

# Revealing Erased Words: The Application of Multispectral Imaging to the Book of Hours 50,1,1 at the Brazilian National Library

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## Abstract

*Multispectral imaging has become an essential tool for the analysis, documentation, and visualization of cultural heritage materials and objects. This study explores the application of this technique to a 15th-century illuminated manuscript held at the Brazilian National Library (Fundação Biblioteca Nacional) in Rio de Janeiro. The manuscript, currently part of ongoing doctoral research, contains erased text due to censorship through scraping. The use of multispectral imaging, incorporating eleven different wavelengths across UV, visible, and IR spectra, proved highly effective in recovering the erased words "pape" and "thoma", thus confirming the hypothesis of scholar Damião Berge regarding the lacunae and linking the codex to a 16th-century historical event.*

## Introduction

Since its initial applications in the 1990s [1], [2], [3], [4], multispectral imaging has been successfully employed in the study of ancient manuscripts, particularly in recovering the legibility of erased texts and images (due to various causes), with the Archimedes Palimpsest Project standing as a significant early milestone [5], [6], [7]. Renowned international institutions, such as the Library of Congress [8], [9], Rochester Institute of Technology (RIT) [5], [7], [10] and Norwegian University of Science and Technology (NTNU) [11], have been dedicated to improving this technology and disseminating the results obtained to expand this knowledge [3]. In Brazil, although the application of this technology is more recent, starting in 2022 for cultural heritage research at PrismaLAB/UFMG [12].

The multispectral imaging technique consists of generating multiple images of the same object captured at different wavelengths using a digital camera or sensor with spectral sensitivity capable of recording information from both visible and non-visible regions (Ultraviolet and Infrared) of the electromagnetic spectrum [1], [3], [4], [6]. One way to generate this type of image is by using a modified conventional digital camera (full-spectrum), a lighting system that covers the full spectrum (at least within the sensor's sensitivity limits), and optical filters with specific wavelengths (band-pass, narrow-band, or interference filters). It is also possible to combine a spectrally narrow-band lighting system, like LEDs, with optical filters to achieve the desired wavelengths [1].

Characterized by its non-invasive and non-destructive procedure, the main objectives of Multispectral Imaging include: document analysis – restoring the readability of erased text and images on parchment and paper, often heavily degraded or in poor condition; surface analysis; analysis of historical fabrics; forensic investigation; material classification [13], [14], [15]. However, the

material composition or elemental makeup of the manuscript was not examined in this study, as it fell outside the scope of the current work.

## Problem

Our study focuses on a luxurious Book of Hours from the second half of the 15th century (ca. 1460), probably produced in Bruges (Belgium) for an English client and later incorporated into the collection of the Royal Portuguese Library. Today, it is part of the collection of the National Library in Rio de Janeiro under the title *Book of Hours, Use of Sarum – CF-50,1,1* [16]. The codex originally contained 200 parchment folios (two of which were cut off) of 242 × 173 mm, with Latin text written in Gothic script using iron gall ink and rubrics in red lake, along with a large number of illuminations (tempera paintings with gold and silver applied). It is generally in good condition, although some folios have suffered localized damage. Below, folios 6v and 57r are shown (Figures 1 and 2).

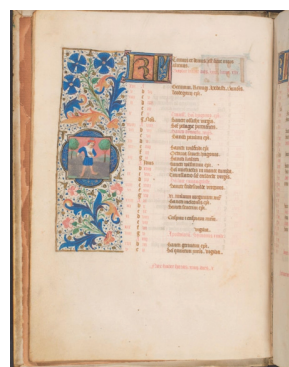


Figure 1. Folio 6v – Visible Light.  
Photo: Leão; Costa, 2024

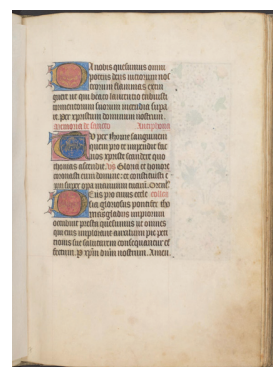
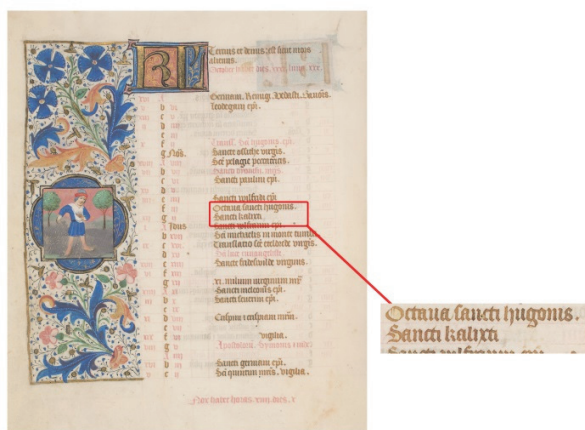


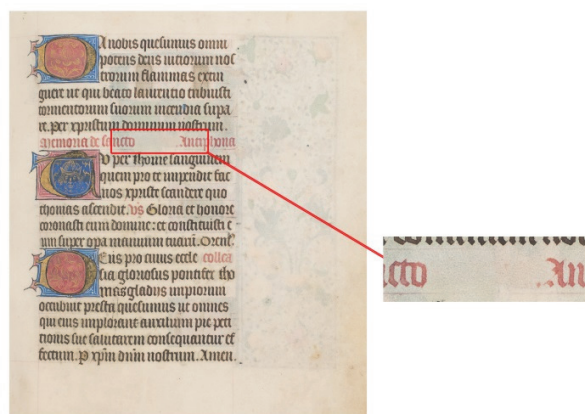
Figure 2. Folio 57r – Visible Light.  
Photo: Leão; Costa, 2024

Throughout the manuscript, various signs of use and ownership can be observed, including annotations, corrections, erasures, overlays, and location codes added by later hands. The codex is currently the subject of an interdisciplinary study to investigate its history, materiality, and values, including scientific imaging documentation and the application of multispectral imaging techniques [17]. Various multispectral techniques were applied to 16 selected folios of the manuscript, based on previously known information or expected findings. For this paper, we have chosen two folios, which present significant erasures due to censorship: 6v and 57r (see Figures 3 and 4).

According to Friar Damião Berge [18], a Franciscan scholar who dedicated part of his research to the Books of Hours in the National Library—particularly this manuscript—in an unpublished study conducted between ca. 1945-1960, the codex once contained devotional references to Saint Thomas Becket (or Saint Thomas of Canterbury), which were later erased. The English archbishop, martyred in 1170 at Canterbury Cathedral, was widely venerated across England shortly after his death and canonization. However, during the Anglican Reformation, King Henry VIII declared him a traitor and, in a 1538 decree, ordered the eradication of his cult. This included the destruction of his shrine and all references to him in liturgical books, as well as the removal of the word “Pope” [19]. As a result, many religious manuscripts in England – particularly Books of Hours – underwent targeted censorship, with names like *Thomas*, *Thoma*, or *Thome*, and the title *pape* systematically erased or overwritten [20]. In this codex, such erasures are evident on folios 2r, 6v, 7v (Calendar for January, October and December, respectively), 57r (Suffrage of St. Thomas), and 128v (Litany of the Saints); Friar Berge also notes the loss of two folios, one of which likely featured an illumination of the saint’s martyrdom and the other his antiphon. In the folios chosen for this article, the erased word “pape” refers to Pope St. Callixtus (6v) and “thoma” to St. Thomas Becket himself in his suffrage (57r).



**Figure 3.** Folio 6v, visible light image and detail showing the location of the erased word “pape”. Photo: Leão; Costa; Barroso, 2024

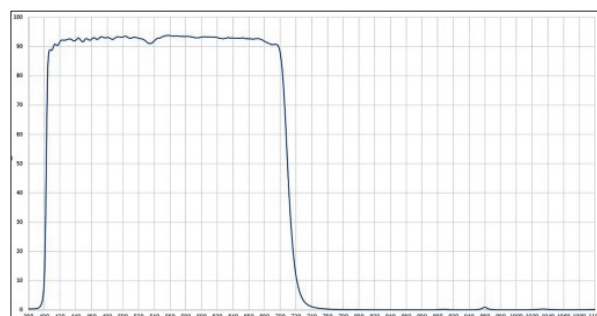


**Figure 4.** Folio 57r, visible light image and detail showing the location of the erased word “thoma”. Photo: Leão; Costa; Barroso, 2024

## Methodology

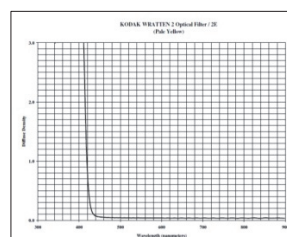
One of the first challenges we faced when building the PrismaLAB system was sourcing appropriate lighting components, due to the limited availability – or even complete lack – specialized narrowband LED systems suitable for multispectral imaging in Brazil. Based on the existing literature, we adopted a hybrid setup, as described below, which allowed us to develop a relatively low-cost multispectral system, with an updated total cost of around USD 2,500 – significantly lower than typical prices found on the international market. This value only includes the DSLR camera, lens, filters and lighting sources.

In this study, a DSLR camera (Canon EOS T6, 18 MP, full-spectrum 350–1100 nm) was used, equipped with a Canon 50mm f/2.5 macro lens. The setup included a hybrid lighting system consisting of LED, halogen, and fluorescent sources, along with optical filters to selectively control the wavelengths captured. The optical filters used were a UV-IR cut filter with a band-pass range from 400 nm to 700 nm, allowing only visible light to pass through; Figure 5, below.

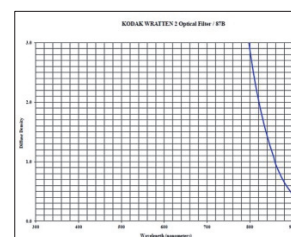


**Figure 5.** Spectral distribution of UV-IR cut Tangsinuo filter BCF700

For imaging under ultraviolet irradiation, a UV-blocking filter (Kodak 2E) designed for UV fluorescence, permitting wavelengths above 415 nm was used; and a UV-visible blocking filter (Kodak 87B), which allowed wavelengths above 720 nm was employed for infrared photography. Figures 6a: Kodak 2E filter and Figure 6b: Kodak 87b filter.



**Figure 6a.** Kodak 2E filter

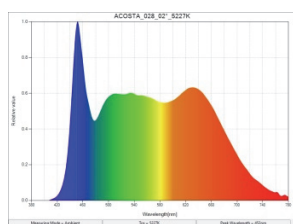


**Figure 6b.** Kodak 87B filter

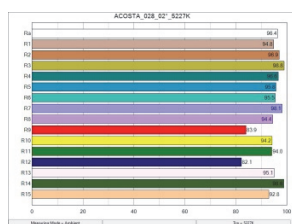
To validate the lighting sources, we used two scientific instruments: the THORLABS CCS200/M Spectrometer (covering a 200–1000 nm bandwidth) and the Sekonic Spectromaster C-7000 Spectrometer (covering a 380–780 nm bandwidth).

The multispectral lighting setup covered a wide range of wavelengths. For visible light, a Yongnuo YN660 LED was used, providing illumination across the full visible spectrum from 400

nm to 700 nm (5000K, CRI 97,6). See Figures 7a and 7b below: Figure 7a: Spectral distribution of Youngnuo 660 LED, white light, 5000K; 7b: Color Rendering Index (CRI) of Youngnuo 660 LED, white light, 5000K.

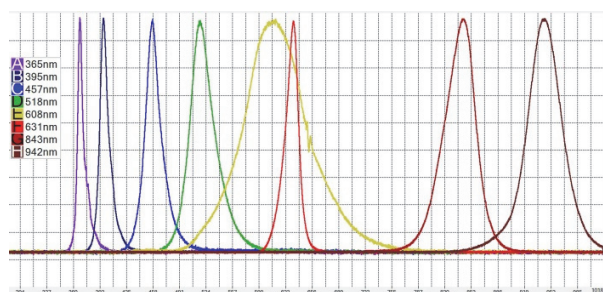


**Figure 7a.** Spectral distribution of Youngnuo 660 LED, white light, 5000K



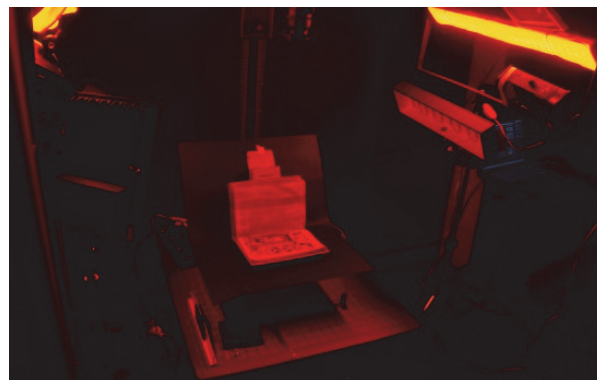
**Figure 7b.** CRI (96,4) of Youngnuo 660 LED, white light, 5000K

Additionally, spectrally narrow-band lighting in the red (631 nm), green (518 nm), and blue (457 nm) wavelengths was included, along with a yellow LED at 608 nm. For ultraviolet radiation, a forensic LED flashlight emitting at 365 nm was employed, along with an electronic fluorescent lamp (blacklight BLB), which had a peak radiation at 365 nm and a minor emission at 403 nm. A 395 nm peak emission LED radiation source, at the visible-ultraviolet boundary of the electromagnetic spectrum, was also included to enhance illumination. Infrared radiation was provided by a halogen/incandescent lamp, which covered a broad range up to 400 nm. Additionally, infrared LED floodlights operating at 843 nm and 942 nm were included in the setup of the imaging system. Figure 8 shows the spectral distribution of the narrow band LEDs used in this study, as described above. From left to right, the wavelengths: UV 365 nm, narrow band 395 nm, Blue 457 nm, Green 518 nm, Yellow 608 nm, Red 631 nm, IR 843 nm and IR 942 nm.



**Figure 8.** Spectral distribution of the LEDs at the PrismaLAB setup

The PrismaLAB equipment was transported from Federal University of Minas Gerais, in Belo Horizonte, the state capital, to Rio de Janeiro City, where it was installed in the National Library's microfilming department. The relocation was necessary because the codex cannot leave the institution due to strict security protocols, given its high historical and material value as cultural heritage.



**Figure 9.** MSI in the Brazilian National Library. Photo: Costa, 2024

A total of 12 RAW (uncompressed) images were generated for each analyzed folio, 6v and 57r. Due to operational logistics, the image generation followed this sequence: Visible Light, White Light (5000K), 400–700 nm (one with a color chart and another without), Red (631 nm), Green (518 nm), Blue (457 nm), Yellow (608 nm); Electronic UV Lamp (365+403 nm), Narrowband LED (395 nm), UV Flashlight LED (365 nm); IR LED (843 nm), IR LED (942 nm), and Halogen Lamp (approximately 400–1100 nm). The RAW images were processed in Adobe Camera RAW®, Raw Therapee, and Gimp, converted to monochromatic, saved as TIFF files in 16-bit format, and further processed in the ImageJ software.

Figures 10 and 11 show the generation and processed versions of the images from folio 6v, in TIFF 16-bit format.



**Figure 10.** Multispectral Imaging of folio 6v. Photo: Leão, Costa, 2024



**Figure 11.** Images of folio 6v after processing, monochrome. Photo: Leão, Costa, Barroso, 2024

In ImageJ, the images were stacked, and enhancement was applied using the PCA (Principal Component Analysis) plugin [3], [8], [21]. Within ImageJ, two separate input sequences were established for image stacking: one maintaining the original image generation sequence, and the other organized by increasing wavelength values associated with each image. And in the PCA

processing, we conducted 11 separate stacking operations, each adhering to the predetermined sequence for its assigned order.

Before processing in ImageJ and the PCA plugin, the monochromatic TIFF images were corrected and aligned in Photoshop® CS4 — a critical yet often challenging step aimed at improving the accuracy of the final results. Since illumination change in each image, visible features captured at varying wavelengths might not appear consistently (or remain uniform) across the imaging sequence. Image registration is the process of determining the optimal geometric transformation to align two images of the same scene, enabling accurate overlay for subsequent image analysis. Misalignment between images can lead to interpretation errors and may compromise the reliability of the outcomes [3], [22], [23].

Returning to the PCA, Principal Component Analysis (PCA) is a widely used multivariate statistical technique designed to reduce the dimensionality of a dataset while preserving its most significant patterns. Principal Component Analysis (PCA) is a widely used multivariate statistical technique designed to reduce the dimensionality of large datasets while preserving their most relevant patterns. It achieves this transformation by converting the original variables into a new set of uncorrelated (that is, maximally distinct) variables called principal components, which are linear combinations of the initial features [6]. These components are constructed such that the first principal component accounts for the maximum variance in the data, with each subsequent component capturing the remaining variance in descending order. By retaining only the top few components, PCA provides a lower-dimensional approximation of the original dataset, facilitating more efficient analysis and visualization. The method is particularly valuable for noise reduction, feature extraction, and data compression, enabling researchers to focus on the most influential underlying structures without substantial loss of information. Thus, PCA serves as a powerful tool for simplifying complex datasets while maintaining interpretability [24]. Furthermore, the application of multivariate analysis represents a deliberate and well-justified research decision when confronting datasets where either the number of features, observations, or both, reaches levels that demand sophisticated analytical treatment to uncover valid and reliable findings [21].

## Results

Sixteen PCA images were generated for folio 6v and eleven for folio 57r; among these, we present the most significant results. The selection of PCA images was based on information derived from each image's histogram, prioritizing optimal contrast and balanced tonal distribution — specifically excluding images that were either excessively bright (approaching white saturation) or overly dark (approaching black). Additionally, we incorporated a lower noise level assessment as a selection criterion. This combined approach was implemented to maximize the enhancement of the erased inscriptions “pape” in folio 6v and “thoma” in folio 57r.

Figure 12 presents the optimal results obtained from Folio 6v. Figure 12a: folio 6v scraped area, visible light. Figures 12b, 12c, 12d: the word “pape” appeared in the scraped area, after “Sancti kalixti”.



Figure 12a. Folio 6v scraped area, visible light



Figure 12b. word “pape”, Folio 6v, PCA image 1



Figure 12c. word “pape”, Folio 6v, PCA image 2



Figure 12d. word “pape”, Folio 6v, PCA image 3

Figure 12. The optimal results for folio 6v. Photo: Leão, Costa, Barroso, 2024

The enhanced visualization outcomes for folio 57r appear in the subsequent figures. Figure 13a: folio 57r, erased area, visible light. Figures 13b, 13c and 13d: the word “thoma” was revealed, between the words “sancto” and a dot, followed by “Antiphona”, in red letters.

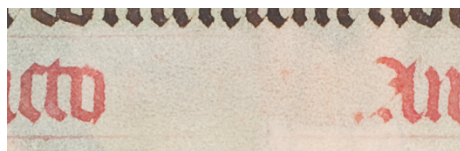


Figure 13a. Folio 57r, scraped area, visible light

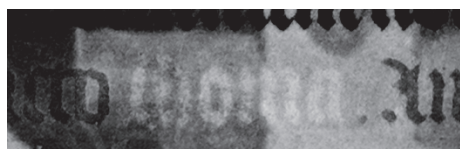


Figure 13b. word “thoma”, Folio 57r, PCA image 1

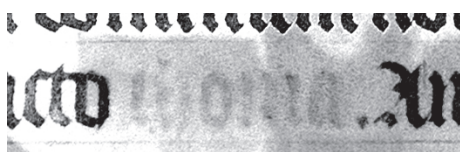


Figure 13c. word “thoma”, Folio 57r, PCA image 2

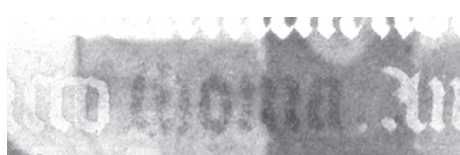


Figure 13d. word “thoma”, Folio 57r, PCA image 3

Figure 13. The optimal results of folio 57r. Photo: Leão, Costa, Barroso, 2024

The multispectral imaging results obtained from folios 6v and 57r of the *Book of Hours 50,1,1* reveal notable variations in contrast levels among the PCA-processed images. Our analysis demonstrates that the erased word “pape” in folio 6v exhibits significantly greater clarity and visibility compared to “thoma” in folio 57r, which presented somewhat less distinct results. A potential cause might be attributed to differences in the chemical composition of each ink, which could result in distinct spectral responses [25]. In folio 6v, the line containing the term “Sancti Kalixti” (corresponding to the erased word “pape”) is written in brown iron-gall ink [17] (Figure 12a). Conversely, in folio 57r, the line associated with the erased word “thoma” is written in red brazilwood lake ink [17] (Figure 13a).

Furthermore, preliminary observations indicate that the colorimetric variations detected in PCA images across folios may potentially derive from variations in processing parameters, specifically the distinct input sequences of source images and their corresponding stacking approaches. While these correlations appear consistent with the experimental conditions, they remain hypothetical and warrant further systematic investigation for conclusive validation.

It is crucial to emphasize that these PCA images were generated exclusively through ImageJ processing without subsequent enhancement in any image editing software, apart from necessary cropping for presentation purposes in this study. However, we acknowledge that advanced image processing tools (e.g. GIMP, Photoshop) could potentially improve these results considerably in terms of sharpness and contrast, potentially revealing additional textual information.

## Conclusion

The results observed in folios 6v and 57r of the *Book of Hours 50,1,1* demonstrate that multispectral imaging was highly successful, restoring the legibility of two erased words – “pape” and “thoma” – and confirming the hypothesis of scholar D. Berge regarding the lacunae. This discovery links the codex to a 16th-century historical event, enriching its interpretive context. By revealing otherwise inaccessible textual information, the technique significantly enhances our understanding of this cultural heritage artifact.

Moreover, multispectral imaging provides material evidence of the erasure, making visible what was once deliberately concealed. This tangible evidence not only supports scholarly interpretations but also offers the broader public an engaging perspective on how science can uncover hidden layers of the past.

While the technique holds further potential for investigating the manuscript’s historical context and material composition, it may also reveal unexpected information – such as erased inscriptions (whether original or later additions), scribal corrections, or other marginalia – that remain invisible under normal lighting. Although some of these findings did emerge during the research process, they fall outside the scope of the present study and will be explored in future work.

This research has successfully achieved its primary objectives, yielding robust results that significantly enhance the investigative capabilities of PrismaLAB. The findings not only validate the methodological framework but also open new directions for future studies in manuscript analysis through advanced spectral imaging techniques.

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## Authors Biographies

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