. (Fig. 8) The relief was low and the refractive index was higher than that of the medium (RI > 1.662). Under crossed polars the particles were anisotropic and high birefringence colours were observed.

In her letter to Maria Wiik in 1915, Schjerfbeck writes that she has mixed carmine lake and emerald green and the result is blue.

> *Guess what, I repainted the background the other day. I mixed together a self-invented poisonous concoction, red and green and you get blue! (Carmine lake no. 7 and emerald green).*[37]

In a letter to Einar Reuter in 1925, she also mentioned having used Veronese green, 'vert-Veronese', in the background of the portrait of Måns Schjerfbeck. This name used for the

33 'Här har en tabell och ser att chrom och zinober äro farliga, men huru skall man vara utan zinober?' Letter from Helene Schjerfbeck to Maria Wiik, 28 January 1914. Westermarck, Helena. Manuscript Collections, Åbo Akademi University Library, Turku.

34 Yrjö and Nanny Kaunisto Collection, Finnish National Gallery / Ateneum Art Museum (A-2005-114), https://www.kansallisgalleria.fi/en/object/552468 (accessed 27 June 2022).

35 Tikkala and Hornytzkyj, 'Luonnontieteellisin analyysimenetelmin tunnistettu Akseli Gallen-Kallelan väripaletti', 53–54.

36 Ester and Jalo Sihtola Fine Arts Foundation Donation, Finnish National Gallery / Ateneum Art Museum (A-2002-456), https://www.kansallisgalleria.fi/en/object/521590 (accessed 27 June 2022).

37 'Vet du en dag målade jag om fonden, blandade en af mig uppfunnen giftblandening, rödt och grönt och det blir blått! (Krapplack no 7 med vert émérande).' Letter from Helene Schjerfbeck to Maria Wiik, 18 March 1915. Westermarck, Helena. Manuscript Collections, Åbo Akademi University Library, Turku. Transl. Lene Wahlsten.

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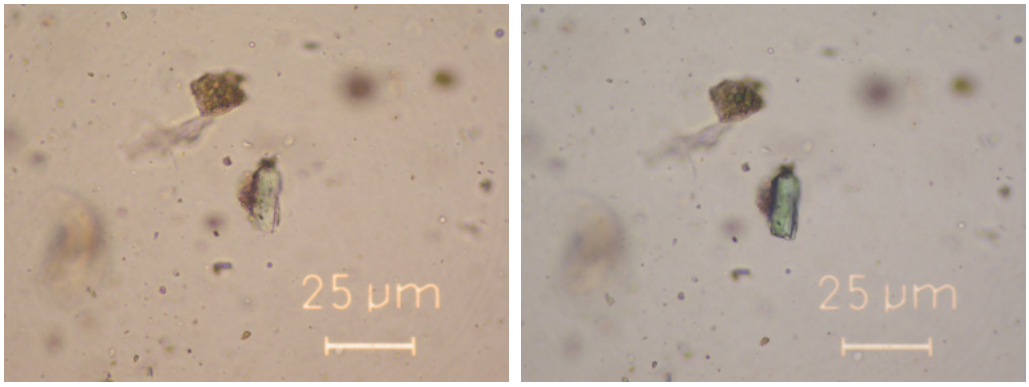

Figs. 9 a–b. A particle of malachite observed in plane polarised transmitted light in different orientations. From Helene Schjerfbeck's painting *Annuli Reading*, 1923 Yrjö and Nanny Kaunisto Collection, Finnish National Gallery / Ateneum Art Museum (A-2005-132)
Photo: Finnish National Gallery / Materials research laboratory, Seppo Hornytzkyj

pigment is vague since it could refer to green earth from Verona, viridian (hydrated chromium oxide) or emerald green (copper aceto arsenite).[38]

Gallen-Kallela had bought an oil-colour tube, which could have been emerald green, from the Finnish colour retailer Suomen Väri- ja Vernissatehdas.[39] This tube is called 'Keisarinvihreä' (Imperial green) and, according to the retailer's catalogue from 1898, it contains arsenic.[40]

Arsenic has also been identified in three of Schjerfbeck's paintings in black and brown areas. For example, in the painting *The Seamstress, Half-Length Portrait* (1927)[41], arsenic was identified in the brown black hair but no copper or cobalt was present in the XRF spectrum. In these three cases, the pigment that contains arsenic has yet to be identified. It could be possible, but highly unusual considering the time, that in these paintings she had used orpiment (As_2S_3), a yellow orange pigment that has a tendency to degrade to grey-brown or white.[42] However, this pigment has not yet been identified from her paintings.

In Schjerfbeck's *Annuli Reading* (1923)[43], an intense peak of copper was present in the XRF spectrum measured from a green area at the left side of the painting. A sample was collected from this area and malachite ($Cu_2CO_3(OH)_2$) was identified with the help of the polarised light microscope. In her letter to Maria Wiik in 1912, Schjerfbeck mentioned 'vert malachite'.[44] When viewed in plane polarised light, malachite particles appeared light green translucent particles and their relief changed from high to low when the microscope table was rotated (Fig. 9). The refractive indices of the particles were higher than that of the medium (RI > 1.662). Under crossed polars the particles were anisotropic and they had high birefringence and showed high interference colours.

38 Carol A. Grissom. 'Green Earth', in Robert L. Feller (ed.), *Artists' Pigments. A Handbook of their History and Characteristics*. Volume 1. Oxford: Oxford University Press, 1985, (141–67) 143; Ralph Mayer. *The Artist's Handbook of Materials & Techniques*. Fifth edition, revised and expanded by Steven Sheehan. London: Clays Lts St Ives Plc, 1991, 61; Eastaugh *et al.*, *Pigment Compendium. A Dictionary of Historical Pigments*, 388.

39 Receipt, Suomen Väri- ja Vernissatehdas O.-Y., 5.7. Akseli Gallen-Kallela Archive. Gallen-Kallela Museum, Espoo.

40 Catalogue of Suomen Väri- ja Vernissatehdas, Helsinki: J. Simeliuksen perillisten kirjapaino, 1898, page 35. Digital Collections. National Library of Finland, (https://digi.kansalliskirjasto.fi/pienpainate/binding/342697?page=35, (accessed 14 May 2021).

41 Yrjö and Nanny Kaunisto Collection, Finnish National Gallery / Ateneum Art Museum (A-2005-111), https://www.kansallisgalleria.fi/en/object/543622 (accessed 27 June 2022).

42 Keune *et al.*, 'Analytical imaging studies of the migration…', 14; Elisabeth West Fitzhugh. 'Orpiment and Realgar', in Elisabeth West Fitzhugh (ed.), *Artists' Pigments. A Handbook of their History and Characteristics*. Volume 3. Oxford: Oxford University Press, 1997, (47–79) 51.

43 Yrjö and Nanny Kaunisto Collection, Finnish National Gallery / Ateneum Art Museum (A-2005-132), https://www.kansallisgalleria.fi/en/object/594229 (accessed 27 June 2022).

44 'Nu har jag tagit neapelgult och vert malachite.' Letter from Helene Schjerfbeck to Maria Wiik, 28 January 1914. Westermarck, Helena. Manuscript Collections, Åbo Akademi University Library, Turku.

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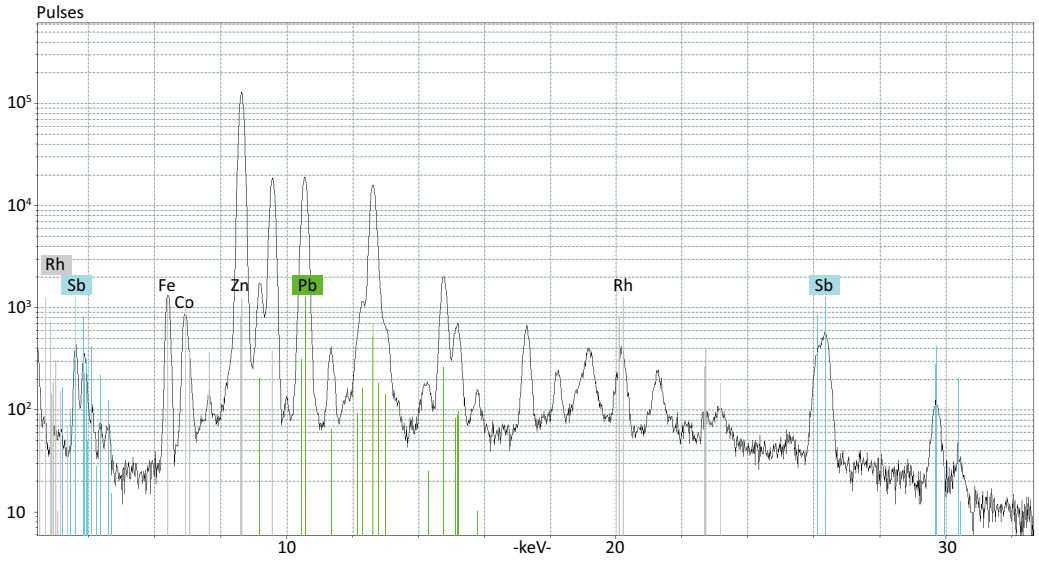

Spectrum 3. EDXRF spectrum measured from the green area of Helene Schjerfbeck's painting *The Landlord II*, 1928, Yrjö and Nanny Kaunisto Collection, Finnish National Gallery / Ateneum Art Museum (A-2005-112)
Figure: Finnish National Gallery / Materials research laboratory, Hanne Tikkala

Among the yellow pigments, both artists often used cadmium yellow (CdS). Of the 27 Schjerfbeck paintings analysed, it was present in 10, and also in 36 of Gallen-Kallela's 43 paintings examined. For example, in *Taos Home in Sunlight* (Fig. 6), Gallen-Kallela has used cadmium yellow in the yellow shades of the bushes. He marked two different types of cadmium yellow tubes in Beckmann's sales catalogue: 'Cadmium yellow light' and 'deep'.[45] Cadmium yellow was identified when cadmium (Cd) peaks were present in the XRF spectrum collected from the green, yellow or orange areas of the painting.

Naples yellow ($Pb_2Sb_2O_7$) was identified in the green area of Schjerfbeck's *The Landlord II* (1928).[46] In the XRF spectrum intense peaks of lead (Pb) and antimony (Sb) were present, together with cobalt (Spectrum 3). The green was a mixture of Naples yellow and cobalt blue. Of the two artists, only Schjerfbeck gives us evidence that she has used Naples yellow.[47]

Pigments containing iron

Pigments containing iron (Fe) have been identified in yellow, orange, red, green and brown areas in both artists' paintings. Their use of these pigments was very common and continued throughout their careers across every decade. Schjerfbeck has mentioned only one pigment, Sienna[48], in reference to these pigments, but in Gallen-Kallela's archive and the museum's collections there are many references: in Beckmann's Syntonos-Colours catalogue Gallen-

45 L. Auerbach & Co., Fuerth (Bavaria). *Sole manufacturers of Beckmann's Syntonos-Colours* (catalogue). Akseli Gallen-Kallela Archive. Gallen-Kallela Museum.

46 Yrjö and Nanny Kaunisto Collection, Finnish National Gallery / Ateneum Art Museum (A-2005-112), https://www.kansallisgalleria.fi/en/object/550406 (accessed 27 June 2022).

47 Letter from Helene Schjerfbeck to Einar Reuter, 26 February 1920. Schjerfbeck, Helene. Manuscript Collections, Åbo Akademi University Library, Turku; Helene Schjerfbeck to Maria Wiik, 28 July 1914. Westermarck, Helena. Manuscript Collections, Åbo Akademi University Library, Turku.

48 'Nu har jag preparerat en duk och satt sienna och blått i kritan för att ha en ton, den blif ändå tungt rödaktig tror jag.' Letter from Helene Schjerfbeck to Maria Wiik, 12 October 1913. Westermarck, Helena. Manuscript Collections, Åbo Akademi University Library, Turku.

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Kallela has marked 'Light Ochre', 'Raw Sienna', 'English red (light)' and 'Burnt Sienna'[49] and the actual oil-colour tubes containing iron pigments are 'Terra di Sienna' and 'Englishroth' (Beckmann's Syntonos-Farben), 'Casslerbraun' and 'Umbra' (Bernhard Kahn & Co), 'Caput mortuum' (Fritz Behrendt Farbefabrik), 'Terra di Sienna' (Becker's Normalfärger AB), 'Lichter Ocher', 'Umbra (Cyprische)' and 'Goldocker' (Dr. Fr. Schoenfield & Co), 'Terra di Sienna', 'Casslerbraun' and 'Demi Ombre Neu' (v. Pereira Temperafarbe), 'Siena', 'Terra di Siena', 'Römische Ocker', 'Lichter Ocker', 'Goldocker' and 'Caput Mortuum' (H. Schmincke & Co).[50] Identification of the specific pigments containing iron in these tubes would require its own research project.

In this research, the identification of pigments containing iron in the colour areas was made when an intense peak of iron was detected in the XRF spectrum measured from a yellow, orange, red, brown or black colour area of the painting. In the XRF spectrum a strong peak of iron appeared, often together with weak peaks of manganese (Mn) and/or titanium (Ti).

Intense peaks of iron were observed in the XRF spectra collected from some of the green areas in both artists' paintings. Therefore, it is possible that iron-containing green earth pigments (celadonite/glauconite) belong to both artists' pigment palettes. Although these pigments were not identified in any of the polarised microscope samples, the presence of green earth in Gallen-Kallela's pigment palette was confirmed in the course of the previous research.[51]

Red pigments

Vermilion (HgS) has been identified in both artists' paintings, but Gallen-Kallela used it more frequently, in fact it occurs in 41 of his 43 analysed paintings. Vermilion was identified in only eight of Schjerfbeck's 27 paintings that were analysed. It was characterised when a strong peak of mercury (Hg) was observed in the XRF spectrum. Vermilion has been identified in one oil-colour tube, 'Karmin-Zinnober' (Dr. Fr. Schoenfield & Co), belonging to the Collection of the Gallen-Kallela Museum.[52] Helene Schjerfbeck writes about vermilion often and speaks highly of it, although she recognised its tendency to change colour.[53]

Red pigments containing iron, as well as other iron-containing colours, were often used by both artists. It is most probable that in Schjerfbeck's pigment palette red iron-rich pigments were her most frequently used red pigments. That is why strong peaks of iron were often present in the XRF spectrum measured from the red colour areas in her paintings.

Purple pigments

In the Schjerfbeck paintings that were analysed all the purples are mixtures of different red and blue pigments and no single purple pigments have been identified, neither have they been noted in her letters. In Gallen-Kallela's paintings, purples are not only mixtures of red and blue pigments but also cobalt violets: cobalt phosphate ($Co_3(PO_4)_2$) and magnesium cobalt arsenate ($Mg_2Co(AsO_4)_2$). Cobalt phosphate was identified in one of the oil tubes belonging to

49 L. Auerbach & Co., Fuerth, Bavaria. *Sole manufacturers of Beckmann's Syntonos-Colours* (catalogue). Akseli Gallen-Kallela Archive. Gallen-Kallela Museum.

50 Tikkala and Hornytzkyj, 'Luonnontieteellisin analyysimenetelmin tunnistettu Akseli Gallen-Kallelan väripaletti', 53–54.

51 Tikkala and Hornytzkyj, 'Luonnontieteellisin analyysimenetelmin tunnistettu Akseli Gallen-Kallelan väripaletti', 38.

52 Tikkala and Hornytzkyj, 'Luonnontieteellisin analyysimenetelmin tunnistettu Akseli Gallen-Kallelan väripaletti', 53.

53 'Här har en tabell och ser att chrom och zinober äro farliga, men huru skall man vara utan zinober?' Letter from Helene Schjerfbeck to Maria Wiik, 28 January 1914. Westermarck, Helena. Manuscript Collections, Åbo Akademi University Library, Turku.

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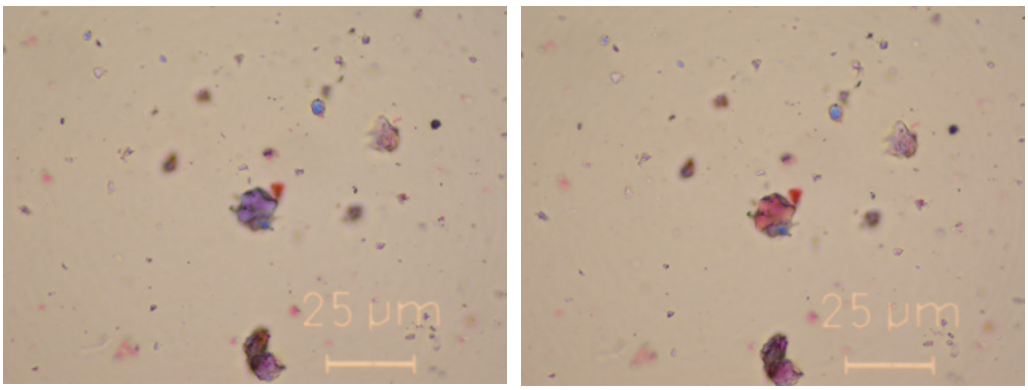

Figs. 10 a–b. A particle of cobalt phosphate observed in plane polarised transmitted light in different orientations. From Akseli Gallen-Kallela's painting *Native American on Horseback*, 1925 Finnish National Gallery / Ateneum Art Museum (A III 2159)
Photo: Finnish National Gallery / Materials research laboratory, Seppo Hornytzkyj

the Gallen-Kallela Museum's collections. This tube was wrapped in thin paper with the name 'Violet cob.' written on it. The tube was manufactured by H. Schminke.[54]

Cobalt violet was identified in six of the 43 analysed paintings. For example, in Gallen-Kallela's *Native American on Horseback*[55] the dark purple areas in the rug on the horse are painted with cobalt phosphate and the violets, while the mountains in *Native American on Horseback in Snow* (1925) (Fig. 14) are painted with magnesium cobalt arsenate. Identification of magnesium cobalt arsenate was possible with both the polarised light microscope and, also when intense peaks of cobalt (Co) and arsenic (As) were observed in the XRF spectrum.

In plane polarised light, cobalt phosphate particles were translucent, pale violet and pleochroic from purple-blue to yellow-orange in colour. (Fig. 10) The relief was low and the refractive index was higher than that of the medium (RI > 1.662). Under crossed polars the particles were anisotropic and they had high birefringence colours masked by the body colour.

Organic pigments

Organic red pigments were not characterised in either of the artists' pigment palettes, even though they are present in the selected paintings.[56] In one painting by Helene Schjerfbeck, *Angel Fragment, after El Greco* (1928–29)[57], a weak peak of bromine (Br) was detected in the XRF spectrum measured from a light pink area. This might refer to the use of eosin containing synthetic organic red pigment that has a tendency to fade rapidly.[58] This phenomenon was detected soon after the pigment had been taken into use as an artists' colour.[59]

Gallen-Kallela favoured red organic pigments that have a strong pink or orange UV fluorescence. The use of organic red pigments was often detected with the help of UV fluorescence or in polarised light microscopy samples. He used these pigments abundantly in large areas, for example in the sky or in the skin areas of human figures. In Schjerfbeck's paintings these pigments and their fluorescence can also be seen, but in a more delicate way as in small brush strokes here and there. With her paintings the detection of the

54 Tikkala and Hornytzkyj, 'Luonnontieteellisin analyysimenetelmin tunnistettu Akseli Gallen-Kallelan väripaletti', 54.

55 Finnish National Gallery / Ateneum Art Museum (A III 2159), https://www.kansallisgalleria.fi/en/object/440830 (accessed 27 June 2022).

56 Organic reds caused so much fluorescence in the Raman spectrum that they could not be identified. Under UV light organic reds appeared pink/orange. This property can refer to the use of madder lakes or kermes lake (cochineal).

57 Ester and Jalo Sihtola Fine Arts Foundation Donation, Finnish National Gallery / Ateneum Art Museum (A-2002-453), https://www.kansallisgalleria.fi/en/object/518535 (accessed 27 June 2022).

58 Muriel Geldof, Matthijs de Keijzer, Maarten van Bommel, Kathrine Pilz, Johanna Salvant, Henk van Keulen and Luc Megens. 'Van Gogh's Geranium Lake', in Marije Vellenkoop, Muriel Geldof, Ella Hendriks, Leo Jansen and Alberto de Tagle (eds.), *Van Gogh's Studio Practices*. Brussels: Mercatorfonds, 2013, (268–289) 286.

59 F. W. Weber. *Artists' Pigments. Their Chemical and Physical Properties*. New York, US: D. van Nostrand Company, 1923, 58–59.

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Fig. 11. Helene Schjerfbeck, *Still Life in Green*, 1930, oil on canvas, 33.5cm x 50cm Antell Collections, Finnish National Gallery / Ateneum Art Museum (A IV 3382)
Photo: Finnish National Gallery / Hannu Pakarinen

UV fluorescence of a red organic pigment is mainly achieved under the stereomicroscope, whereas in Gallen-Kallela's works the UV fluorescence can be seen with the naked eye.

In her letter to Ada Thilén in 1902, Schjerfbeck asked her friend to send her two tubes of organic red paint; 'krapplack no 2' and 'krapplack no 7'.[60] Number 7 is a paint she mentions that she has used in her blue 'poison mixture'.[61] When it comes to Gallen-Kallela, a lot of evidence for the use of organic pigments was found in the Collections and Archives of the Gallen-Kallela Museum. There are four oil-colour tubes that were labelled as a reference to organic reds: 'Münecher lack' (Bernhard & Co, Kölnen Farben Fabrik), 'Karmin-Zinnober' (Dr. Fr. Schoenfeld & Co), 'Krapplack' (Garance) (v. Pereira's Temperafarbe) and 'Alizarin-Madder' (markings are unclear).[62] Judging from the names of the red organic pigments it can be said that the first three represent the type of organic pigments derived from cochineal insect species, and the last one is derived from madder plants. Gallen-Kallela has marked tubes named 'Madder Lake, deep' and 'Carmine-Vermilion' as to be purchased, in Beckmann's Syntonos-Colours sales catalogue.[63]

Indian yellow, a mixture of the calcium (Ca) and magnesium (Mg) salts of euxanthic acid, is the only organic yellow pigment identified in Helene Schjerfbeck's paintings, but no organic yellows were identified either in Gallen-Kallela's paintings or in his oil-colour tubes. For example, in Schjerfbeck's painting *Still Life in Green* (1930), it occurs in the green shades as a mixture of cobalt blue, viridian and iron oxide pigments (Fig. 11). Indian yellow is a complex compound of calcium (Ca) and magnesium (Mg) salts of euxanthic acid. The pigment is derived from the urine of cows fed with mango leaves.[64] This pigment has been identified

60 Letter from Helene Schjerfbeck to Ada Thilén, 18 December 1902. Westermarck, Helena. Manuscript Collections, Åbo Akademi University Library, Turku.
61 Letter from Helene Schjerfbeck to Maria Wiik, 18 March 1915. Westermarck, Helena. Manuscript Collections, Åbo Akademi University Library, Turku.
62 Tikkala and Hornytzkyj, 'Luonnontieteellisin analyysimenetelmin tunnistettu Akseli Gallen-Kallelan väripaletti', 53–54.
63 L. Auerbach & Co., Fuerth, Bavaria. *Sole manufacturers of Beckmann's Syntonos-Colours* (catalogue). Akseli Gallen-Kallela Archive. Gallen-Kallela Museum.
64 A. H. Church. *The Chemistry of Paints and Painting*. London, Great Britain: Seeley, Service & Co. Limited, 1915, 174–75; Norbert S. Baer, Abraham Joel, Robert L. Feller and Norman Indictor. 'Indian Yellow', in Robert L. Feller (ed.), *Artists' Pigments. A Handbook of Their Characteristics*. Volume 1. Washington: National Gallery of Art, 1986, (17–36) 17, 25.

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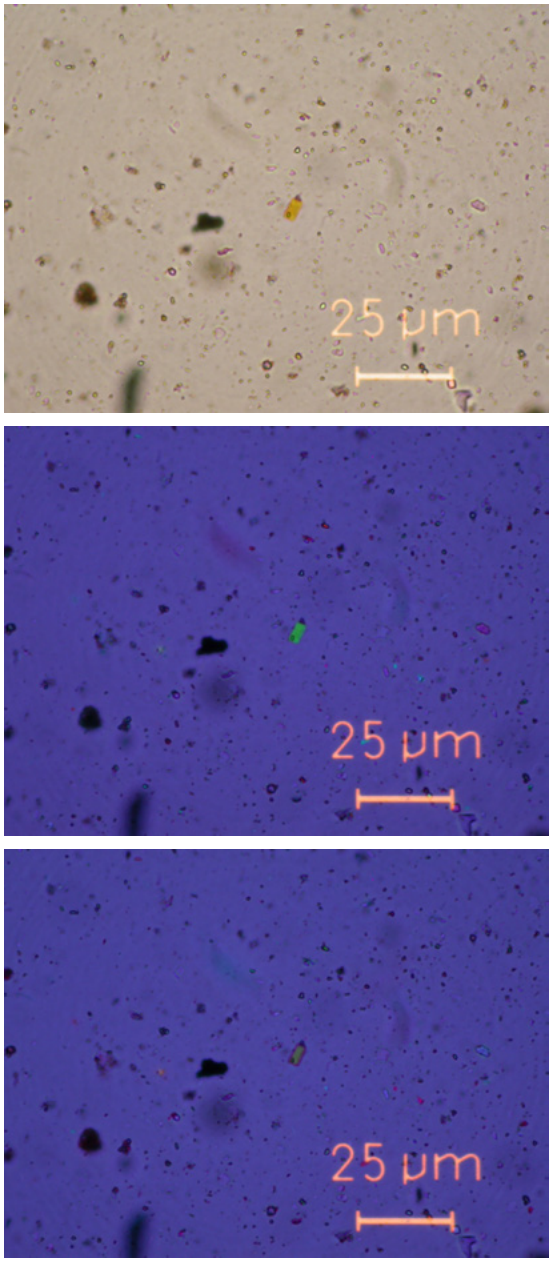


Figs. 12 a–c. An acicular particle of Indian yellow observed in plane polarised transmitted light and in cross-polarised transmitted light in different orientations of the λ-filter. From Helene Schjerfbeck's painting *Einar Reuter III*, 1919–20, Friends of the Ateneum Collection, Finnish National Gallery / Ateneum Art Museum (A-1998-498)
Photo: Finnish National Gallery / Materials research laboratory, Seppo Hornytzkyj

in only a few oil paintings that were made before the end of the 19th century.[65] After that other synthetic yellow pigments, such as aureolin and azo pigments, were labelled under the name of Indian yellow.[66]

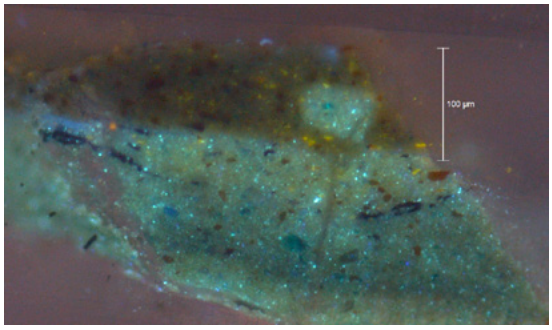
Indian yellow was identified by its optical properties. In polarised light, Indian yellow particles were pale yellow or almost colourless translucent acicular or lath-shaped single particles or aggregates. Sometimes finely fibrous spherulites were also observed. The relief of the particles was low and the refractive index was lower than that of the medium (RI < 1.662). The particle size was fine and it seemed to be easily dispersed in the medium when the sample was prepared for the polarised light microscopic examination. Under crossed polars the particles had high birefringence which was masked by the strong body colour or by the anomalous blue-green interference colours. The spherulites often had a well-developed standing extinction cross. The optic sign of the acicular particles was length slow (Fig. 12). Under ultraviolet light Indian yellow had a strong yellow fluorescence, which can be seen in a micrograph taken of a cross-section sample from the green pear in the painting *Still Life in Green* (Fig. 13).

In her letter to Einar Reuter in 1920, Schjerfbeck wrote about a colour mixture she had used – Indian yellow together with Prussian blue and red pigment:

> *A new work has commenced here, not yet the little lady, but it is again my mistress. I think it will be in green and red, not like Nanna in Naples yellow, cobalt and red, but in Indian yellow, Prussian blue and red. Maybe a blue cup in her hand, I am not sure. She is beautiful.*[67]

Meanwhile, no reference to the use of Indian yellow has been found in the private archive of Akseli Gallen-Kallela.

Fig. 13. A cross-section sample in UV-light. From Helene Schjerfbeck's painting *Still life in Green*, 1930, Antell Collections, Finnish National Gallery / Ateneum Art Museum (A IV 3382)
Photo: Finnish National Gallery / Materials research laboratory, Hanne Tikkala



65 Baer *et al.*, 'Indian Yellow', 18.
66 Eastaugh *et al.*, *Pigment Compendium. A Dictionary of Historical Pigments*, 193.
67 'Ett nytt arbete är börjat här, ej den lilla fröken än, det är min värdinna åter. Jag tror det blir i grönt och rött, inte som Nanna neapelgult-cobolt o. rött utan Indian yellow – bleu de Prusse o. rött, - kanske en blå bägare i hennes hand, jag vet ej. Hon är vacker.' Letter from Helene Schjerfbeck to Einar Reuter, 26 June 1920. Schjerfbeck, Helene. Manuscript Collections, Åbo Akademi University Library, Turku. Transl. Lene Wahlsten.

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Black pigments

Bone black is one type of black pigment that is present in some of the paintings of both artists. It was identified with the help of an XRF spectrometer when intense XRF peaks of calcium (Ca) and phosphorous (P) were observed in an XRF spectrum collected from the black or dark areas of the works.

In her letters, Schjerfbeck did not refer to the use of bone black or any other blacks. Bone black was identified in three of Gallen-Kallela's oil-colour tubes. The manufacturers were Fritz Behrendt Farben, Dr. Fr. Schönfeld & Co and H. Schmincke & Co.[68] Gallen-Kallela had also made a mark beside a bone black tube in the Beckmann sales catalogue of Syntonos-Colours.[69]

Fig. 14. Akseli Gallen-Kallela, *Native American on Horseback in Snow*, 1925, oil on canvas, mounted on plywood, 19.5cm x 26cm Finnish National Gallery / Ateneum Art Museum (A III 2160)
Photo: Finnish National Gallery / Yehia Eweis
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White pigments

Both artists have used zinc and lead whites frequently. In Schjerfbeck's paintings zinc white was used as the main white[70] in 21 of the 27 paintings examined, which is more often than in Gallen-Kallela's paintings. In 24 of his paintings the lead white was the main white and in only 15 the main white was zinc white. In the remaining four paintings he used both in equal combination.

Zinc white was identified when strong peaks of zinc were present in the XRF spectrum measured from a white area. Lead white was identified correspondingly.

Considering the decade in which these works were made, titanium white (TiO_2) is the most extraordinary pigment to have been found in Gallen-Kallela's paintings from his period in America (1923–26). It was identified in 13 of the 43 paintings that were examined. Identification was achieved mainly by means of the EDXRF spectrometer when strong peaks of titanium (Ti) were present in the XRF spectrum. Anatase, the earlier crystal form of titanium dioxide white, was identified by Raman spectrometry in three paintings made during Gallen-Kallela's time in America.[71] It was identified when strong peaks at wavenumbers 395cm^{-1}, 514cm^{-1} and 637cm^{-1} were present in the Raman spectrum. The early form of titanium dioxide white is co-precipitated with barium sulphate. Barium sulphate was identified when peaks at wavenumbers 452cm^{-1} and 985cm^{-1} were present in the Raman spectrum (Spectrum 4). The Raman spectrum was measured from a lilac in the snow area in *American Native on Horseback in Snow* (1925) (Fig. 14).

A note written by the artist himself during his stay in America was found in Gallen-Kallela's personal archive: 'Higgins recom. Webers Permalba white.'[72] (Fig. 15) The name Higgins refers to an American artist Victor Higgins, who invited Gallen-Kallela to work in Taos, New Mexico. A catalogue of artists' materials including price lists, from A. H. Abbot & Co.,

68 Tikkala and Hornytzkyj, 'Luonnontieteellisin analyysimenetelmin tunnistettu Akseli Gallen-Kallelan väripaletti', 53–54.
69 L. Auerbach & Co., Fuerth, Bavaria. *Sole manufacturers of Beckmann's Syntonos-Colours* (catalogue). Akseli Gallen-Kallela Archive. Gallen-Kallela Museum.
70 The main white used in the work has been determined by the intensity of energy peaks in the XRF spectrum, not by its weight percentage.
71 Anatase and rutile are polymorphs of titanium dioxide. Polymorph means that compounds have the same chemical composition but different atomic structure.
72 Akseli Gallen-Kallela Archive. Gallen-Kallela Museum.

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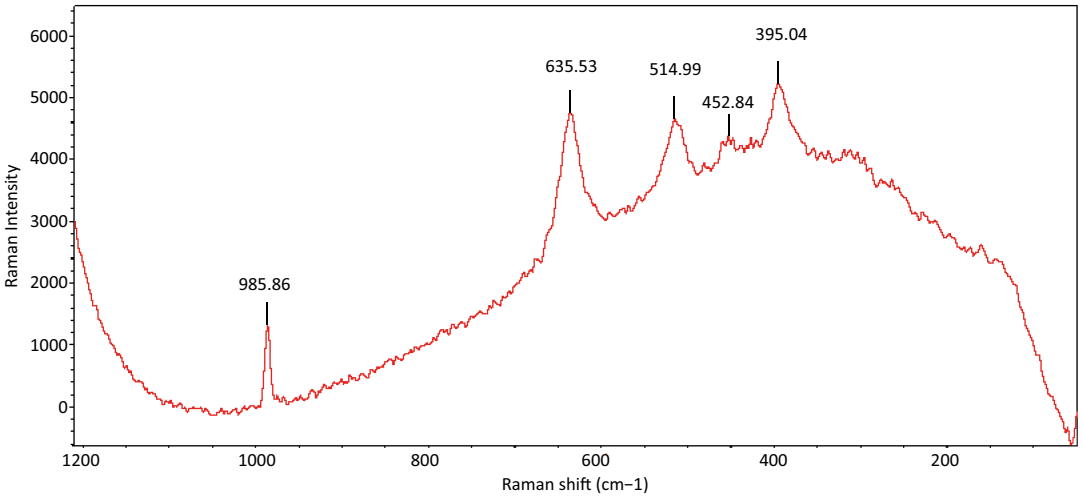

Spectrum 4. Raman spectrum measured from the white area of the Akseli Gallen-Kallela's painting *Native American on Horseback in Snow*, 1925, Finnish National Gallery / Ateneum Art Museum (A III 2160)
Figure: Finnish National Gallery / Materials research laboratory, Seppo Hornytzkyj

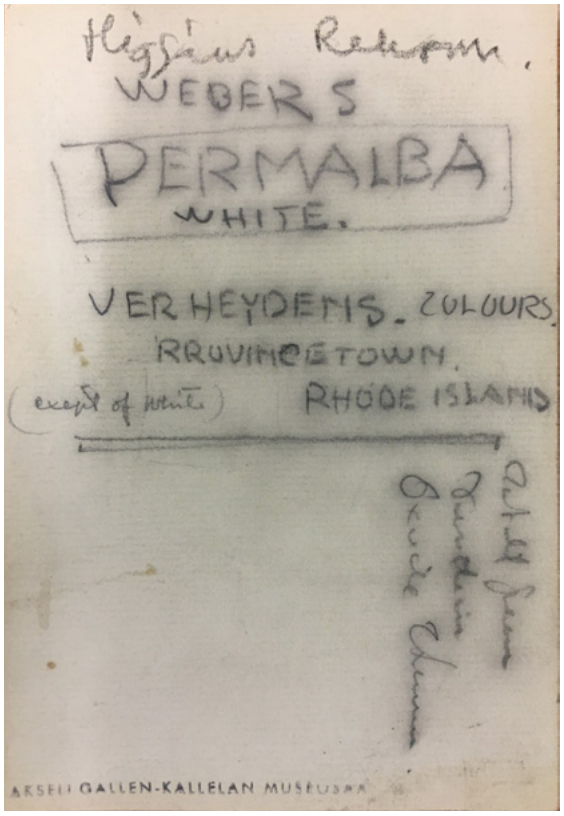

Fig. 15. A note written by Akseli Gallen-Kallela. Akseli Gallen-Kallela Archive, Gallen-Kallela Museum, Espoo.
Photo: Finnish National Gallery / Hanne Tikkala

a supplier in Chicago, was found in the archive.[73] It had listed Webers Permalba white oil-colour tubes as one of its items (Fig. 16). Permalba is the earliest titanium white oil paint to have been on sale in the US.[74]

A weak XRF peak of titanium (Ti) was present in the XRF spectrum of the samples collected from some of Schjerfbeck's paintings. Anatase was not identified with the Raman spectrometer, so it was concluded that titanium is part of the chemical

73 Akseli Gallen-Kallela Archive. Gallen-Kallela Museum.

74 Alan Phenix, Alexia Soldano, Klaas Jan van den Berg and Birgit van Driel. 'The Might of White: Formulations of titanium dioxide-based oil paints as evidenced in archives of two artists' colourmen, mid-20th century', in Janet Bridgland (ed.), *ICOM-CC 18th Triennial Conference Proceedings: 'Linking Past and Future'*. Art. 0104. ICOM Committee for Conservation. Paris: ICOM-CC, 2017, https://www.researchgate.net/publication/321081571_The_might_of_white_Formulations_of_titanium-dioxide_based_oil_paints_as_evidenced_in_archives_of_two_artists'_colourmen_mid-twentieth_century (accessed 25 February 2022).

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Fig. 16. Cover and a page from the artists' materials catalogue of A.H. Abbott & Co, Chicago. Home Library of Akseli Gallen-Kallela, Gallen-Kallela Museum, Espoo.
Photo: Finnish National Gallery / Hanne Tikkala

composition of iron oxide colours that are abundant in her paintings. The same applies to some of Gallen-Kallela's paintings[75].

Conclusions

The contents of Akseli Gallen-Kallela's basic pigment palette has been defined based on the pigments that occur in nearly all of his paintings analysed in the course of this research. His basic pigment palette includes cobalt blue, vermilion, chrome green, cadmium yellow, iron oxide pigments, lead white and zinc white. In all probability, it also includes synthetic ultramarine and viridian. In the case of Helene Schjerfbeck, the work of defining and identifying the basic pigment palette is still in progress. Based on the research focusing on works dating from the 1920s, it includes cobalt blue and iron oxide pigments, as well as zinc and lead white.

When comparing the contents of the pigment palettes used by these two artists in the 1920s, it becomes apparent that Gallen-Kallela continued to favour the pigments of his basic pigment palette. The pigments found there – vermilion, chrome green, and cadmium yellow – appear in Schjerfbeck's pigment palette too, but considerably less often than in Gallen-Kallela's. Schjerfbeck appears to have been more experimental with her pigment mixtures than Gallen-Kallela, who in the majority of his works used some of the pigments in his pigment palette in a more regular manner. Both artists used high-quality artists' oil- and tempera-tube colours with mostly stable and resistant pigments. The mediums in their works and the painting technique of Helene Schjerfbeck will be subjects of future research.

75 Tikkala and Hornytzkyj, 'Luonnontieteellisin analyysimenetelmin tunnistettu Akseli Gallen-Kallelan väripaletti', 38.

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During his years in America, Gallen-Kallela experimented with a pigment that was new on the market – titanium white – on the recommendation of his fellow artist, Victor Higgins. However, its properties perhaps left him unconvinced because on his return to Finland this pigment no longer features in his works. Schjerfbeck, who lived in Finland throughout the 1920s, did not use this pigment at all. It is possible that painters working more elsewhere in Europe and in America than in Finland in the early 20th century adopted the use of this pigment earlier. It was not sold in Finland during the 1920s as an artists' colour and it was probably not familiar at that time to most Finnish artists. However, it would require further research in order to confirm this. In continental Europe it was not until the 1970s that titanium white established its position, whereas in America painters adopted it almost as soon as it came on the market.

Generally speaking, the contents of the pigment palettes used by Schjerfbeck and Gallen-Kallela are the same, but the preferences of the two in terms of using the pigments differ significantly. In the 1920s, Schjerfbeck clearly preferred zinc white over lead white, whereas Gallen-Kallela used them both more equally.

Both artists favoured cobalt blue and it appears that they often used synthetic ultramarine as well. However, establishing that synthetic ultramarine belongs to the basic pigment palettes of the artists requires further research. The third shade of blue used by Gallen-Kallela was cerulean blue, whereas the third alternative for Schjerfbeck was Prussian blue.

Both used vermilion, although Gallen-Kallela did so considerably more frequently than Schjerfbeck, who seems to have favoured red pigments containing iron. In addition, both artists often used organic red pigments. Gallen-Kallela used them in significantly larger quantities and in larger colour areas in his paintings than Schjerfbeck, whose works only feature them as highly thought-out and subtle additions in small areas. Based on the archival research, both used cochineal (carmine) and Gallen-Kallela used madder lake (alitzarin). It is possible that both artists used other synthetic organic red pigments too. Schjerfbeck might have also used geranium lake, eosin-containing synthetic organic red pigment that has a high tendency to fade.

Indian yellow pigment was identified in three of Schjerfbeck's works. This is the first time that Indian yellow has been identified in Finnish artists' paintings. Globally, it has very rarely been identified in oil paintings dating to the 20th century. Indian yellow was not identified in Gallen-Kallela's paintings.

In the 1920s, Gallen-Kallela no longer used any green pigments that contained arsenic, but he used two different types of cobalt violet – magnesium cobalt arsenate and cobalt phosphate. Schjerfbeck did not use cobalt violets in the 1920s, but in five of the works that were examined there is emerald green (copper aceto arsenite), whereas Gallen-Kallela always used chrome green, most likely viridian, having already abandoned emerald green from his pigment palette. Schjerfbeck also used malachite, a pigment rarely identified in the Finnish artworks from the 20th century.

In terms of yellow pigments, cadmium yellow was used by both artists, but considerably more often by Gallen-Kallela. In addition, both used yellow pigments containing iron, but Schjerfbeck was the only one to use Naples yellow. Both artists also used chromium yellow.

The research has raised a number of additional questions. What is the unstable cobalt pigment, which Helene Schjerfbeck mentioned she had used? Another important question is, did she use orpiment, which has now degraded to greyish-brown? If she did use this, it would have had a major influence on the colour scheme of the paintings containing it. Another important question is the date when titanium white began to be used in Finnish art. As a result of this study, we know that Akseli Gallen-Kallela was the first Finnish artist to use it, but when the others started to use it is still a question to be answered.