Non-invasive, accessible multi-analytical ink analysis for improving the legibility of compromised historical handwriting

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Keywords: Manuscripts; Inks; Multi-Analytical Approach.

The legibility of handwriting in a historical manuscript can be compromised by overwriting, crossing out or erasure. This affects the interpretation of authors' original records, notes, and draft texts. Inks used for later edits often have chemical or physical properties similar to those of the original writing, making their discrimination challenging; in other cases, ink traces may be partially or entirely removed from the support.

To improve legibility and support the study of writing stages in such altered manuscripts, this research focuses on ink characterisation and discrimination using a non-invasive and accessible methodology. A multispectral method, Hypercolorimetric Multispectral Imaging (HMI) [1], was employed in combination with complementary traditional spectroscopic techniques, including X-ray fluorescence (XRF) and micro-Raman spectroscopies [2]. After validation on laboratory samples, the methodology was applied to original manuscripts preserved at the Biblioteca Nazionale Braidense (Milan) and the Biblioteca Universitaria di Pavia MiC (Pavia).

The multispectral method enabled partial visualisation of an erased portion of text (Fig. 1a), probably considered prohibited, on a page of Manuscript Aldini 211 (Ms.Ald.211), a XIV century *herbarium*. Contrast enhancement was achieved by applying the Normalised Difference Index (NDI) tool to a UV-induced fluorescence image and to the first principal component from Principal Component Analysis (PCA) performed on the same dataset, generating an image based on different material responses across diagnostic channels (Fig. 1b). Spectroscopic analyses indicated that the text was written using iron gall ink; in particular, micro-Raman spectroscopy confirmed this attribution through the characteristic signal of the metal-polyphenol complex at 1480 cm^{-1} (Fig. 1c).

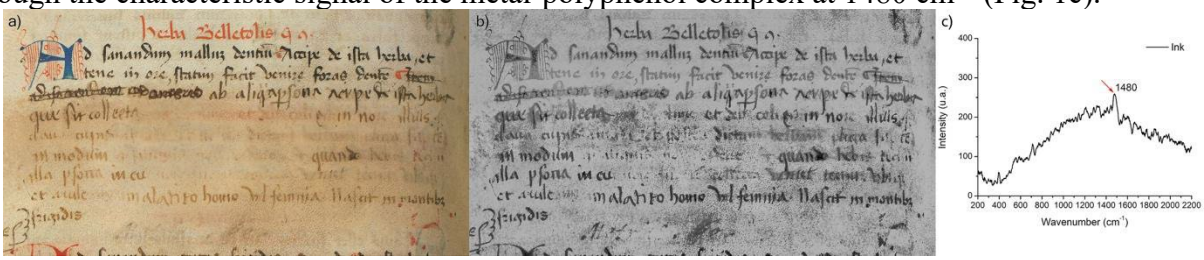

Figure 1. (a) Visible image of an erased portion of text on a page of Ms.Ald.211. (b) Image obtained from NDI processing. (c) Micro-Raman spectrum excited at 785 nm of the ink used for the text.

References

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[2] I. Rabin, R. Schütz, et al., *Comparative Oriental Manuscript Studies Newsletter*, **2012**, *3*.