Transmitted light imaging in VIS and IR, in the study of paintings: a brief report on the behavior of the main historical pigments

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ABSTRACT

The aim of this paper is to evaluate the behavior of 50 historical pigments in the two spectrum ranges VIS and IR, by using transmitted light. For this study, pigments were bound with oil and were applied in several layers over underlying lines, drawn with different media. The purpose of this study was to evaluate the behavior of pigments in the two spectrum ranges, comparing visible and infrared photographs with the respective images taken with transmitted light. The main idea is to compare the optical properties of each pigment in visible (VIS), transmitted light (TL), infrared (IR) and infrared transmitted (IRT). This was achieved by assessing visible and infrared photographs in incident and in transmitted light. The ultimate goal is to understand aspects such as transparency and opacity as well as the ability to block light. Finally, the intention is to classify the pigments by their behavior noting their similarities and differences, considering the aforementioned factors. Since photographic techniques are very common in the study of painting, this study has been considered useful to classify patterns of behavior, which will allow greater systematization of these types of imaging.

KEYWORDS Transmitted light, Transradiation, Infrared, Multiband, Pigments, Art diagnostics, Painting

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1. Introduction: transmitted light imaging techniques in the study of paintings

In the last decades, the study of paintings with non-invasive methodologies has been continuously growing as a respectful practice towards heritage, and nowadays with the spreading of low-cost methods, many art historians, conservators or restorers use imaging as a starting point in the meta-formal research on paintings (Poldi and Villa 2006). In fact, for the diagnostic study of paintings, it is very common to use basic technical photography (TP) in order to observe the surface and the possible alterations affecting the works of art (Matteini and Moles 2001). When dealing with panels, in addition to visible photography (VIS), raking light (RL) is used. For the study of canvases and other translucent surfaces (parchment, cloths, paper, etc.) transmitted light (TL) becomes a helpful tool (Riley and Berger 1971). These latter techniques are generally carried out by the restorers to evaluate the conditions of paintings since, as it is known, the altered varnishes, cracks, and other types of alterations of the support or the pictorial layers can be easily recognizable with such imaging tests (Cardinali et al. 2002); (Cucci et al. 2012); (Dupont 1977); (Moutsatsou et al. 2011). Infrared transmitted imaging (IRT) is a commonly used infrared photographic technique, which reaches up to 1100 nm and is performed with the characteristic TL backlighting conditions (Kushel 1983). For some years, it has been considered a non suitable technique for the study of paintings, (due to the effect of heating of IR radiation, which is pernicious for paintings). However, digital photography has allowed it to be considered again due to the short time of exposure to the light that there is needed to take the IR image (Cucci et al. 2012).

Table 1: Applications and results of transmitted light techniques in painting studies

	VIS	TL	IR	IRT
Ductus /Brush-strokes	Green	Yellow	Orange	Yellow
Pentimenti	Orange	Yellow	Green	Green
Underdrawing	Red	Yellow	Green	Green
Pigments visual identification	Red	Yellow	Yellow	Yellow
Inner condition	Orange	Green	Orange	Green
Superficial condition	Green	Yellow	Orange	Orange
Inpainting	Yellow	Yellow	Yellow	Yellow

Green	Very good to excellent results mainly
Yellow	Medium to good results on average
Orange	Poor to fair results in many cases
Red	Very poor results (only in very few cases)

Table 1 indicates the suitability of each technique depending on the scope of the research.

When TL and IRT are used together with VIS and IR respectively, an interesting range of data about the way the painting has been made can be extracted, as well as about the materials that had been used. That happens, specially, if the results in such images are compared with one another. Thus, they provide much more information, covering subjects either about its own materiality, or about the execution process, in addition to their contribution to the collection of data regarding the state of conservation (Table 1).

Especially useful for the procedural study are TL and IRT (Vervat et al, 2005); (Cucci et al. 2012). The reason is that they allow the observation of brushstrokes, giving also information on the thickness of the pictorial layer. They also report on the ability of materials (especially pigments) to absorb or reflect the light, while they also allow highlighting the hidden elements, the *pentimenti* and any other modifications made to the painting. (Herrero-Cortell et al 2018). Furthermore, when the two types of transmitted light techniques are performed together and the results can be compared, important differences in pigment behavior can be appreciated, as these are images obtained in two different regions of the spectrum.

2. Scope and methodology

The main objective of this paper is to describe some differences in the visual behavior of historical pigments, when confronting, VIS, IR, TL and IRT. The purpose is to summarize the general characteristics of the main common pigments when transmitted light techniques are chosen for the study of paintings. Specifically, the paper proposes an experimental approach regarding the observation through TL and IRT of the behavior of 50 pigments and historical lacquers, mainly produced by KREMER® (although some others have been manufactured by the authors following the indications of historical recipe books). Nevertheless, in order to permit the comparisons VIS and IR standard imaging have also been considered.

The pigments and lakes were applied using a rectified linseed oil as a binder, on a cloth prepared with a layer of gesso (rabbit glue with carbonate and calcium sulfate). The area painted with each pigment was divided into four strips, corresponding to the number of layers, starting from one layer up to four levels, thus producing a crescendo of glazes thicknesses. Furthermore, in order to evaluate the behavior of the underlying design through the transmitted light techniques (in addition to its interaction with pigments), lines were drawn using different mediums. In this way, it was thus possible to evaluate the transparency and opacity properties of the pigments. Line 1 corresponds to charcoal; the line 2 to the black pencil Conté; line 3 is graphite line; line 4 is sanguine; line 5 is metallogallic ink; line 6 is metallogallic ink in a 50% aqueous solution, and finally line 7 is sepia-colored ink.

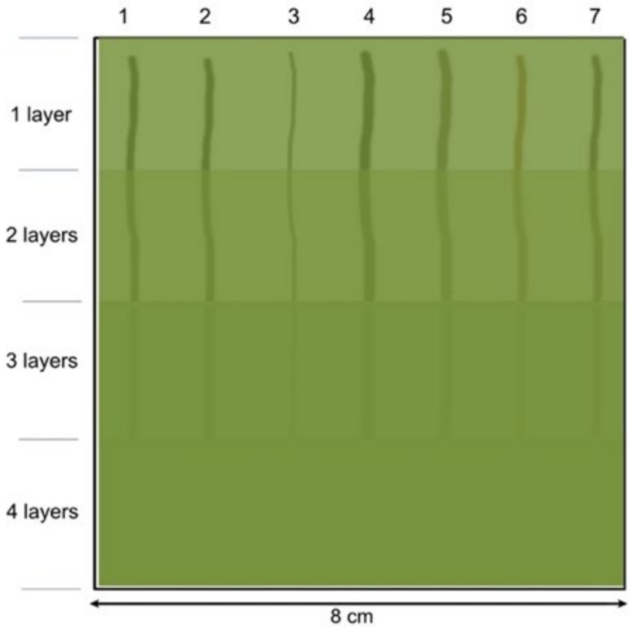

Fig. 1. Diagram showing how pigments were applied over underlying lines, in four layers.

VIS, IR, and IRT were carried out using a *Nikon® D7200 DSLR* (24 MP, CMOS sensor) digital camera modified "full spectrum" (sensitivity between about 360 and 1100nm), coupled with *Nikkon Nikkor®* 50mm lens. The following filters were used: X-Nite CC1 for Visible (VIS), Transmitted Light photography (TL); Heliopan RG1000b for Infrared (IR), and Infrared Transmitted (IRT) (Cosentino, 2014); (Herrero-Cortell et al. 2018). Two halogen lamps (1250W) were used for VIS and IR imaging, while for TL and IRT only one lamp was set perpendicularly at the back of the canvas at a distance of 2m. To keep the canvas in a vertical position of 180° from the ground, a special easel was constructed. It is an aluminum structure that holds the stretcher by its sides with two sliding clamp rails. In order to avoid light pollution, the reflected light was removed by using a parasol, which fitted the back of the canvas while mounted in the easel (figure 2). The American Institute of Conservation Photo Documentation (AIC PhD) target was used for calibration images. The images were shot in RAW mode and then color corrected, balancing white by using the N8 neutral grey patch in the AIC target5. They were also exposure corrected: N8 patch 150 +/- 5 for VIS. The same patch was also used for correcting IR images: 100 +/- 5 for IR and IRT. The purpose of this study was to evaluate the behavior of pigments in the two spectrum ranges, comparing visible and infrared photographs with the respective images taken with transmitted light. The ultimate goal is to understand aspects such as transparency and opacity as well as the ability to block light, highlighting factors that will allow greater systematization of this type of imaging.

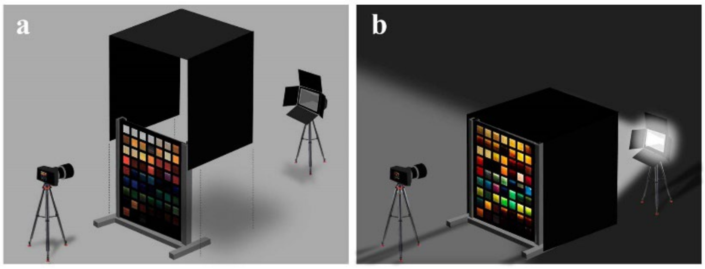

Fig. 2. Disposition of the camera, the canvas and the light for the imaging techniques in which transmitted light is used TL and IRT. A special easel was constructed to hold the canvas allowing a proper back lighting.

3. Results and discussion

Once the TL and IRT photographs were taken the results considered were compared with the VIS and in the IR. This work became very important in order to appreciate how the behavior of each pigment changed by carrying out the different techniques, considering whether it was opaque, semitransparent or transparent. In the same way, it could be demonstrated how the superposition of the various layers of each pigment sometimes generates a graduated tonal effect in some of the techniques. With this term, we refer to the ability to absorb more or less the light according to the thickness of the layers. For example, if the application is very thin the color can be very light, while in the areas where there is an overlap of layers the color increases becomes deeper proportionately, and thus its tonality becomes darker. It must be considered that some pigments show graduated tonal scales both in the visible and in the infrared range, either with reflected or transmitted light. Other pigments show these tonal scales only in VIS, being perfectly homogenous in IR. Finally, some others appear like flat colors in VIS, while they can show graduated tonal scales in TL, IR, or IRT. In order to understand their main differences, they have been organized in families by their color, confronting, thus, their VIS, TL, IR and IRT appearances.

3.1 *Yellow pigments*

Unlike other families, such as whites, the behavior of yellows is quite heterogeneous (figure 3). Gold ocher and raw Sienna (figure 3, samples 1 and 2) present a medium hiding power, being sienna slightly opaque. They both tend to slightly block the light if the layer is very thin, so they can be perceived in IR and IRT as a medium gray scale. They both show a graduated tonal scale in all the technical images. On the other hand, orpiment (figure 3, sample 3) and Naples yellow (figure 3, sample 4) suffer great variations in their opacity depending on their application: while with thin layers the passage of light can be total, the thicker layers tend to block the light. Nevertheless, they are semitransparent in VIS while they are both transparent and present graduated scales in IR and IRT. Lead-tin yellow (figure 3, sample 5) and chrome yellow (figure 3, sample 6) behave uniformly, regardless of the thickness of the application, allowing more light to pass through. They are both semitransparent in VIS and have homogenous gray level in IR. However, much more translucent are those of cadmium (figure 3, sample 8) and cobalt (figure 3, sample 9), whose light blocking capacity is as low as that of arzica lake (figure 3, sample 7). Not even the greater hiding power of cadmium yellow provides any type of luminous block in IRT, thus all three yellows are perceived as very light whites or grays.

3.2. *Red pigments*

Many reds are known for their transparency in IR techniques (figure 4), although that is not true for all pigments. Cinnabar and vermilion (figure 4, samples10, 11) are known for their high hiding power in VIS (although cinnabar tends to be slightly more translucent than its artificial version). Generally, they both usually are quite flat, allowing little transparence, even if the application is not very thick. They also tend to block light in TL. Instead, in IR the thickness is a key factor to visualize a hypothetical underlying design, allowing to see the underdrawings traces only if the pictorial layer is thin. The lead red (minium) (figure 4, sample 13) is, on average, much more transparent in all the techniques, showing little variations even if the application is more or less thin, and thus is not a graduated tonal scale pigment. In IRT, it behaves like a uniform light gray, which allows us to see any underlying trace, including the sepia dye, which is often invisible in many pigments. The red lakes (figure 4, samples 16, 17, 19), show a predictable transparency,

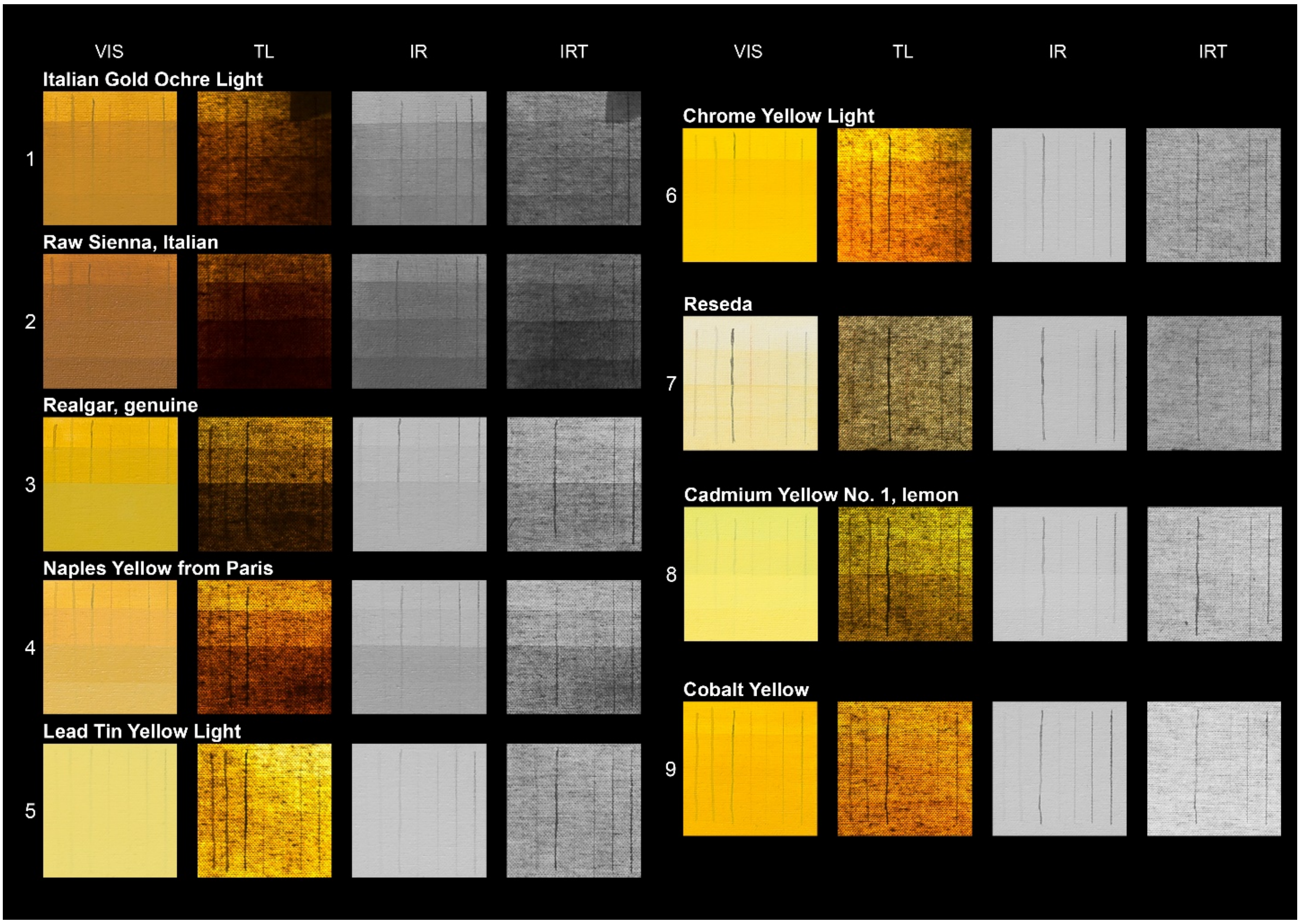

Fig. 3. Yellow pigments observed in VIS, TL, IR and IRT.

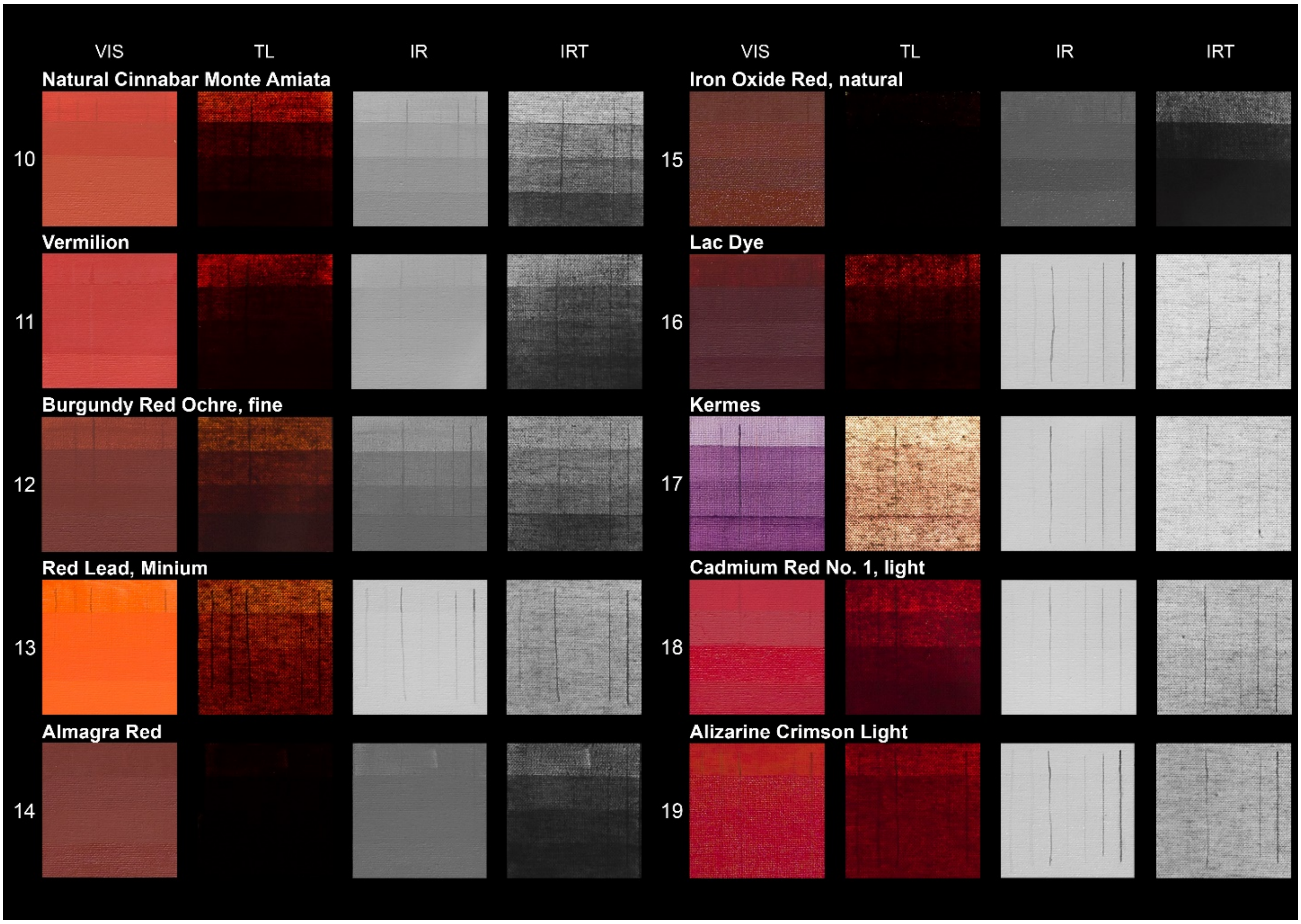

Fig. 4. Red pigments observed in VIS, TL, IR and IRT

both in visible and in IR, so in IRT the light block is very low. Only lac dye (figure 4, sample 16) is relatively more opaque in VIS, while all the others are very translucent. Cadmium red (figure 4, sample 18), which presents a high hiding power in VIS, shows graduated scale in TL, while is as transparent as lakes in IR techniques. The iron reds, burgundy red ocher, almagra and iron oxide (hematite) (figure 4, samples 12, 14, 15), despite all of them being in the category of earthen pigments, exhibit some differences among them. While almagra and iron oxide (figure 4, samples 14, 15) have a high opacity in IR which does not allow the visualization of the underlying lines, burgundy is more translucent. Their respective behavior in TL and IRT is similar. Almagra and hematite can perfectly block the light even if sometimes they are able to form dark gray graduated scales. Instead, burgundy (figure 4, sample 12) is quite more transparent.

3.3. Blue and purple pigments

Lapis lazuli, azurite, and blue bice (Figure 5, samples 20-22) exhibit similar behaviors in IR and IRT, while in TL lapis presents a higher light-blocking power, while bice is the most translucent. All of them are sensitive to the thickness of the application, becoming medium or dark gray if the application is very thick. In general, only the charcoal and the metallogallic ink lines can be partially perceivable in IR, so for the best visualization of any underdrawings an IRR device with a greater penetration strength is required. Prussian blue (figure 5, sample 23) has a very specific pattern of behavior. Although in the VIS it can be partially transparent, favoring an identification of the underlying lines if the application is not very thick, both in IR and in IRT it behaves like a highly opaque pigment that does not allow identification of any underdrawings. In fact, in IRT, if the application is thick, it forms an impenetrable dark spot, as it happens in TL. Like azurite, only the IRR image is able to reduce some opacity. Indigo (figure 5, sample 24) and smalt (figure 5, sample 25), even if they present tonal scales, are clearly transparent in the IR band. However, their behavior is not identical. Indigo is the most transparent of them, and therefore in IR it can be very sensitive to the thickness of the application while in IRT the light passes through it homogeneously. If the application is thick, it can eventually block the light. Smalt, instead, is very transparent in all the bands.

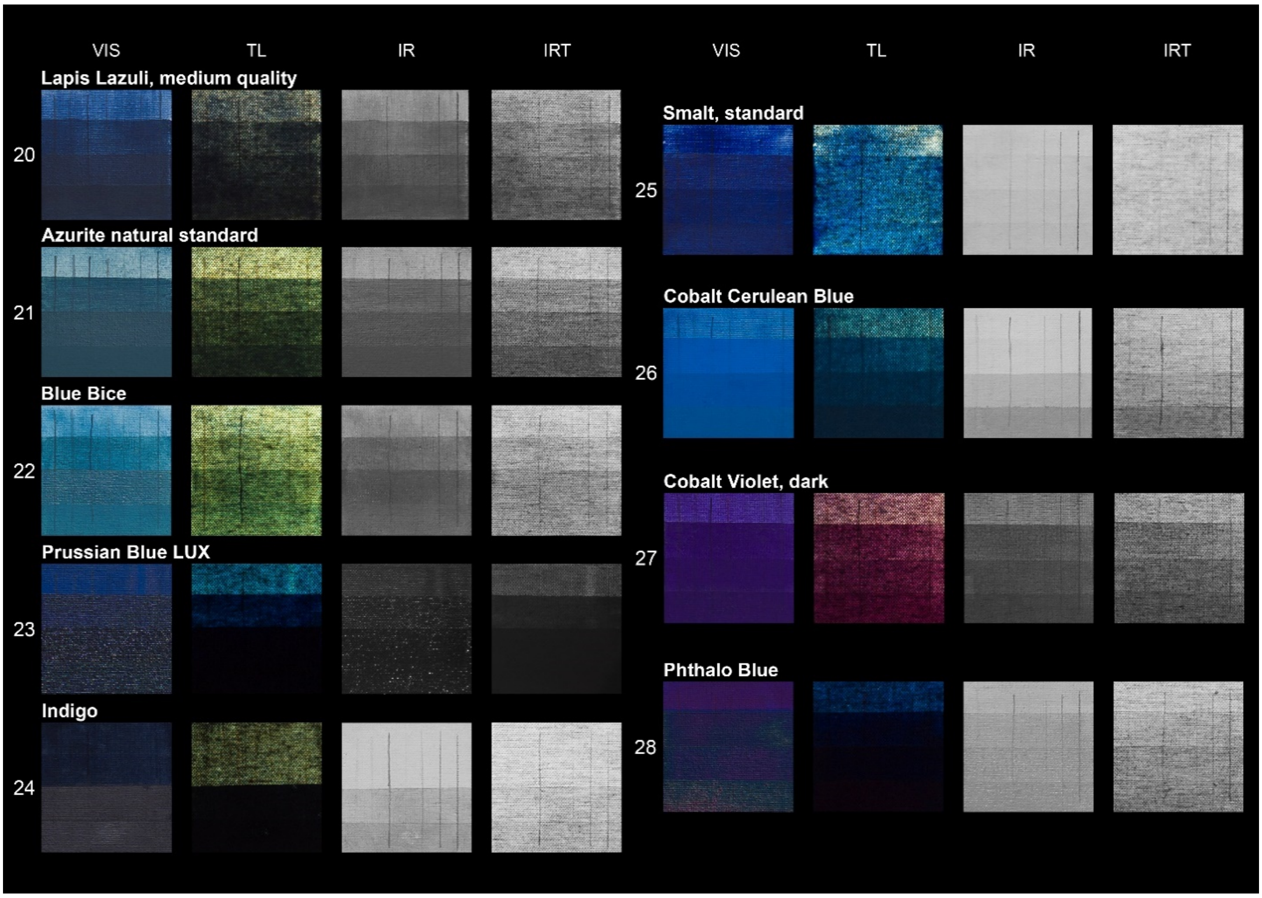

Fig. 5. Blue pigments observed in VIS, TL, IR and IRT.

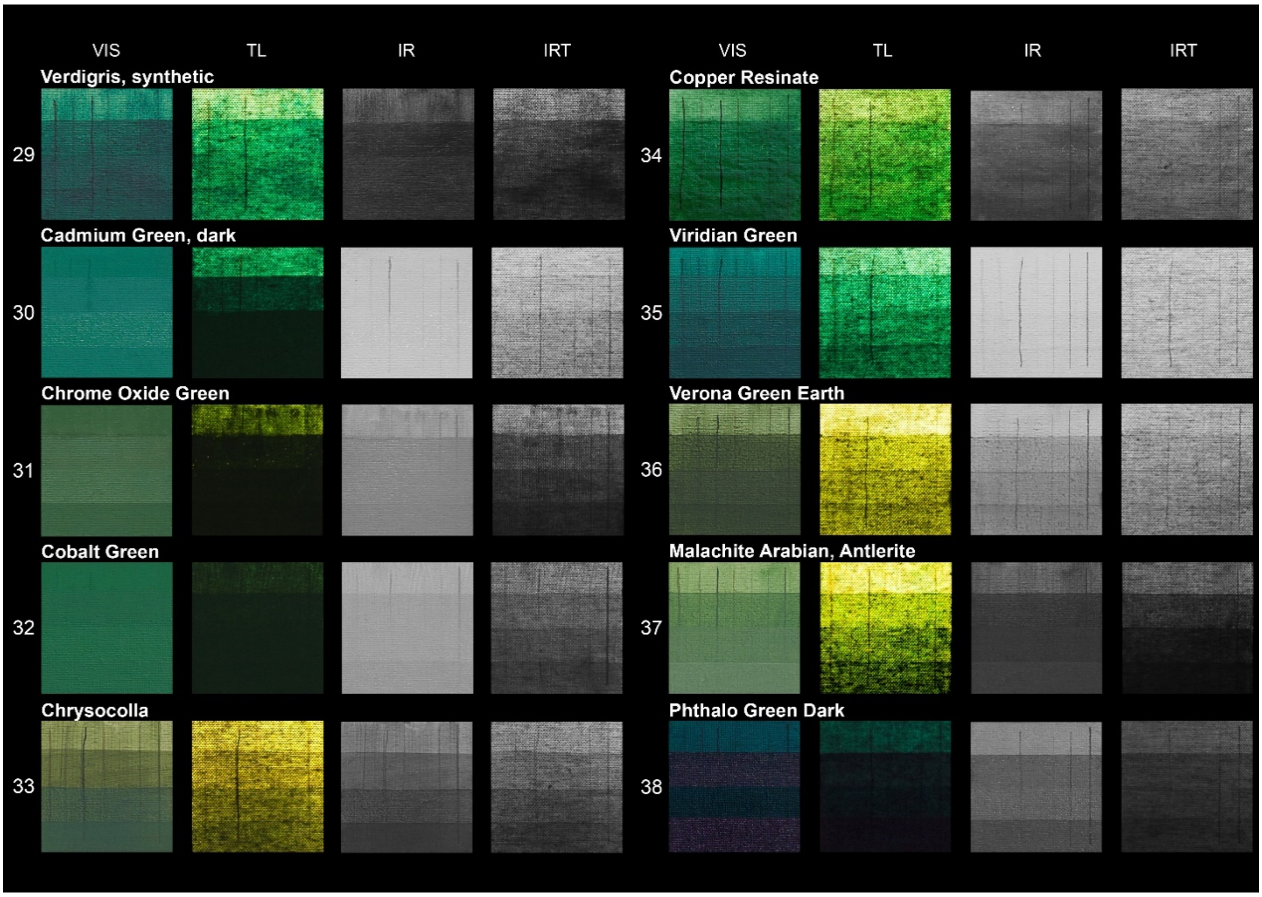

Fig. 6. Green pigments observed in VIS, TL, IR and IRT.

Phthalocyanine blue (figure 5, sample 28) has a similar response in TL, IR and IRT to that of indigo, although it is slightly less transparent. Finally, cerulean blue and cobalt violet (figure 5, samples 26, 27) exhibit very different behaviors. Therefore, they show significant differences in VIS and IR depending on the thickness of the layers. In

general, the response of the cerulean blue in IR is in the form of light gray, with high transparency, which allows the identification of the carbon lines and the metallogallic ink. Instead, the cobalt violet is darker in both IR and IRT, which makes difficult to perceive any underdrawings line.

3.4. Green pigments

As it happens with other color families, the different nature of greens creates varied behavior patterns (Figure 6). Sometimes, some greens based on the same element can react very differently. A good example is chromium oxide green (figure 6, sample 31) and viridian (figure 6, sample 35), a chromium oxide dihydrate green. Chromium oxide green is one of the pigments with greater hiding power in VIS and in the TL blocking the incident light. Indeed, in IR it manifests itself as a quite opaque pigment, of medium gray. It only allows you to guess some of the underlying lines if the application is very thin. In IR, in fact, the difference in thickness between the different layers is not perceptible, while in IRT it responds with a graduated pattern, being quite more translucent, despite displaying a medium-dark grey scale. Being of the same family, viridian (figure 6, sample 35) is a translucent pigment both in the visible and in the TL, a feature that allows the observation of underlying lines. Likewise, in the IR range it behaves like a transparent pigment, regardless of the thickness of its application. Cadmium green (figure 6, sample 30) shows a similar behavior of viridian in IR and IRT despite being less transparent than viridian. However, in the visible range, cadmium green is a pigment whose transparency directly depends on the thickness of the application, and while its appearance in VIS tends to be quite homogenous it is capable of forming graduated scales in TL. The copper greens, verdigris, chrysocolla, resinate and malachite (figure 6, samples 29, 33, 34, 37), are also a good example of materials with a common matrix (copper) exhibiting different behaviors. While verdigris and resinate, which have similar compositions based on copper acetate, malachite and chrysocolla are copper based carbonate and silicate minerals, respectively. They have something in common, being very translucent in VIS, and only the natural pigments have some hiding power in thick applications. Even in TL they behave like pigments that allow the light to pass permitting the observation of underlying lines, even if they show graduated scales. However, the main differences are observed in the IR band. Although generally the response of copper greens is always dark, especially deeper in verdigris and malachite, but, definitely it can be lighter or darker depending on the thickness of the application or the number of layers. In IRT these colors are always semitransparent, however the reading of the underlying lines becomes practically impossible. Verona green earth (figure 6, sample 36) shows a quite transparent behavior in all the ranges, presenting a light medium gray in the IR and forming graduated tonal scales in all the techniques with the exception of IRT in which it tends to form a quite flat gray tone, although significant changes in the thickness of the pictorial film could eventually respond with graduated scales. Cadmium green (figure 6, sample 30) has great hiding power and its behavior is very similar to that of cobalt green (figure 6, sample 32) in all the considered spectral ranges. Their ability to block light in TL is very high, while in IRT they are much more translucent. In IR they respond like a very light gray although they still have some power to hide the underlying lines. Finally, phthalocyanine green (38) is a very intense color, which does not permit the complete vision of the underdrawings. Both in IR and IRT, it forms graduated scale and shows a translucent appearance.

3.5. Brown, White and Black pigments

Earthen browns are very heterogeneous pigments: they present hundreds of shades and hues; some of them tend to be quite translucent while others are very opaque. Only deep browns have been chosen here, and those closer to ochers or red earths have been discarded (figure 7). However, in general, they share many characteristics with ochers and earth reds. Umber pigments (figure 7, samples 39, 40) are semitransparent and form strong graduated scales in all set of measurements. They both block the light in TL and IRT, unless they are applied in very thin layers. Burnt Sienna earth (figure 7, sample 41), is very opaque and shows little gray variations except in IRT. Its ability to block the light is very significant, as it was described for iron oxide pigments (hematite and almagra red).

White colors are a quite homogeneous family. They display the main differences in VIS, where, some of them are quite transparent while others tend to be opaque. Titanium dioxide, rutile (figure 7, sample 42), and lithopone present a high hiding power. They have quite similar patterns of behavior in all the ranges. Despite their opacity, in general, the behavior of whites in TL and IRT regarding the ability to let light pass through them is reasonably good and, in fact, their light blocking response is very low. Only titanium (figure 7, sample 42), and lithopone (figure 7, sample 44) are able to slightly block the light in TL when the layer is quite thick. That happens especially with titanium, which also presents a characteristic tonal scale. Zinc white (figure 7, sample 45) proves to be very transparent to the passage of light in all tests. Something very similar happens with the chalk of Bologna (figure 7, sample 46), whose uses as pigment are very limited when oil is chosen as a binder. (Doerner, 1998).

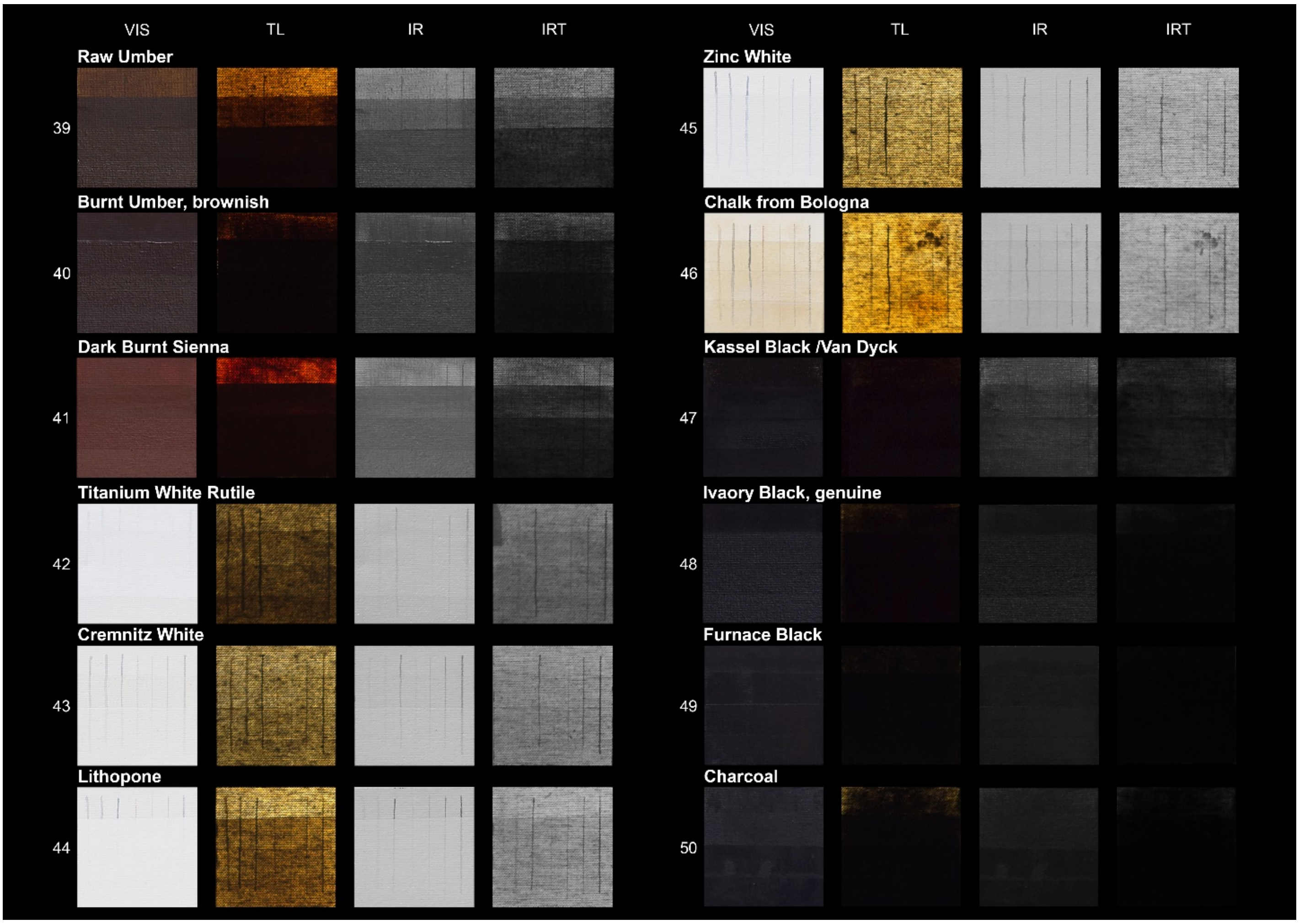

Fig. 7. Brown, white and black pigments observed in VIS, TL, IR and IRT

A high opacity in the VIS, TL, IR and IRT is the common characteristic among all Black pigments (figure 7, samples 47-50). They tend to have a high hiding power, and thus their ability to block light is also very high, being the Kassel Black (figure 7, sample 58), the only one that permits a bit the light to pass through it, although this fact has little application due to the darkness and hue of the color, which does not permit to read underdrawings.

4. Conclusions

Along this paper it was highlighted that the pigments respond differently to the passage of light in the visible and infrared bands. Although a relatively constant behavior is observed in some pigments, some others have disparities between their own behavior, depending on the chosen technique. A table containing all the pigments and colorants used in this study has been made in order to classify their respective behaviors in VIS, TL, IR and IRT (Table 2).

The light, passing through the brush strokes can finally allow to preliminary guess which pigments could have been used in a painting, by considering the palette and the period of the artwork (even if other analysis methods must therefore verify the hypothesis). The data obtained can contribute to a greater readability of the results of painting when performing TL and IRT imaging. This paper therefore intends to be a contribution to the proper interpretation of such light transmitted techniques performed on paintings with translucent supports. Finally, the selection of pigments covers the main historical specimens from antiquity until the twentieth century. For this reason, we hope that this experiment will be of help to conservators, restorers, art technicians, dealing with artworks and even art historians.

			VIS				TL				IR				IRT			
Nº	PIGMENT	REF	O	S.T	T	C	O	S.T	T	C	O	S.T	T	C	O	S.T	T	C
1	Italian Gold Ochre Light	*K 40220*		■		■			■	■			■	■			■	■
2	Raw Sienna, Italian	*K 40400*		■		■			■	■			■	■			■	■
3	Realgar, genuine	*K 10800*	■			■			■	■		■		■			■	■
4	Naples Yellow from Paris	*K 10130*		■		■			■	■		■		■			■	■
5	Lead Tin Yellow Light	*K 10100*		■					■				■				■	
6	Chrome Yellow Light	*S 549*		■		■			■				■				■	
7	Reseda	*(S/N)*			■	■			■				■				■	
8	Cadmium Yellow No. 1, lemon	*K 21010*		■					■	■			■				■	
9	Cobalt Yellow	*K 43500*			■	■			■				■				■	
10	Natural Cinnabar Monte Amiata	*K 10610*	■					■		■		■		■			■	■
11	Vermilion	*K 42000*	■					■		■	■			■			■	■
12	Burgundy Red Ochre, fine	*K 11574*	■					■		■		■		■			■	■
13	Red Lead, Minium	*K 42500*		■					■	■			■				■	
14	Almagra Red	*K 40545*	■				■				■					■		■
15	Iron Oxide Red, natural	*K 48600*	■				■				■			■		■		■
16	Lac Dye	*K 36020*	■					■		■			■				■	
17	Kermes	*K 36045*			■	■			■				■				■	
18	Cadmium Red No. 1, light	*K 21120*	■						■	■			■				■	
19	Alizarine Crimson Light	*K 23600*		■					■				■				■	
20	Lapis Lazuli, medium quality	*K 10510*		■		■			■	■		■		■			■	■
21	Azurite natural standard	*K 10200*		■		■			■	■		■		■			■	■
22	Blue Bice	*K 10184*			■	■			■	■		■		■			■	■
23	Prussian Blue LUX	*K 45202*		■		■		■		■	■			■	■			
24	Indigo	*K 36007*		■				■		■			■	■			■	■
25	Smalt, standard	*K 10000*			■				■				■				■	
26	Cobalt Cerulean Blue	*K 45730*	■						■	■			■	■			■	■
27	Cobalt Violet, dark	*K 45800*		■		■			■	■		■		■			■	■
28	Phthalo Blue	*K 23050*	■				■					■		■			■	
29	Verdigris, synthetic	*K 44450*			■	■			■	■	■			■		■		■
30	Cadmium Green, dark	*K 44510*	■					■		■		■					■	■
31	Chrome Oxide Green	*K 44200*	■				■				■					■		■
32	Cobalt Green	*K 44100*	■				■					■		■			■	■
33	Chrysocolla	*K 10350*			■	■			■				■	■			■	■
34	Copper Resinate	*K 12200*			■				■				■				■	
35	Viridian Green	*K 44250*			■	■			■	■			■				■	
36	Verona Green Earth	*K 41700*			■	■			■	■			■	■			■	
37	Malachite Arabian, Antlerite	*K 103700*		■		■			■	■	■			■		■		■
38	Phthalo Green Dark	*K 23000a*		■					■	■			■	■			■	■
39	Raw Umber	*K 40610*	■					■		■		■		■			■	■
40	Burnt Umber, brownish	*K 40710*	■				■				■					■		■
41	Dark Burnt Sienna	*K 40430*	■				■					■		■		■		■
42	Titanium White Rutile	*K 46200*	■						■	■		■				■	■	
43	Cremnitz White	*K 46000*			■				■			■					■	
44	Lithopone	*K 46100*	■						■				■				■	
45	Zinc White	*K 46300*			■				■				■				■	
46	Chalk from Bologna	*K 58100*			■				■				■				■	
47	Kassel Black /Van Dyck	*K 41000*	■				■					■		■		■		■
48	Ivaory Black, genuine	*K 12000*	■				■				■			■	■			
49	Furnace Black	*K 47250*	■				■				■			■	■			
50	Charcoal	*(S/N)*	■				■				■			■	■			

Table 2 lists the fifty pigments that have been used in this study, including their main behavior characteristics in VIS, TL IR and IRT. Aspects like opacity (o), semi-translucency (s.t), translucency, (t) or graduated tonal scale response (C) have been considered for each imaging technique.

5. Conflict of interest declaration

The authors wish to state that no financial or personal interests have affected the objectivity of the study, and that no conflicts of interest exist.

6. Funding source declaration

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8. Short biography of the authors

Miquel Herrero-Cortell - He holds a PhD in Art History. He has a degree in Fine Arts from the Polytechnic University of Valencia (UPV) and a degree in Art History from the University of Valencia (UV). He holds a Master's Degree in Conservation and Restoration of Cultural Heritage and a Master's Degree in Artistic Production. He has developed his work as a researcher focusing on the field of materials and painting techniques, as well as on painting diagnosis. He is currently teaching at the Universitat Politécnica de València.

Paola Artoni - She holds a PhD in Beni Culturali. From 1999 to 2009 she worked for Ministero per i Beni e le Attività Culturali in the Museum of the Ducal Palace in Mantua. Since 2010 she's Functionary technical responsible of the Centre Laniac (Laboratorio di Analisi Non Invasive per l'Arte Antica, Moderna e Contemporanea), in Dipartimento di Culture e Civiltà, (University of Verona). She held courses for introducing non-invasive diagnostics applied to cultural heritage in the same university, from 2011 up to now.

Marta Raïch - She has a degree in Audiovisual Communication by the University of Lleida (Spain). She is a Technician in Image Production. She is specialized in scientific photography applied to works of art, as well as artistic diagnosis. She is currently developing her research and work as a technician at the Centre d'Art d'Època Moderna (CAEM) of the UdL where she carries out technical and scientific imaging, while she also develops design and layout tasks.

References

Cardinali, M., De Ruggieri, B., Falucci, C. (2002) Diagnostica artistica. Tracce materiali per la storia dell'arte e per la conservazione, Roma: Palombi Editori.

Cosentino, A. (2014). 'Identification of pigments by multispectral imaging; a flowchart method'. Heritage Science, *2*(1), 8, doi: 10.1186.

Cosentino, A. (2016) 'Infrared technical photography for art examination', e-Preservation Science, 13, p. 1-6.

Cucci, C., Picollo, M. and Vervat, M. (2012) 'Trans-illumination and trans-irradiation with digital cameras: Potentials and limits of two imaging techniques used for the diagnostic investigation of paintings', Journal of Cultural Heritage, Vol. 13, p. 83-88, doi:10.1016/j.culher.2011.07.002

Doërner, M, (1998) Los materiales de la pintura y su empleo en el arte. BArcelona: Reverte

Dupont, F. (1977) 'Correspondence: transmitted infrared photography', Studies in Conservation, n. 22, p. 42-44.

Herrero-Cortell, M. A., Raïch, M., and Artoni, P. (2018) 'Multi-band technical imaging in the research of the execution of paintings. The case study of the portrait of Carlos IV, by Francisco de Goya,' Ge-conservación/conservação, vol 14, p. 5-15. doi: 10459.1/65860

Kushel, D. A. (1983) 'Applications of trasmitted infrared radiation to the examination of artifacts', Studies in Conservation, n. 30, p. 1-10. doi: 10.1179/sic.1985.30.1.1

Matteini, M. and Moles, A. (2001) Ciencia y Restauración. Método de Investigación, Guipúzcoa: Nerea.

Moutsatsou A., Skapoula D., and Doulgeridis M. (2011) ' The Contribution of Transmitted Infrared Imaging to Non-Invasive Study of Canvas Paintings at the National Gallery – Alexandros Soutzos Museum, Greece", in E-Conservation magazine, 22, p. 53-61.

Poldi, G., & Villa, G. C. F. (2006). *Dalla conservazione alla storia dell'arte: riflettografia e analisi non invasive per lo studio dei dipinti* (Vol. 3). Pisa: Edizioni della Normale.

Riley, O. H. and Berger, G. A, (1971) 'New developments in the conservation of works of art', Art Journal n. 1, Vol. 31, p. 37-40. doi:: 10.1080/00043249.1971.10792967

Vervat, M., Vigna, A., Cucci, C. and Picollo, M. (2005). 'Il restauro del pascolo a Pietramala di Telemaco Signorini: un esempio di diagnostica su dipinti moderni con impiego della ripresa fotografica in transilluminazione', in Lo stato dell'Arte III: Atti di convegno IGIIC, Palermo, 2005, Firenze: Nardini, p. 84-89.