Paintings' alternations in the past and in the future: non-invasive x-ray based imaging of subsurface information and how to improve upon it

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In the last decade we (and other groups) have developed and applied the method of Macroscopic X-ray fluorescence (MA-XRF) imaging to ca 100-150 oil paintings in diverse musea of fine arts in Europe and the US. This series includes works by famous 15-19th century artists Flemish and Dutch artists such as Van Eyck, Memling, Rubens, Van Dyck, Rembrandt, Magritte and Van Gogh. Also stained glass windows, illuminated manuscripts and artistic drawings can be examined by means of MA-XRF to yield information that is relevant for different purposes, be it authentication, art-historical study or conservation.

MA-XRF shares several useful characteristics with commonly employed methods for paintings' inspection such as X-ray radiography (XRR), Infra-red reflectograhy (IRR) and the more recently developed hyperspectral imaging methods that make use of camera's sensitive to parts of the ultraviolet, infrared and visual wavelength spectrum:

(i) While the X-rays employed energize the material in the irradiated spot (< 1 mm) on the artwork during a brief (< 1 s) period, no (discernable) damage results;

(ii) The penetrative x-rays allow to visualize 'hidden' layers in altered paintings that, for various reasons, were covered up by paint strata during/after the artwork creation

MA-XRF differs from XRR and IRR in three important ways:

(a) it is a scanning method, involving stepwise irradiation and spectral data recording, thus taking (substantially) longer than XRR, IRR and more modern full-field imaging methods, to record relevant imaging data, typically taking 1-10 h per m^2

(b) it provides multiple elemental images of the investigated painting areas, allowing (sometimes only approximate) identification of the inorganic pigments that were employed and their distribution at the brushstroke level; the largely orthogonal nature of the data usually permits a straightforward interpretation of the data cube.

(c) its information depth depends on the energy of the X-ray fluorescence radiation employed, varying between a few to hundreds of micrometers, which is in a suitable range to allow superficial and subsurface visualization on the projected distribution of various elemental constituents while the less relevant structure of the ground layer/substrate panels usually is not or only vaguely observed.

The strong and weak points of MA-XRF (and its more recent extensions) for visualization of different types of paintings alterations will be illustrated by examples involving artworks by the above-mentioned painters; in each case, the benefits that might be gained by (automated) post-processing of the data, e.g. towards noise reduction, feature extraction and/or visualization of anomalous patterns will be addressed.