

# POSSIBILITIES OF APPLICATION OF MULTI-SPECTRAL IMAGING IN RESEARCH WORKS AND FOR PALEOGRAPHIC AND CODICOLOGICAL ANALYSIS OF DALMATIAN BENEVENTANA FROM THE COLLECTION OF THE RESEARCH LIBRARY OF DUBROVNIK LIBRARIES

**Jelena BOGDANOVIC**, M.A. in classical languages and Library science.  
Research library of Dubrovnik  
Dubrovnik, 20000, Croatia

**Tina DI REDA**, mag. art. Conservator-restorer  
Research library of Dubrovnik  
Dubrovnik, 20000, Croatia

## ABSTRACT

The paper focuses on the possibilities offered by Multi-spectral Imaging Technique (MSI) in preservation research and analysis of cultural heritage objects.

From the Manuscript's Collection of the Research Library of Dubrovnik, Dubrovnik Libraries, which are protected cultural goods of the Republic of Croatia (959 manuscripts), the oldest ones are fragments of manuscripts written in Beneventan script dating from 10/11th century onwards.

The aim of Multi-spectral analysis of faded, covered text was finding possible palimpsests, identifying the materials on which the text was written, identifying the types of ink and pigments used for writing. It can provide analysis of calligraphy initials with the application of new techniques of spectral recording. In addition, in the field of conservation and restoration of parchment and leather for the purpose of preserving, investigating the materials, technique and intent of making, we wanted to identify changes that have occurred over time all of these as a tool in reevaluating and discovering a new historical data. While using multi-spectral imaging technique on the seven fragments of manuscripts written in Beneventan script from the Library manuscript's collection, we have seen a more complete and accurate representation of the cultural property that cannot be obtained without the use of this technique. The aim was to investigate whether the multi-imaging technique applied on the seven fragments could be a good tool to apply on the whole Corp of the Dubrovnik's Manuscripts and Fragments in perspective with a goal to find the hidden historical data and information on the text to contribute to the thesis of existing a Benedictine scriptorium in the oldest Dubrovnik's Benedictine monastery on the island of Lokrum?

**Keywords:** multi-spectral imaging, Dalmatian Beneventan, Documentation and Paper research work

## 1. INTRODUCTION

Based on the obtained results of multispectral Imaging of seven Dalmatian Beneventan fragments from the Manuscript's Collection of the Research Library of the Dubrovnik Libraries, the aim is to point to unexploited possibilities for the recovery of faded, deleted text, text covered with adhesive, stains, reading the palimpsests, subsequent interventions on the text as well as the identification of the material on which the text was written, the types of ink and pigment used as possible tools that enable the dating of the manuscript for the purpose of applying this technique to the comprehensive analysis, i.e. reevaluating the

detected data in historical context of the The Corps of Beneventan Dubrovnik Manuscripts and Fragments, which could help in discovering a scriptorium in Benedictine monasteries in the Dubrovnik area – eg. the Abbey of St. Mary on the island of Lokrum. The Research Library of the Dubrovnik Libraries hosted from 18 to 20 March 2019 an international scientific meeting together with a workshop, the type of research was used for the first time in this area with the multi-spectral imaging system applied on the fragments of Beneventan manuscripts written in Dalmatian type on parchment: *Multispectral Imaging: Imaging a Future for the Past / Discovering lost texts on manuscripts by Multispectral Analyses*. The results show that using multispectral imaging technique can come up with valuable information on cultural goods, in this case on the Dalmatian Beneventan fragments of manuscripts (data, origin, deleted texts), about their materials and techniques, changes that have occurred over time (including additions, palimpsests). The results of multispectral imaging applied on the small number of Beneventan fragments show the technique applicable to whole Corps of Beneventan Dubrovnik Manuscripts and Fragments which could lead to invaluable new data.

## 2. WORKSHOP ON THE FRAGMENTS

The collaboration between the Research Library of the Dubrovnik Libraries and professors Roger Easton and David Messenger (Rochester Institute of Technology, CIS Rochester), and Ken Boydson (author of The EV™ system, MegaVision), gave us important tools to our research.<sup>1</sup> The fragments of Beneventan manuscripts that have been recorded are as follows:

1. Sg. A - 478: *Homiliarum*. 13th c. (2 fragments glued to the cover. 11th and 18th rows),
2. Sg. A - 1.006: *Moralia and Job* by Gregorius Magnus. 12th c. (26 rows),
3. Sg. CR - 20.799: *Patristica*. 13th c. (37 lines),
4. Sg. CR - 20.911: Unknown text (badly damaged, faded text, unknown dates and contents, 19 lines),
5. Sg. CR - 206: *Liturgica*. 12th c. (45 rows),
6. Sg. A -1.349: *Vitae sanctorum*. 11th c. (27 lines),
7. Sg. CR - III - 195: Liturgy. Incunabulum 68: *Etymologiae* by Isidorus de Seville found in *Summa de virtutibus et vitiis* by Guilielmus Paraldus (Brescia, 1494).

<sup>1</sup> The meeting was realized with the mediation of Dr. Francis Brassard, a lecturer at the RIT campus in Dubrovnik, Croatia.

Multi-spectral imaging of Dalmatian Beneventan fragments of the manuscripts was performed using the EV™ system with an EV Camera, which includes MegaVision's Monochrome E7 50-megapixel back, other lower resolution digital backs, computer controlled shutter, computer controlled aperture, custom multispectral parfocal and responsive over the entire range of silicon sensitivity lens. It was used 13 sets of LED lights: Ultraviolet: 365 nm, visible wavelengths: 420, 450, 470, 505, 530, 560, 590, 615, 630, 659 nm and infrared 940 nm. In total 23 images per object: fluorescence imaging (10 images illuminated with ultraviolet light (365nm) and visible (450 nm)) and captured through different visible and infrared filters. The images taken are computer-generated and partly processed at the workshop in the Library, partly at RIT Center for Imaging Science in New York.

### 3. THE CORPS OF BENEVENTAN DUBROVNIK MANUSCRIPTS AND FRAGMENTS

The Benedictine movement as a movement of culture and literacy in the Archdiocese of Dubrovnik began to develop from 1023. with the foundation of the first independent Abbey of St. Mary on the Lokrum Island. There were four independent Benedictine Abbeys in the Republic of Dubrovnik: St. Mary on the island of Lokrum, St. Mary on the island of Mljet, St. Mihajlo in Paklena on the island of Šipán and St. Jacob in Višnjica. In addition to these abbeys, the existence of smaller Benedictine monasteries was confirmed in the wider Dubrovnik area: on the island of Mrkan, in Rožat in the Rijeka of Dubrovnik, in Prožura on the island of Mljet, on the island of St. Andrew on the open sea and on the St. Peter near the city of Cavtat. There were also five other Benedictine monasteries and cenobia, as well as a large number of female Benedictine monasteries.<sup>2</sup> Beneventan script *scriptura Beneventana* was a Medieval Latin script that developed from the ancient Roman cursive minuscule first developed towards the middle of the eighth century. It was mostly used in south Italy, where it originated in the Benedictine monastery of Monte Cassino. Also, it was used in Dalmatia (especially in the scriptorium of the Benedictine Abbey of St. Chrisogonus in Zadar). It was practiced until at least the middle of the sixteenth century. The Corps of Beneventan Dubrovnik Manuscripts and Fragments is the only corps in Dalmatia with the items written in Beneventan script in the period from the 11<sup>th</sup> to the 15<sup>th</sup> century. The Franciscan Monastery of the Order of the Friars Minor and the Dominican Monastery of St. Dominicans in Dubrovnik are the richest sources of fragments dating from the 11th and 12th centuries. Similarities between the fragments point, however, to the common origin of the fragments.<sup>3</sup> The Dubrovnik Fragment Group constitutes a homogeneous group of beneventane-type wraps, among other things, of the same form of unusual abrasions.<sup>4</sup> A number of 12th-century fragments are also preserved by the Dubrovnik State Archiv. Dubrovnik Research Library preserves the oldest fragment of Manuscripts, dating from the 10th/11th centuries, also the oldest manuscript in the Manuscript Collection and Library Collection, originating from the Benedictine monastery of St. Mary on the island of Mljet (Caput IV. *De serpentibus*; Caput V. *De vermibus*). The preserved fragment of the manuscript was bound by the incunabula *Summa aurea de virtutibus et vitiis* by

Gulielmus Paraldus (Brescia,1494) - Incunabulum 68. The fragment is a part of the Encyclopedia in twenty books *The Origin of Words or Etymology* by Isidore of Seville, a section dealing with zoology. From the Manuscripts Collection of the Library that are culturally protected goods by the Croatian government, containing 959 manuscripts, we extracted the oldest corp for the multi-spectral imaging - fragments of manuscripts written in the Dalmatian Beneventan script (*scriptura Beneventana* or *littera Beneventana*). Those fragments were preserved because they were used as the covers or spine of incunabulas or were inside the incunabulas as well as in the 16th century books.

#### 3. 1. Benedictine scriptorium in Dubrovnik area

The name of the script as Beneventan was proposed by the paleographer Elias Every Loew<sup>5</sup>. The Beneventan script was more closely modeled in the second half of the 8th century in the *scriptorium* of the Benedictine Abbey of Monte Cassino. From Beneventan script developed Dalmatian Beneventan script. The historical context of the transfer of *beneventana* as a letter in the Dalmatian area is unknown.<sup>6</sup> It is difficult to date the *beneventana* for the large number of rules that the scribe had to obey, and also for the Dalmatian scripts developed distinctive lines in the writing. The genetic development of the *beneventana* in Dalmatia had continuity. The Dubrovnik Beneventan Corps has its own specifics that indicate the existence of *scriptorium* or perhaps that scribes transcribed scripts in their rooms. It is interesting that the numerous portrayals of a scribe depict a monk (or some saint who writes) most often alone in his room, not in large scriptorium.<sup>7</sup> According to Rozana Vojvoda, there was a scriptorium in the oldest Benedictine Abbey of St. Mary on Lokrum Island. According to Miho Demović, there were several Dubrovnik medieval *scriptoria*: *The scribe possessed such a perfect letter-shaping skill that it would appear as if the manuscript was printed rather than written in one of Dubrovnik's medieval scripts.*<sup>8</sup> E. A. Loew was the first one to associate this valuable Missal in Beneventan script with Dubrovnik as its place of origin, dating it to the 13th century.

### 4. DOCUMENTATION IN THE CONSERVATION-RESTORATION

Multi-spectral imaging can also be used for digitalization, giving it an edge over classic digitalization as it reveals to us the unprecedented possibilities that we can discover in one document. But certainly a more useful application of multi-spectral imaging would be in research work in documenting cultural property before, during, and after conservation and restoration process, multi-spectral imaging can play a key role in such and similar researches, that will provide reliable knowledge that enables the advancement of cultural heritage revealing its importance and entirety. Documentation in the conservation and restoration profession has been an important factor since the beginning of the profession. Conservation development has brought with it large amounts of data on cultural property, this information is now gathered, organized and digitally archived. Today, documentation plays a vital role in defining cultural objects, sites of significance, integrity,

<sup>2</sup> (Ostojić, 2010, p. 114)

<sup>3</sup> (Vojvoda, 2011, p. 105)

<sup>4</sup> (Vojvoda, p. 121)

<sup>5</sup> (Loew, 1914, p. 13)

<sup>6</sup> (Vojvoda, p. 121)

<sup>7</sup> (Stipčević, 2006, p. 181)

<sup>8</sup> (Demović, 2011, p. 19)

scope, and threats, and is crucial for understanding, protection and management. Working on cultural monuments where unique (usually complex) items are concerned, there is a certain challenge and something unpredictable. In order to minimize unpredictable surprises, and do a superb job, a conservator-restorer must produce detail, high-quality, logical documentation. *Documentation could perhaps most easily be defined as the systematic and complete recording (both written and photographic) of all relevant information on the cultural property, which includes recording the current status of the cultural good, as well as the records during the conservation and restoration works and the state of the good after the works have been completed.*<sup>9</sup> The purpose of photographic documentation may be to: illustrate the extent and location of damage and / or decay; show details of new or old information contained in the facility; to indicate the size of the whole object or the normal location of the object; show how it is treated during conservation work; show the coloration of certain parts of the object or the whole object; and, among other things, to illustrate analytical or technical work or results. By applying spectral imaging we obtain a more complete and accurate representation of the cultural property. We obtain information useful for determining current and future criteria for preservation. *Information can take the form of creating very accurate and standard color images. Imaging also allows us to see the invisible and distinguish indistinguishably. Spectral imaging can distinguish materials of different spectral signatures - mainly materials of different chemical compositions - that may differ from the image obtained in the resulting image.*<sup>10</sup> Highly accurate color standard images are extremely high resolution and give us a detailed view of the state of the cultural property, an insight into the current state of view; therefore, the spectral imaging used for documentation is also used as research equipment.

WHY IS DIAGNOSTIC RESEARCH NECESSARY? Investigation works should detect the cause of the damage and concisely define the reasons why the object in need of conservation and restoration treatment. In conservation and restoration research, the following information should also be defined: materials and design techniques, changes that have occurred over time, causes of damage, intentions, values, the entirety of the artefact on which all activities must be coordinated, the context of the artefact and the reconstructed history of the artefact.<sup>11</sup> The above mentioned data can be obtained during spectral imaging. The information obtained is valuable for determining: origin, date, authenticity and used materials. Further on next subjects will be processed: USE OF MULTI SPECTRAL IMAGING IN DIAGNOSTIC RESEARCH OF DALMATIAN BENEVENTANA ABOUT THEIR: Materials and manufacturing techniques, Changes that have occurred over time (including additions), Causes of degradation: to illustrate the extent and location of damage and / or deterioration.

## 5. DIAGNOSTIC RESEARCH ON MATERIALS AND MANUFACTURING TECHNIQUES

### 5. 1. Visual analysis

Multi-spectral imaging is very helpful in visual analysis of paper and parchment. For example, with paper through the use

of a translucent light, it can be seen whether it is handmade or factory-made, does it have a watermark, or filigree that is an identification display, pattern, or sign in the paper that gives us information about the time and place of origin of the paper. When watermarks are present on a paper, it is possible to roughly date documents, books and art on paper.



Figure 2 Difference between handmade paper vs. factory-made paper- left/right  
Figure 3 Watermark found in manuscript vs. found on line

In visual analysis of parchment and leather, when magnifying the images obtained by spectral imaging, it is possible to identify the type of parchment and see if the parchment has a mark (holes). Studying details such as follicle patterns, skeletal marks, and scar tissue, opacity and color variations can tell a lot about the animal's type and skin condition. By observing patterns of hair holes, it is possible to determine the type of animal from which the parchment is made. After spectral imaging, the resulting image can be enlarged to see the arrangement of the follicles and determine the type of parchment. The ultra violet light often helps to make these features even more visible. Ultraviolet light often shows the fluorescence of natural fats in the skin, as well as other process substances. Holes on parchment can also be made intentionally as a unique mark of a parchment maker. In our cases, no parchment marks (holes) were visible.



Figure 4 Sg. CR- 20.799 identification of the type of parchment - used goat skin

### 5. 2. Condition and rating

Another use of multi spectral imaging is to determine the condition and rating of an artifact. Insights into the footage can determine the wear of a shape that affects the integrity of the structure. By spectral imaging and additional analysis, we can obtain an estimate of the conservation state, record the condition or specific property of the object surface at a given moment.



Figure 5  
Fragment condition  
assessment: relatively good  
condition

## 6. THE CHANGES OCCURED

Understanding the relative chronology involves identifying the stages when the changes are made, it is visible as differences in the recordings. In order to fully understand the information obtained, it is necessary to understand the *rules* on which they are based. Their understanding also avoids errors in the work with cultural property that could lead to erroneous results during scientific research, so it is necessary to define the whole subject on which all activities must be coordinated.

<sup>9</sup> (Braun, 2006, p. 2)

<sup>10</sup>(Boydston)

<sup>11</sup> (Vokić, *Preventivno konzerviranje slika, polikromiranog drva i mješovitih zbirki*, 2007, p. 123-139)





Figure 6 Sg. A -1006 visibility of changes on fragment occurred over time

**6. 1. Showing the coloring of certain parts of the object vs. the whole object**

Multi spectral imaging can distinguish colors that are visually similar in appearance. For this purpose, a database of inks and pigments, used on paper and parchment could be developed to identify them. MSI overcomes the disadvantages of RGB, and allows for better distinction between inks. By identifying the ink and according to a historical overview of the use of individual inks, it is possible to approximately date the cultural property. UVR is used to distinguish apparently the same colors (inks, ballpoint pens, watercolors, tempera, oil colors ...) that look the same in visible light, and will not look the same on a UV image. In this sense, UVR is a complementary method to IRR. Infra red penetrates deeper into the layers and reveals a sub-image and a signature on the paintings and drawings



Figure 7 Ink differences - image taken in visible light and IR

**6. 2. Previous interventions - professional vs. non-professional**

Different materials fluoresce differently. MSI is an excellent method of defining subsequent additions on paper and parchment. Traces of different material on the recorded surface can be seen, and materials that reflect UV light differently from their surroundings. The use of MSI due to the different chemical composition of the paper in the photo shows the patches in the paper that cannot be seen by human eye.



Figure 8 Image in visible light and IR - readability under a layer of paper glued to the surface of the parchment – Sg. A – 478 Figure 9 Visible light parchment vs. UV parchment (UV recording - visible patches on paper and damage to newer dates - light coloured parts)

**6. 3. Find lost texts**

Paper and parchment through history have been expensive and rare materials and have often been used repeatedly. The parchment was scraped and reused-known as the palimpsest, and paper often shows corrections and inscriptions of recent dates that are different from the original ones. Spectral imaging makes it possible to distinguish between letters and other evidence of use based on subtle traces such as corrosion of parchment where there used to be ink and the spectral signature of ink stains that cannot be distinguished by the human eye. At very high resolutions it is possible to see the difference in thickness where the ink on the parchment was located or the corrosion of the parchment where the acid ink used to be, even if the ink itself was completely erased. This ability opens

significant new opportunities for recovering text from palimpsests.<sup>12</sup>



Figure 10 Fragment from incunabula, above-image under visible light, below - taken under UV, IR and visible light, and images processed and obtained result is readability of lost text

**6. 4. Show details of new or old information contained in the case**

Images obtained can be used as an excellent technique in showing details on paper and parchment. Images allow us to magnify it to the smallest detail and thus facilitate exploratory work.



Figure 11 Enlarged detail of fragment from book CR - 206 photos on the right - visible residual fibres of parchment paper (visible light and UV)

**7. CAUSES OF DEGRADATIONS**

Multi spectral imaging can be used to illustrate the extent and location of damage and / or deterioration, and to identify defects such as stains, tears, abrasions, deformation on paper and parchment. By identifying damage, the selection of materials and techniques during conservation and restoration operations is simplified. Further on, images and identification of the most common degradation on paper and parchment are presented.

**7. 1. Stains from solid particles** (deposited from the air such as dust, soot, smoke deposits ...). Stains that accumulate on the surface of the paper after a while can create permanent stains that enter the paper structure.<sup>13</sup> These stains are easily recognizable because they are on the surface and on the edges of the object and are usually easily removed with a soft brush or eraser.

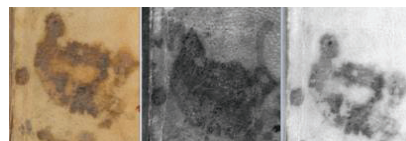


Figure 12 Enlarged detail of stains from solid particles (visible light and UV light 365nm and IR slight 940nm)

<sup>12</sup> (Hanneken, 2016)  
<sup>13</sup> (Vokić, 2008, p. 13)

7. 2. **Grease stains** can be recognized for their amorphous brown colour and blurred edges. They are usually round in shape and are visible from the face and back of the paper because they penetrate the paper structure. They are harder to remove and one of the bleaching methods or one of the solvent use methods is used to remove them.

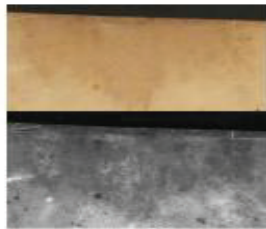
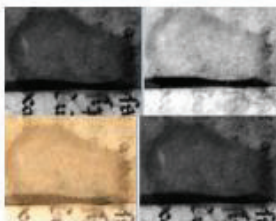


Figure 13 Detail of grease stain (visible light and UV)

7. 3. **Water stains** are also easy to spot. They are typically irregular in shape and have clearly defined edges that are darker in color, usually brown or yellow<sup>14</sup>. They are best removed by wet treatments, washing.

Figure 14 Enlarged detail water stains (visible light IR and UV)



7. 4. **Foxing** is manifested as small brown spots visible on paper at irregular intervals. Its appearance has not been fully understood, the appearance is linked with a high RH and contact of paper with glass. One of the bleaching methods should be used to remove foxing.<sup>15</sup>



Figure 15 Enlarged detail of foxing (visible light and UV)

7. 5. **Stains from oxidation** are manifested as dark yellow color of paper or parchment.<sup>16</sup> Usually, the stain extends over the entire surface. It is created by a process of oxidation, the loss of electrons from the paper molecules, and causes brittleness. The lignin contained in the papers is acidic and susceptible to oxidation and is the main cause of the yellowing of the paper. These stains are not soluble and cannot be dispersed, and can be mitigated by any of the cleaning and bleaching methods.

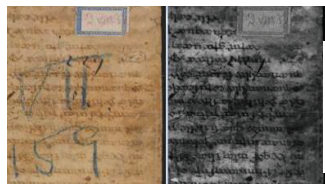


Figure 16 Detail of stains from oxidation (visible light and UV)

7. 6. **Stains from micro-organisms** (stains from bacteria, moulds, fungi, algae, mosses, lichens and insects) these stains are usually being found at the site of the micro-organisms themselves. Stains can be in a wide range of colours depending on the pigmentation of the microorganisms.<sup>17</sup> No stains were found during imaging.

7. 7. **Missing parts** can be caused by chemical and / or physical action. Missing parts include pieces of paper carrier or parchment that have been lost. They can be produced chemically, biologically and mechanically.

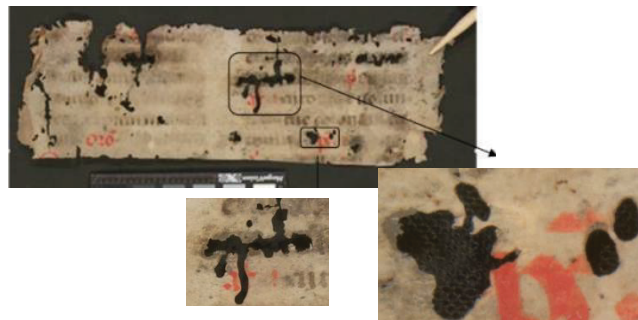


Figure 16 Enlarged detail of Fragment from the Ink. 61 with details of defects caused by the action of insects (visible light and UV)

7. 8. **Bends and deformations.** The paper is hygroscopic, and the parchment is a highly hygroscopic material, so it absorbs moisture from the air, resulting in its expansion or reduction. If they are in a place where oscillations in temperature and relative humidity take place, deformations can occur.

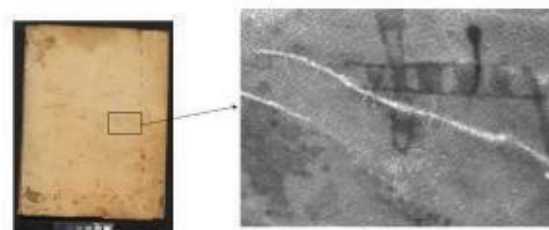


Figure 17 Detail of bend visible in UV light

7. 9. **Abrasion** is a mechanical damage to the surface of the paper or parchment. Physical damage is seen as a minor or greater loss of fibres from the surface of the paper or the surface of the parchment.

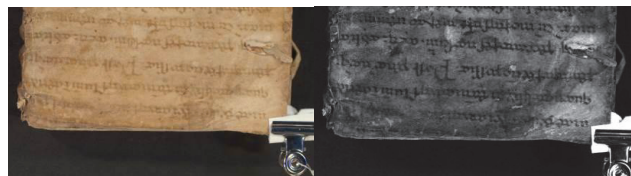


Figure 18 The lower part of the front cover of Sg. CR - 20.911 showing abrasion under visible light and UV light in the highlighted area

<sup>14</sup> (Laszlo & Dragojević, 2010, p. 56 )

<sup>15</sup> (Laszlo & Dragojević, 2010, p. 50)

<sup>16</sup> (Laszlo & Dragojević, 2010, p. 56)

<sup>17</sup> (Laszlo & Dragojević, 2010, p. 50)

## 8. CONCLUSION

Documentation is an invaluable part of the history of a cultural property and should be produced and stored in a manner that ensures maximum durability. MSI is an excellent method of defining subsequent additions on paper and parchment. Traces of different material on the recorded surface can be seen, and materials that reflect UV light differently from their surroundings. The use of MSI due to the different chemical composition of the paper in the photo shows the patches in the paper that cannot be seen by human eye. MSI can be used to assist in the selection of conservation and restoration interventions according to the best results in terms of: physical, chemical, aesthetic and historical uses and, among other things, to illustrate analytical, technical work or results. Using MSI, we learned about the relative age of individual items, identified the materials of manufacture, recorded the dimensions of the items, established the number of layers, gained insight into the structure, identified irregularities on the items, and identified the causes of degradation of individual items. There is no scientific findings yet that involves questions of the origins of Beneventan script and its development in the Dubrovnik area. Tracing historical data on the fragments of the manuscripts is possible by using investigation works in documentation and preservation to reevaluate historical findings.

Results of paleographical analyses (Brown, Vojvoda) of the preserved manuscripts and fragments written in Beneventan script that belong to the Dubrovnik's corps from the late eleventh to thirteenth century has shown that they belong to the homogenous group and probably come from the same scriptorium, library - it could be the first founded Benedictine monastery at the island of Lokrum from 11th century. As Vojvoda mentioned, one document called *Lokrum's forgeries* assumes that there was a scriptorium in the monastery. The document was transcribed in the monastery at the late twelfth century under the donation of the ruler of Zahumlje. The document resembles the scripts preserved in the Library, Franciscan and Dominican monasteries in Dubrovnik. Two manuscripts from the thirteenth century, *Missale Ragusinum* and *Labellus of St. Nicholas*, shows a hagiographical evidence that they were created in Dubrovnik. Using MSI technology, we shed light on historical concerns through forensic methods. Multispectral imaging is an excellent tool that can be used for future research works on the whole Dubrovnik's Corp of the Manuscripts and Fragments written in Beneventan script with the main objective of finding new information and hopefully shed light on the question about the existence of a scriptorium in the oldest Benedictine abbey of St. Mary on the island of Lokrum.

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