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UV-visible-NIR reflectance spectrophotometry in cultural heritage: Background paper

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Diffuse reflectance spectrophotometry in the ultraviolet, visible and near-infrared (UV-vis-NIR) range is becoming a widely-used tool for the non-invasive analysis of cultural heritage objects, especially in its variant with optical fibres, commonly dubbed FORS (Fibre Optic Reflectance Spectroscopy). It is especially useful to study objects such as medieval manuscripts for which sampling is prohibited by current conservation standards. This brief describes the most common types of application of FORS in the analysis of cultural heritage objects; it also illustrates the instrumentation used and the main advantages and limitations of the technique.

Although the application of reflectance spectrophotometry to the study of artworks dates back to the late 1930s, it is only since the late 1970s that this method has been used to monitor colour changes and identify pigments on painted surfaces. During the last 20 years, with the advent of fibre-based instruments, cultural heritage applications of UV-vis-NIR reflectance spectrophotometry have grown rapidly: FORS is quickly becoming one of the most widely used analytical tools for the non-invasive analysis of works of art and the identification of artists' materials.

Sturdy, portable equipment with extended sensitivity in the near-infrared range (up to 2500 nm) has now been adopted by the cultural heritage community and is increasingly preferred to the previously available spectrophotometers, usually limited to the UV and visible range or just beyond (approx. 200 to 1000 nm).

The ability to probe an extended spectral range means that a great deal of information can be gained not only about electronic transitions (such as ligand field and band-to-band effects) but also about vibrational transitions, of which the overtones and combinations can be observed in the NIR range. The availability of this additional knowledge expands the range of artists' materials that can be reliably identified using this method.

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What is FORS good for?

The list at the end of this brief shows a selection of published studies reporting on the application of FORS analysis to a variety of cultural heritage materials, including pigments and paint binders in paintings on panel, parchment and wall, as well as canvas and plastics (see Fig. 1).

General comments can be made on the suitability of FORS for the study of different types of objects:

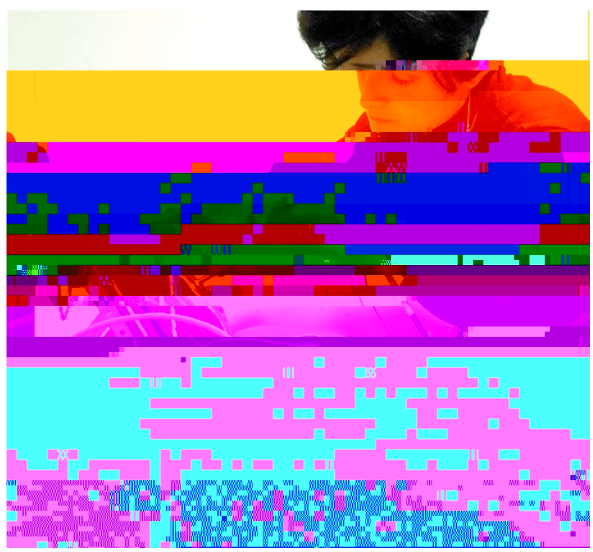

Fig. 1 A 14th century illuminated manuscript analysed with a fibre-optic spectroradiometer.

Painted surfaces – FORS is especially useful for the identification of blue, green, white and red pigments (see Fig. 2). FORS spectra of most yellow and black pigments are not characteristic enough to allow identification, except at times within a broad category (*e.g.*, iron oxides and hydroxides, or carbon-based pigments). Binding media and varnishes can also be broadly categorized (see Fig. 3), although complications can arise when their spectral features overlap with those of the support, as is the case especially for parchment.

Paper and parchment – these two materials can be easily differentiated when doubts exist, and FORS can be used along with other tools to study their degradation mechanisms.

Textiles – FORS allows distinction between wool, silk, cotton, and bast (*e.g.*, linen or hemp) fibres. This can be useful to identify the exact nature of the support for paintings on canvas, and for the characterization of tapestries as well as historic carpets, costumes and upholstery fabrics.

Plastics – FORS has recently been used to study the degradation of plastic materials used in 20^{th} century artworks and objects. This type of application is likely to become more common in view of the growing interest in the fugitive nature and complex material composition of much contemporary art.

Advantages and limitations

FORS has the advantage of being completely non-invasive and very quick – a good quality spectrum can be obtained in less than 10 speci