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PHOTOGRAPHIC AND TECHNICAL EXAMINATION: A VALUABLE TOOL FOR THE CONSERVATION TREATMENT OF WORKS OF ART ON PAPER AND PARCHMENT

Zusammenfassung

Optische Untersuchungstechniken umfassen Beobachtung und fotografische Aufzeichnung unter Verwendung von Beleuchtung in verschiedenen Bereichen des Spektrums. Im sichtbaren Bereich können Restauratoren durch Variation des Beleuchtungswinkels und der Beleuchtungsposition Kunstwerke im Auf-, Streif- und Durchlicht untersuchen und aufzeichnen. Im nicht

sichtbaren Bereich gibt es UV-induzierte sichtbare Fluoreszenz-Fotografie, UV-Reflexions-Fotografie, IR-Bildgebung, multispektrale und hyperspektrale Bildgebung und Falschfarben-IR-Bildgebung. Die vorgenannten Techniken sind ein wertvolles Instrument, welches Kunsthistorikern, Kuratoren und Konservatoren Informationen für die Bestimmung der geeigneten Behandlung von Kunstwerken auf Papier und Pergament liefern kann.

Keywords: non-destructive documentation, UV photography, multispectral imaging, hyperspectral imaging, false colour infrared imaging

Introduction

Photographic and technical examination can be a valuable tool for the study and conservation treatment of works of art on paper and parchment, useful for scholars, art historians, curators, and conservators. Technical examination is the first line of approach to the study of a piece of artwork. It is a non-destructive methodology, as it encompasses non-sampling examination methods for the support, media, surface and underlying layers of an object, by direct or magnified observation using a variety of illumination sources and techniques. In particular, it involves a methodology that

uses illumination in the visible range and the non-visible range of the spectrum.

In the visible range, by varying the angle of illumination, conservators can examine and record works of art in normal (or visible) light, as well as raking and transmitted light. These photographic techniques can record the identification details of the works, but they can also provide information about the media, the technique, and the support, as well as the condition of the works. The techniques that involve recordings in the non-visible range of the spectrum include Ultraviolet-Induced Visible Fluorescence photography, UV reflectance photography, infrared imaging, multispectral and

hyperspectral imaging and false colour infrared imaging. All these are imaging techniques exploit different radiations to record the various layers of a work of art: the ultraviolet radiation only reacts with the surface layer of a work, the visible has the ability to penetrate transparent or semi-transparent materials, the infrared radiation penetrates opaque painting layers, while X-rays penetrate solid material with wood and metals.¹

This technical examination can be used to determine the original materials of the object and the characteristics of these materials, to determine the history of the object based on the evidence of its physical condition, to detect the presence of alterations and their implications for the physical condition of the object, and to determine the presence of components or conditions that may influence conservation treatment and to aid in the evaluation of ongoing treatment. It precedes and guides instrumental analysis in which the structure and composition of the artwork are determined by analytical methods requiring sampling.²

The visible range of the spectrum: methods using visible radiation

Normal light photography

For the photographic setup, visible light sources of equal intensity, incident to the surface of the object should be placed at approximately 25° to the object, to give as even illumination as possible and to minimize surface gloss. The object should be perpendicular to the camera.³

This method reveals and records the following:

- a. the artistic details of the work, the image or the design, the media and technique,

1 J. DYER, G. VERRI & J. CUPITT, "Multispectral Imaging in Reflectance and Photo-induced Luminescence modes: a User Manual", European CHARISMA Project, 2013.

2 *The AIC Guide to Digital Photography and Conservation Documentation*, ed. Jeffrey Warda, American Institute for Conservation of Historic and Artistic Works, Washington DC, 2011.

3 [https://www.conservation-wiki.com/wiki/Visual_Examination_\(PCC\)](https://www.conservation-wiki.com/wiki/Visual_Examination_(PCC)) (latest access 13-6-2019)

- b. the colouration of paper and special characteristics,
- b. the identification details, like the signatures, collection and ownership stamps, notes, collection classification numbering, the name of the printer, the creator or the printing house,
- c. the various effect of the technique on the paper support,
- d. the original mount and method of hinging or the frame,
- e. the presence of linings or secondary support,
- f. the indications for previous use of the support,
- g. the condition of the work, like the mechanical damages, the deformations and planar distortion, the discolouration, the chemical changes, the alterations and damage on media, as well as the previous treatments or interventions,
- h. the stages and the results of conservation treatment.

Raking light photography

For the setup of the raking light photography, only one light source is needed, which is located on one side of the object at a low (raking) angle so that the projected light is almost parallel to the surface of the object. The standard 5-10° position used in photography may only reveal part of the information. However, changing the angle of illumination or proximity to the object can reveal different information or intensities of the problem.⁴ The camera is placed perpendicular to the object.

Raking light photography can be used to study and record:

- a. the painting or drawing technique, the surface textures and character of media,
- b. the topography of paper and media,
- c. the surface texture of paper, the degree of smoothness or burnishing of paper,
- d. the characteristics of paper resulting from the method of manufacture,
- e. watermarks and to distinct felt and mould impressions,

4 [https://www.conservation-wiki.com/wiki/Visual_Examination_\(PCC\)](https://www.conservation-wiki.com/wiki/Visual_Examination_(PCC)) (latest access 13-6-2019)

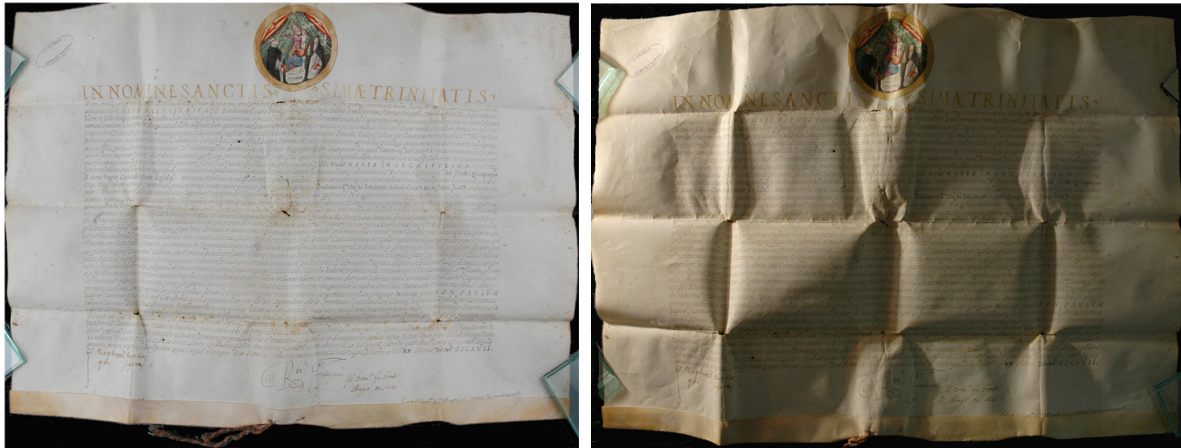


Fig. 1: Raking light photograph, a 17th-century patent letter for the foundation of the catholic brotherhood of Rosary in the Greek island of Naxos. Folding pattern of the document is evident

- f. platemarks and embossing as a result of printing techniques and blind stamps,
- g. the condition of the works, the damages on the surface and the core of the paper,
- h. the results of folding practices (Fig. 1), but also the presence of ruling and pricking,
- i. cracking of media, painting layers tenting flaking,
- j. indentations made in prepared surfaces on paper by metal point, especially when drawing line colour has faded.

Transmitted light photography

For the photographic setup, the light source is underneath or beneath the work, at a vertical position. The light source commonly used is a lightbox or the work is held at a safe distance from a light source. The camera is perpendicular to the object.

Transmitted light is usually applied to reveal the presence of watermarks and to record them (Fig. 2), but it can also reveal and record:

- a. paper structure and the method of paper manufacture, as well as the method of application of the watermark,
- b. the thickness and opacity of paper, variations in sheet thickness,
- c. the presence of impurities (like hair and wood chips), irregularities and defaults in pulp distribution, that provide indications for the quality of the paper support,



Fig. 2: Transmitted light photograph, a watermark depicting a foolscap with seven points, from a 17th-century print

- d. inscriptions or drawings on the verso, concealed by linings,
- e. the presence of mechanical damage (holes, tears, folds, thinned areas), the results of insect damage, previous treatment, but also the extent and intensity of discolouration.



Fig. 3: Visible light photograph (left) and UV induced visible fluorescence photograph (right), detail of a 17th c. printed map of Thrace (Greece) by Ortelius. In the UV-induced visible fluorescence photograph, the yellow presents red fluorescence indicating cadmium yellow, while lack of UV-absorption points towards the absence of metal-containing pigments

Non-visible range of the spectrum: methods using UV radiation

For examination of works of art with ultraviolet illumination, UV visible induced fluorescence photography and UV reflectance photography can be used.

Ultraviolet induced visible Fluorescence Photography

This method is based on the ability of ultraviolet radiation to cause the visible fluorescence of some substances. The recorded information comes exclusively from the visible region of the spectrum, so all other radiations, such as ultraviolet and infrared, must be cut off. For this reason, barrier filters in front of the camera lens should be used. This technique can be applied both with cameras with film and digital cameras. Lamps emitting at 365nm (within the UV region) should be employed and set at symmetrical setup. The object must be perpendicular to the camera.⁵

5 A. A. KAMINARI, 'Copy letters using iron gall inks: An historical and physicochemical study for the development of a forensic analytical methodology incorporating both chemical and non-destructive imaging techniques' (un-

published doctoral thesis, Kingston University, Kingston upon Thames, UK, 2014), 88.

Fluorescence varies in intensity and colour in different organic compounds. It also depends on the nature of the radiation. Fluorescence provides information about support, media and pigments. It can be seen with the naked eye and may be recorded photographically. In ultraviolet-induced visible fluorescence colour photography, the different fluorescence wavelengths of the substances result in the recording of different colours on the film. Different colour in the fluorescence of visibly similar substances shows differences in their composition. As some substances absorb the radiation without producing fluorescence, they show up as a deep purple or black, while others appear lighter. These differences can also be recorded in black and white ultraviolet-visible induced fluorescence photography, but images should be interpreted only by the change in the grey tones.

Thus, characteristic fluorescence, reflection, or absorption may provide indications for the use of specific media (e.g., titanium dioxide fluoresces deep purple and zinc

white and yellow-green), inks (e.g., iron gall ink which appears black, while carbon-based inks show no difference), and dye-stuffs in coloured inks, pencils, and copy pencils that fluoresce distinctively (Fig. 3). In the same context, it can be used to study details obscured by darkening of support, faded inks (e.g., iron gall ink inscription, metal point sketch), suspected alteration or removal of ink.^{6,7}

This technique can also provide indications for the presence of fillers, additives, or optical brighteners in the support, as well as the application of a gesso priming or preparation. In transparent papers, it can provide indications for the method of manufacture (overbeating, or sparse paper pulp) or the presence of transparentizing agents like oils or resins as they fluoresce characteristically. Likewise, oil stains or the absorption of oil media by the paper support present the same behaviour.⁸

Additionally, the application of old varnishes (e.g., mastic, dammar) can be indicated as they fluoresce characteristically. Finally, various adhesives fluoresce characteristically (e.g., dextrans fluoresce blue-white; gum arabic fluoresces slightly, while animal glue yellow).

UV induced visible fluorescence photography can be useful for the assessment of the condition of the works and the results of conservation treatment. It can be used:

- a. to discern the stage of deterioration of inked areas, when iron gall ink has been used as drawing media,
- b. to indicate oxidation of cellulose caused by drawing, printing, or writing media as it fluoresces at first stages and then gradually turns to UV absorption,

- c. to discern the provenance of foxing and to reveal the presence and extent of cellulose/media deterioration resulting from foxing,
- d. to distinguish tidelines from other types of discolouration,
- e. to distinguish adhesive residues from tapes and repairs,
- f. to reveal and record the extent of mould damage on a work,
- g. to discern the provenance of discolouration and distinguish between stains,
- h. to discern rust stains and extent of damage,
- i. to detect alterations and discontinuities in the homogeneity of paper, media or varnishes which result from erasures, loss, local treatments, repairs, retouching,
- j. to study the changes caused by conservation treatment, or record and control the result of any intervention, e.g., tidelines caused by the local application of water or pH measurements, washing results on iron gall drawings.

UV reflectance photography

The value of the method is due to the different absorption levels that various surfaces exhibit in the ultraviolet region. The result is a high contrast image that can help differentiate between the areas and leads to their classifications based on their different physicochemical properties (Fig. 4). In this case, from all the reflected radiation, only the ultraviolet between 320nm and 380nm is of importance and must be recorded. For this reason, special barrier filters are used in front of the camera lens, that permit the passing of this wavelength only, while they cut off all other radiation. Lamps emitting within the UV region should be employed and set at symmetrical setup. The object must be perpendicular to the camera. As ultraviolet radiation is not visible, the use of colour films has no purpose, and black and white films should be used.⁹

6 [https://www.conservation-wiki.com/wiki/Visual_Examination_\(PCC\)](https://www.conservation-wiki.com/wiki/Visual_Examination_(PCC)) (latest access 13-6-2019).

7 A. COSENTINO, 'Identification of pigments by multispectral imaging: a flowchart method', in: *Heritage Science* (2014), 2/8. <http://www.heritagesciencejournal.com/content/2/1/8> (last access 7-8-2019).

8 P. BANOU, A. ALEXOPOULOU & B.W. SINGER, 'Investigation of oil binder absorption into paper support with ultraviolet-induced visible fluorescence and ultraviolet reflectance photography', in: *e-Preservation Science journal*, 14 (2017), 1-8.

9 KAMINARI, note 5, 87.

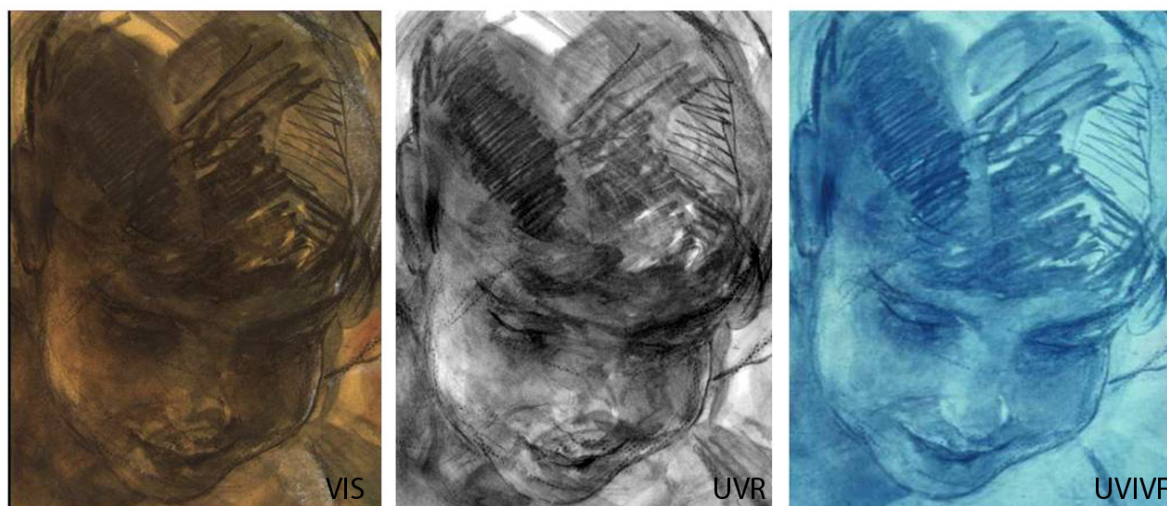


Fig. 4: Visible light photograph (left), UV reflectance photograph (middle), and UV induced visible fluorescence (right) of 19th c. an oil study on paper (detail). Comparative study of the images can provide details of the drawing technique and indicate the use of various media not discernible with the naked eye.

Non-visible range of the spectrum: methods using infra-red radiation

For the recording of works of art within the infrared region, IR photography, IR reflectography cameras, multispectral and hyper-spectral imaging and false colour infrared imaging can be used. As substances react differently to near IR than to visible light, these techniques can be used to:

- a. detect information visually incoherent, indistinct, or invisible parts of the composition,
- b. reveal underpaintings, underdrawings, obscured or faded inscriptions, when created with carbon-containing media (carbon black ink, graphite, charcoal), which absorb IR strongly (Fig. 5),
- c. read through linings or secondary supports,
- d. read through discolouration and accumulated and embedded dirt,
- e. reveal details of the technique or the changes in composition or any type of intervention,
- f. provide indications for the presence of certain pigments and inks.

IR photography

In infrared photography, the film or image sensor used is sensitive to near-infrared

light from about 760 nm to about 900 nm, which differentiates it from thermal imaging, which exploits the range of far-infrared radiation. It includes the use of films, and since they are usually also sensitive to visible light, a visible light barrier filter must be used. In the cultural heritage section, b/w films are employed in contrast to colour infrared photography which is mainly for artistic purposes.

IR reflectography

Infrared Reflectography is also a non-destructive diagnostic method for research of works of art, which takes advantage of the penetrating capability of the infrared radiation, between 760nm and 2700nm, through the upper colour layers of the object, thus multiplying the in-depth observation that can reach the sketches (Fig. 6). Use of longer wavelengths is forbidden, as in those regions the radiation can cause heat side effects that could damage the work of art. The detection of the infrared radiation is made with the help of an electronic system that transforms the non-visible radiation into a black-and-white optical image (i.e., the reflectogram).

Infrared reflectography provides useful information about the paint layers of an object, which cannot be confused with

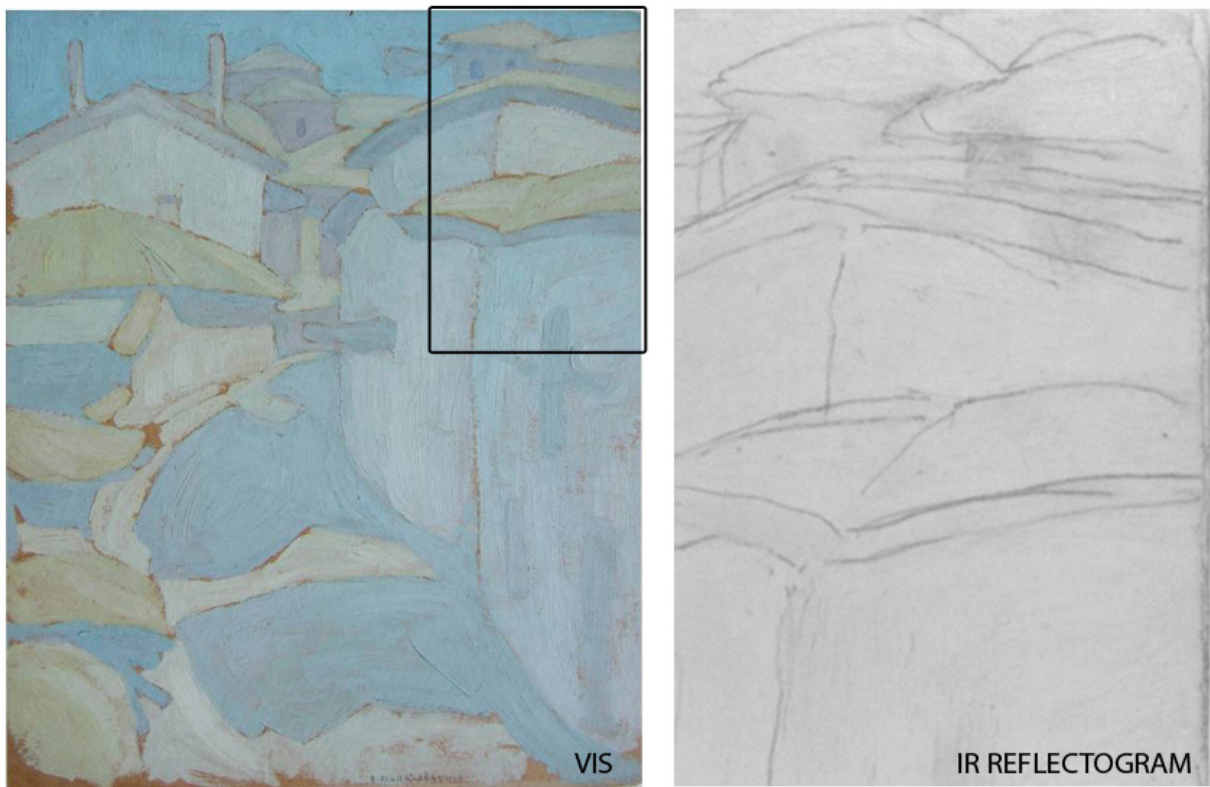


Fig. 5: Visible light photograph (left) and IR reflectography (right) of a 20th c. oil painting on paper board that reveals pencil underdrawings (detail of the marked area).

those of the substrate. The most important advantage of the method is that it can be combined with appropriate mathematical processing software. This multiplies the interpretation and measurement possibilities that describe and characterize the behaviour of the layers due to their different physicochemical parameters.¹⁰

Multispectral and hyperspectral imaging

Multispectral and/or hyperspectral imaging analysis or imaging spectroscopy is a non-invasive method of investigation that allows the simultaneous collection of spectral and spatial information of a surface in the visible and near-infrared regions.¹¹ Primarily used for underdrawing detection in paintings it has also been successfully applied to the scientific investigation of manuscripts, archival

material, works of art on paper, the evaluation of conservation treatments and digital imaging for documentation.^{12, 13, 14, 15} While infrared reflectography provides images of the continuous spectral area in the infrared, information is collected from specific and defined wavelengths in multispectral and hyperspectral imaging. In multispectral imaging, the infrared region is divided into five continuous bands, and in hyperspectral imaging into 34 different spectral bands.

10 A. ALEXOPOULOU & I. CHRYSOULAKIS, *Science and Works of Art* (in Greek), (Athens: Gonis Publishing, 1993), 171-182.

11 A. ALEXOPOULOU, A. KAMINARI, A. PANAGOPOULOS, E. PÖHLMANN, 'Multispectral documentation and image processing analysis of the papyrus of tomb II at Daphne, Greece', in: *Journal of Archaeological Science*, 40 (2013), 1242-1249.

12 P. BANOU, A. KAMINARI, A. MOUTSATSOU, A. ALEXOPOULOU, B.W.SINGER, 'Investigating the Conservation Problems of Oil Paintings on Paper Supports', in: *Works of Art and Conservation Science Today* (International Symposium, Thessaloniki, Greece 2010).

13 R. PADOAN, TH.A.G. STEEMERS, M.E. KLEIN, B.J. AALDERINK & G.DE BRUIN, 'Quantitative Hyperspectral Imaging of Historical Documents: Technique and Applications', in: *9th International Conference on NDT of Art*, Jerusalem Israel (2008), 1-10.

14 C. FISCHER & I. KAKOULLI, 'Multispectral and hyperspectral imaging technologies in conservation: current research and potential applications', in: *Reviews in Conservation*, 7 (2006), 3-16.

15 D. M. CHABRIES, S. W. BOORAS & G. H. BEARMAN, 'Imaging the past: recent applications of multispectral imaging technology to deciphering manuscripts', in: *Antiquity* 77, 296 (2003), 359-372.

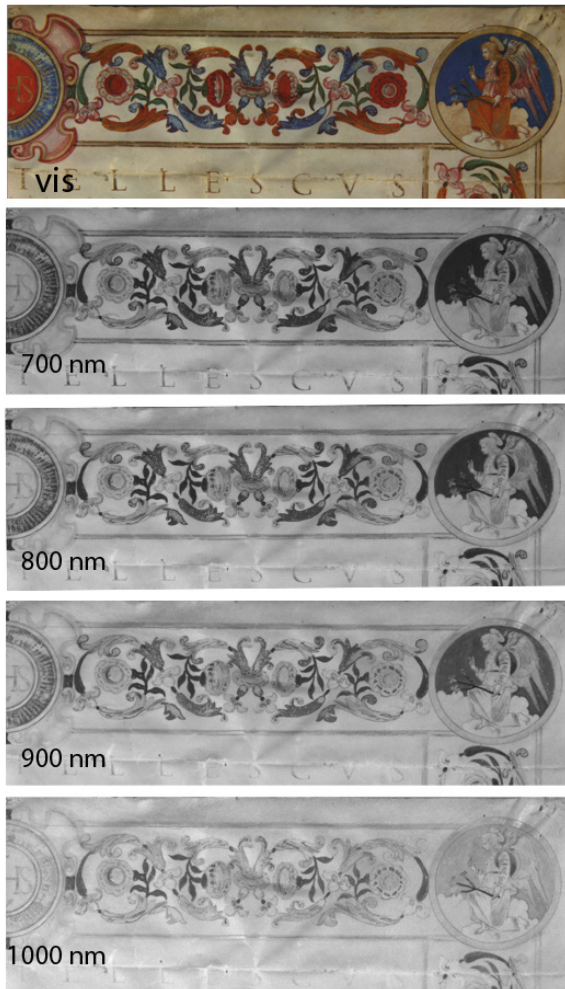


Fig. 6: Hyperspectral images in 700, 800, 900, and 1000 nm of the spectrum, detail of tempera decoration on a 17th c. Jesuit foundation document

This enables a more thorough study of the behaviour of the materials.

Spectral imaging systems used in conservation science are capable of acquiring and analysing spectral cubes that contain both spectral and spatial data.¹⁶ The cube contains high definition images across multiple spectral bands that are used for calculating a full spectrum per image pixel. These systems usually comprise a filtering or dispersing device and a camera detector driven by specialized software to control image and data acquisition.

False-colour infrared

Another useful function of a multispectral technique is the infrared false colour

recording of the object. Infrared colour images allow a sharper visualization of the original material because infrared radiation tends to be less scattered by thin cloudy layers such as varnishes, consolidants, glues, etc. that often cover the original surface. False-colour infrared has been used as a non-invasive method for studying coloured material *in situ* on paintings or manuscripts.^{17, 18, 19}

The technique consists of the combination of images acquired in the green, red, and infrared regions to create a false-colour image that contains and highlights with colour the information from both the visible and the infrared regions. It is worth noting that the false colour is usually quite different from the true visible colour. The materials may have similar absorbance spectra in visible light, but they may highly differ in their near-infrared (NIR) absorbance. Thus, as the colours can be immediately perceived by the researcher, similar coloured materials may be differentiated and identified by their false colour rendition (Fig. 7). The specific false colour that each material produces depends on its interaction with IR light; the interaction is strictly related to the chemical composition of the material. Images can be obtained by using a multispectral/hyperspectral camera and symmetrical lighting conditions, provided illumination includes both the visible and infrared regions.^{20, 21}

17 A. ALEXOPOULOU, N. LIAROS, A. PANAGOPOULOU & A. KAMINARI, 'False Colour Infrared Imaging as a Tool for the Study of Pigments Used in Ceramics from Areas Within the Mediterranean Basin', in: *Conservation and the Eastern Mediterranean* (IIC Congress, Istanbul, Turkey 2010).

18 M. C. BUOSO, D. CECCATO, D. ZAFIROPOULOS, 'False-Color Infra Red Photography in the Identification of Pigments Used for a Late 13th Century Illuminated Manuscript', in: *Laboratori Nazionali di Legnaro (LNL) Annual Report, Applied and Interdisciplinary Physics Instrumentation* (2009), 153-154.

19 M. E. KLEIN, J. H. SCHOLTEN, TH. A. G. STEEMERS, G. DE BRUIN, 'Hyperspectral Imaging e A Novel Non-destructive Analytical Tool in Paper and Writing Durability Research', in: *Non-Destructive Investigations and Microanalysis for the Diagnostics and Conservation of the Cultural and Environmental Heritage* (Art '05, 8th International Conference, Lecce, 2005), 1-16.

20 KAMINARI, note 5, 106.

21 ALEXOPOULOU, KAMINARI, PANAGOPOULOS, PÖHLMANN, note 11.

16 FISCHER & KAKOULLI, note 13, 3-16.



Fig. 7: Visible light photograph (left) and infra-red image (right) of a 20th-century tempera painting on paper. "Hellas" by J. Tsarouhis

Conclusion

Without a doubt, photographic and technical examination can provide valuable information for conservators, conservation scientists, curators, art historians and in general scholars of works of art on paper and parchment. Furthermore, comparative study of these images can provide an even better insight into the techniques, the materials and the condition of artwork on paper or parchment support.

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