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### Revealing the invisible and inaudible in UCL Special Collections

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A black and white photograph of a hand reaching out to touch a transparent, buttoned garment (possibly a lab coat or protective suit) displayed inside a glass case. The image is layered with semi-transparent black rectangles that serve as a background for the text.

# Picturing the Invisible

Exploring interdisciplinary  
synergies from the arts  
and the sciences

Edited by  
Paul Coldwell and Ruth M. Morgan

 **UCLPRESS**

# Picturing the Invisible



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 **UCL**PRESS

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## Revealing the invisible and inaudible in UCL Special Collections

Adam Gibson, Tabitha Tuckett, Katy Makin,  
Cerys Jones, Jieran Sun and Melissa Terras

### Introduction

Rare books, manuscripts and archives housed in libraries and institutions are often perceived as invisible to all but a privileged few. Whether this perception is accurate or not, it has begun to be challenged over the last few decades by the powerful combination of digital photography and the internet, which together enable images of some of the most fragile and carefully preserved material to be easily viewed and disseminated. However, the increased visibility of collections is now balanced by a range of advanced imaging techniques addressing what has so far remained invisible in standard digitisation and to the naked eye. This chapter surveys some of these techniques, and how we have used them to attempt to picture otherwise invisible text and materiality in medieval manuscripts and early printed books.

Many libraries and archives now routinely digitise as much of their special collections as resources permit, and copyright and data restrictions allow. One of the reasons they do this is to improve access for readers, who indeed often expect historic material to be accessible digitally. Digitisation allows researchers to access collections without the need to travel, it facilitates linking data so that objects in different collections may be studied together, it offers access for less well-funded researchers, and it can open up collections to new opportunities for outreach and crowdsourcing, including through social media (Terras 2015, 63). Most major collections in the UK now have well-developed digitisation

strategies and programmes that are addressing the complex issues of copyright, ownership, metadata, storage, access, increased visitor numbers (resulting from increased online presence) and the impact of photography on the physical originals.

However, advanced imaging and computational techniques that use scientific approaches to reveal further details about objects and artefacts not visible to the naked eye and come under activities now known as heritage science, are not yet routinely deployed in this sector, despite these approaches being able to recover otherwise illegible text, detect underwriting or inform conservation practices. This is partly due to limited access to expertise and the high cost: they often require expensive equipment and intensive image processing. It may perhaps also be due to an assumption that the appeal of imaging special collections lies only in transmitting text rather than examining its materiality – an assumption that pervades our language across digital contexts, where we describe the written word and its referent as ‘content’, ‘information’ and ‘data’ rather than using the range of language associated with physical books or manuscripts.

The slow adoption of advanced imaging in heritage science is also partly because it is relatively unusual to have the opportunity to carry out sustained, joint approaches to imaging library and archive materials, involving colleagues both from special collections and the growing field of heritage science. Advanced imaging is usually undertaken as part of a multidisciplinary team of imaging scientists and computer scientists, librarians, curators and conservators, and historians and other humanities scholars (Dillon et al. 2014). The expense, time and broad range of skills required means that it is frequently outside the scope of most libraries and archives.

In this chapter, we describe such a collaboration that brought together imaging scientists based in the UCL Digitisation Suite with staff from UCL Special Collections. The UCL Digitisation Suite is co-located with UCL Special Collections, allowing the close working relationship to develop that is necessary for such projects. The Suite is supported by both UCL Faculty of Engineering and UCL Faculty of Arts and Humanities as well as UCL Library Services, and aims to provide a space in which people can learn, research and experiment with digitisation and heritage science technologies.

A range of non-invasive digital-imaging investigations was undertaken on materials held in UCL Special Collections. We demonstrate that the use of non-invasive imaging methods such as multispectral imaging and reflectance transformation imaging can provide further

information that can help in identifying and understanding library and archive objects, and enhancing catalogue information and description, ultimately helping in discovery and research. However, there remain issues about resourcing, retention of data and information and informed interpretation of results, that need to be addressed before this type of digitisation becomes more commonplace in special collections.

## Introduction to the collections

UCL Special Collections<sup>1</sup> is part of UCL Library Services and is one of the foremost university collections of manuscripts, archives and rare books in the UK. It holds extensive collections of medieval manuscripts and early printed books, as well as significant holdings of eighteenth-century works, and highly important nineteenth- and twentieth-century collections of personal papers, archival material, books on the history of science and literature, notably Jewish collections and the George Orwell Archive.

Some of the items described in this chapter form part of an extremely varied collection of around 150 fragments of medieval and early modern manuscripts in a variety of languages, predominantly Latin. They are primarily leaves from Christian liturgical texts such as missals, breviaries, psalters, bibles, antiphonals and graduals, but there are also several fragments from popular medieval textbooks such as the *Codex Justinianus* (a legal text originally put together in the sixth century CE, but translated and transformed many times during the medieval period). The early provenance of the UCL fragments is obscure, but most appear to have been removed from the bindings of other manuscripts or early printed books, where they had generally been used as pastedowns or outer coverings. This method of recycling was increasingly common from the late fifteenth century onwards where manuscript copies on parchment of texts that were no longer used were recycled as decorative covers and endpapers or to reinforce the binding of new printed works. The origins of some items in this collection can be traced to Germany, particularly the music fragments, which have distinctive German or Bohemian musical notation. A small number of texts, such as fragments of works by Justinian, are clearly Italian in their script and decoration, and they may have originated in Bologna, where the university was a centre of legal studies in the medieval period.

Some of the fragments were purchased by Professor Robert Priebsch (Professor of German at University College London, 1898–1931) at a sale

in Bonn in the early 1920s in order to give his students practical experience of medieval palaeography. It is not known precisely how many he purchased, but surviving records indicate that this number is likely to be small and therefore does not account for the whole collection that has since been accrued.

The rare books in this study indicate the wide range of provenance of UCL's historic collections. Although founded in the early nineteenth century, the College's library has acquired significant earlier holdings. One of the books discussed below belongs to the library of Charles Kay Ogden, and was acquired in 1953 with funding from the Nuffield Foundation.<sup>2</sup> Ogden, who founded the Basic English movement, collected medieval, early modern and later books and manuscripts related to writing, language, communication, cryptography, written signatures, annotations, palimpsests and what he described as 'word magic' (Ogden 1937, 234). He was interested in the marks people make on the page and how we interact with books physically. The example below is typical, and one of a number of books in the Ogden Collection that may have been formerly owned by Ben Jonson. Another book used in our project comes from the rich historical collections of the Hertfordshire Natural History Society, whose rare botanical books were deposited with UCL in 1935. We invited the Royal College of Physicians to contribute the third printed book in this project from their historic collections.<sup>3</sup> Their rare books include a number formerly owned by the sixteenth-century mathematician and astrologer John Dee, one of which was imaged as part of this work.

## Multispectral imaging

For the work described in this chapter, we used two different methods of imaging to reveal the invisible, which highlight some of the various advanced imaging methods that have been applied to books and manuscripts. For example, we have previously used eight different imaging methods in an attempt to read writing in the papyrus that constitute Egyptian mummy cartonnage and masks, and all of these methods have also been applied to documents and manuscripts (Gibson et al. 2018). Here, we concentrate on two methods: multispectral imaging (MSI) and reflectance transformation imaging (RTI). We outline the techniques here and then describe their application to a range of documents and manuscripts later in the chapter.

The human eye is an extraordinarily effective system for detecting light. There are three different light sensitive cells in the retina, which can

detect wavelengths of light between about 400 nm, which are seen as blue, and about 700 nm, which are perceived as red. As there are only three different detector cells, much of the processing that allows different colours to be distinguished occurs in the brain. By dilating or contracting the pupil, it is possible to see in bright light and faint light. Indeed, when the eye is dark adapted, we can see in conditions that can be 10 billion times darker than full sunshine. In humans, two eyes are arranged to give overlapping views that give some sense of depth perception. In comparison, a standard digital camera has a detector that is based on silicon and is sensitive to a wider range of wavelengths than the eye, allowing sensitivity to the ultraviolet (to about 350 nm) and the near infrared (about 950 nm). Such a camera usually has a filter that excludes near infrared light, so that its spectral response is matched to that of the eye.

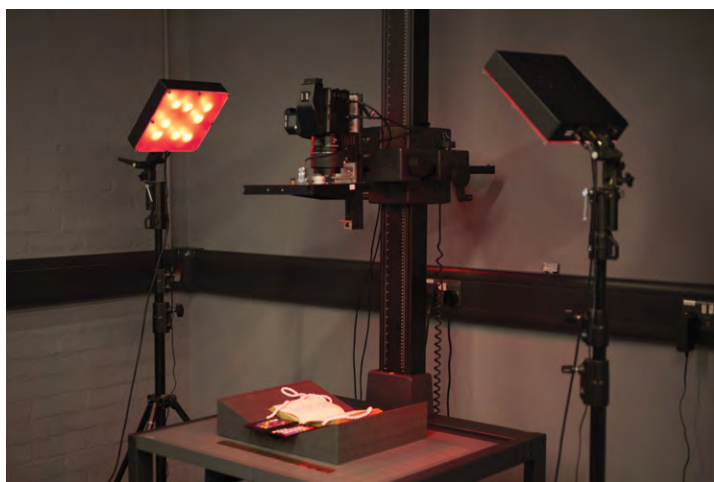
In multispectral imaging, it is possible to exploit the increased spectral range, excellent spatial resolution and controllable lighting conditions that are available with a digital photography system to produce images that show features that are invisible to the naked eye (Liang 2012, 309–11). The increased spectral range allows the visualisation of features under ultraviolet and near infrared illumination. A particular advantage of this is that the longer infrared wavelengths tend to penetrate a medium such as paper or parchment deeper than shorter wavelengths. These advantages allow the detection of specific pigments with increased clarity, and also allow us to see through the outer surface and expose under-drawings or writing that has been overwritten. The excellent spatial resolution allows fine detail to be seen, but perhaps more important is the ability to control the illumination. In particular, if we illuminate in a certain wavelength but then use a filter to prevent that wavelength from being detected by the camera, it is possible to detect fluorescence. Fluorescence occurs when an object is illuminated by short-wavelength light (typically ultraviolet or blue) and then re-emits the light as a different colour (often blue or green). Under certain conditions, fluorescence can be seen by eye, for example, when white clothing glows in a night club.

Multispectral imaging is now widely used to image heritage objects following initial success of imaging the Dead Sea Scrolls (Bearman and Spiro 1996), artworks (Casini et al. 1999) and the Archimedes Palimpsest (Easton et al. 2003). For example, MSI can be used for condition monitoring (Marengo et al. 2011), to detect traces of ink and distinguish between different pigments (Cosentino 2014), and highlight faded text (Giacometti et al. 2017). Two general approaches are taken. One is to

illuminate with white light and use the camera to distinguish between the wavelengths, perhaps using wavelength filters or some other method to split the white light into its colour components. The other method is to illuminate with different wavelengths ([Jones et al. 2020](#)). For example, the illumination used in this work generates light at 16 different wavelengths, giving better wavelength sensitivity compared to the three available in the eye. MSI is usually assumed to be safe for collection items as the illumination is approximately equivalent to that which an object would receive in a few days on display, although it is possible that the light levels could damage particularly light-sensitive pigments.

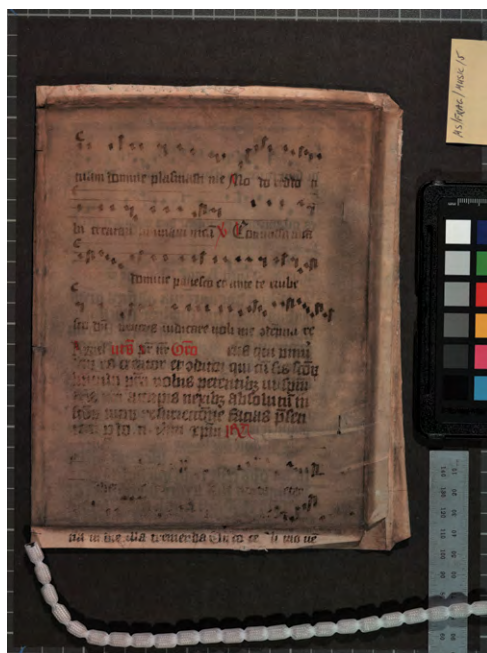
The system used in this work was provided by R. B. Toth Associates LLC (VA, USA) and is based around a PhaseOne 60 megapixel, 16-bit monochrome IQ260 digital back with a 120 mm apochromatic lens (PhaseOne, Denmark) and lighting and filter wheel provided by Equipoise Imaging LLC (MD, USA). The lighting consists of two panels, each able to illuminate at 12 wavelengths from 370 nm to 940 nm, and a filter wheel, which is able to insert a long-pass filter in front of the camera lens to exclude the illumination light (figure 2.1).

As an early test of the system, a fragment of a liturgical manuscript containing music (probably a noted missal) held by UCL Special Collections ([MS FRAG/MUSIC/5](#)) was imaged. It is believed to be from the thirteenth century and contains Catholic songs, prayers and chants



**Figure 2.1** The UCL Multispectral Imaging System, showing camera, filterwheel, lighting panels and copy stand.

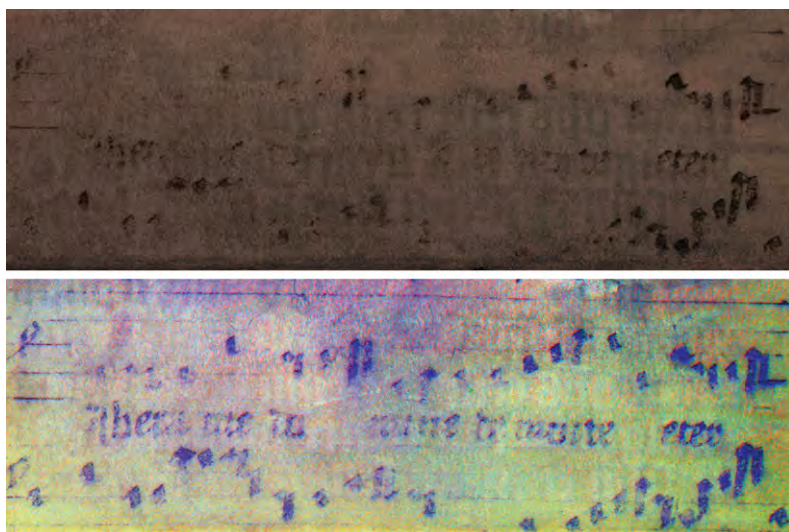
Credit: Adam Gibson.



**Figure 2.2** Music fragment [MS FRAG/MUSIC/5](#).

Credit: UCL Special Collections/Adam Gibson.

(figure 2.2). The musical notation at the bottom of the document is unclear and it was imaged using the multispectral imaging system in an attempt to provide clarification. Images were obtained using 12 wavelengths, some augmented with filters, to give 16 images in total. A set of images like this is difficult to view and analyse in a natural way, so some image processing is generally necessary to interpret them. Often, this is just a simple subtraction of one image from another but in this case, principal component analysis (PCA) was employed ([Tonazzini et al. 2019](#)). This method takes a series of data (in this case images, arranged by wavelength) and generates a new set of images with the same total information content, but restructured so that the first image contains as much information as possible and each subsequent image contains decreasing amounts of information (mathematically, they are uncorrelated, meaning that each subsequent image is independent of the others). PCA has a number of advantages: by maximising the information in a few images, it can allow the information to be compressed into fewer images; images with less information tend to contain more noise and can be rejected to suppress noise; and certain features sometimes appear



**Figure 2.3** Part of music fragment [MS FRAG/MUSIC/5](#) imaged under visible lights (top) and following principal component analysis to maximise the legibility of the musical notation (bottom).

Credit: UCL Special Collections/Adam Gibson.

more strongly in some of the images' output from the PCA analysis than they do in the original image set. In this particular case, we chose three PCA images that showed the musical notation most strongly and assigned them to the red, green and blue channels of a standard digital image. Figure 2.3 shows that the notation is more clearly visible in the false colour, processed image than in the original full colour image. The text can be read as '*Libera me, Domine, de morte æterna*', the opening of a responsory from the Office for the Dead.

## Reflectance transformation imaging

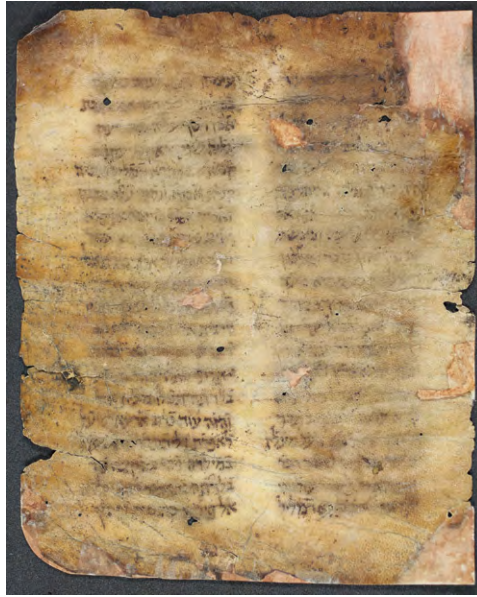
MSI can highlight changes due to different wavelengths of illumination but pays no attention to the surface shape of the object. Manuscripts and the printed page are often assumed to be flat, 2D objects with no surface structure and, indeed, it is sometimes assumed that the legibility of the writing is the only consideration. They are, however, real physical objects and their physicality is important. Concentrating on making the text visible may by implication make the physical structure invisible, and methods that recover both structure and legibility can enhance the

visibility of both. For example, the structure of paper or parchment is important to conservators and can be useful to curators and researchers for dating, provenance and general book history, as well as indicating what animal the parchment came from, how the paper was made, or how either was treated or coated, or ink or pigments applied. Folds and creases can reveal how the document was used, and any impressions in the surface of a printed page could give indications as to what printing technology was used.

Reflectance transformation imaging (also called polynomial texture mapping) is used to highlight surface texture in a document or other object (Malzbender et al. 2006). This technique, a type of computational photography, is now commonly used in heritage applications; for example, to image graffiti (DiBiasie Sammons 2018) and similar features (Earl et al. 2010). A camera is mounted in a fixed position and a number of photographs, typically around 50, are taken of the object with a flash being used to light it from different angles. Some researchers use a dome to hold the camera and flashes in fixed positions (MacDonald et al. 2018), but for maximum flexibility we use a camera on a copystand and a hand-held flash, along with various calibration targets. In raking light photography, photographs are taken with illumination from a position almost parallel to the surface. By taking many photographs at raking light angles and higher angles, and processing them, a virtual surface can be generated where every pixel shows the intensity of the reflected light and the angle of the surface. This is visualised in an interactive viewer, allowing the user to control a 'virtual light source' and explore the surface shape of the object. The spatial resolution of RTI is the same as that of each photograph, so with a high performance camera and lens, it is quite easy to relight individual letters, allowing extremely detailed analysis. The interactivity of the virtual light source can be attractive to an end-user as they can interact actively with the image rather than just viewing it passively.

## Revealing a Hebrew text

Our work on a Hebrew manuscript fragment gives a more detailed indication of what these techniques can achieve. This manuscript (MS FRAG/HEB/1) consists of two folios (i.e. two sheets, so four sides of writing) on parchment. The two folios are believed to come from the same manuscript. Some text on the first folio is legible and has been identified as coming from the Book of Genesis. It is arranged in two



**Figure 2.4** Part of [MS FRAG/HEB/1](#) illuminated under natural lighting, showing how faded the writing is to the eye.

Credit: UCL Special Collections/Jieran Sun.

columns, with each verse in Hebrew followed by an Aramaic translation. Much of Folio 2 is faded and blurred, so the aim of the work was to image the manuscript to see if it was possible to increase the contrast to reveal more detail and make the writing legible. The edges of the manuscripts are damaged and have been heavily restored, and there is some evidence of annotation by a Hebrew scribe (figure 2.4).

For [MS FRAG/HEB/1](#), because the aim was to enhance legibility, we chose to image with MSI. An upgraded multispectral imaging system was used that could illuminate at 16 wavelengths, which, with filters, gave a total of 23 photographs. Ultraviolet and blue wavelengths were found to give most contrast as the parchment fluoresced and so became brighter at shorter wavelengths while the ink did not. Indeed, simply viewing the unprocessed images acquired under shorter wavelengths appeared to give better contrast than viewing under room lights. Principal component analysis enhanced contrast further (figure 2.5), particularly when supported by more image processing such as inversion (converting black to white and vice versa), normalisation (increasing the intensity of the brightest pixel to maximum and decreasing that of the darkest pixel to



**Figure 2.5** Principal Component Analysis of *MS FRAG/HEB/1*, showing part of the sheet illuminated under room lighting (left) and the increased legibility offered by PCA (right).

Credit: UCL Special Collections/Jieran Sun and Cerys Jones.

minimum) and histogram equalisation (distributing the intensity values equally). These post-processing techniques can all improve apparent visual contrast but may need to be optimised for each individual case.

The improved contrast has allowed Vanessa Freedman, the Hebrew & Jewish Studies Subject Liaison Librarian at UCL, to read the text of the second folio, which she identified as Genesis 35: 11–17. It is arranged in the same way as the first folio, with each Hebrew verse followed by an Aramaic translation taken from a second century translation of the Torah known as *Targum Onkelos*. We are now confident that the two folios are indeed from the same manuscript but are not consecutive. Revealing this previously unknown connection will change the way that the two folios are stored and described in the catalogue.

This case study demonstrates how MSI, with the associated image processing, may enhance the contrast and enable a reader to decipher illegible text – and so picture the invisible – but it also illustrates the breadth of multidisciplinary skills required to embark on a study like this. It is necessary to assemble a team not only of imaging scientists and archivists, but also historians who can advise on the date and context of

the document, and scholars who can read and understand the language, in this case Hebrew and Aramaic. Each discipline brings a different lens of viewing and insight, which together can reveal that which was previously unknown or invisible.

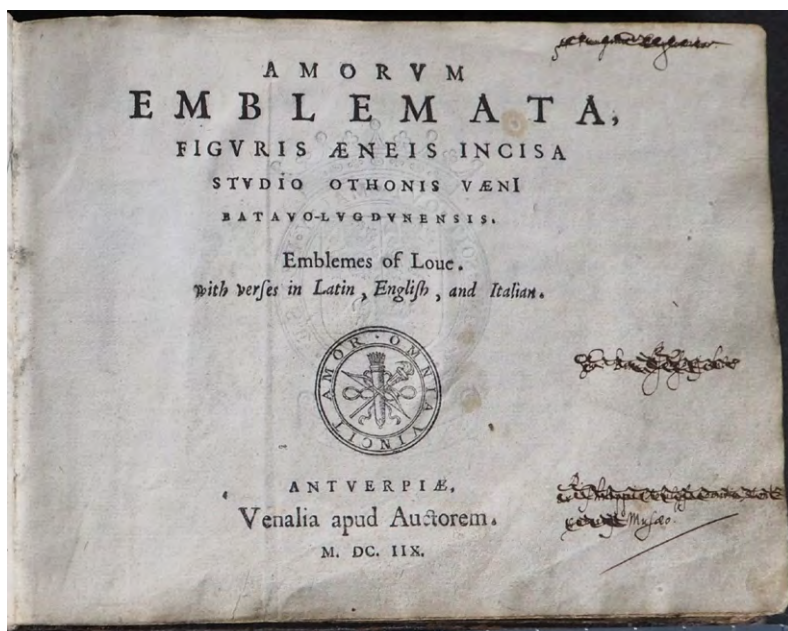
## Revealing writing that has been overwritten

Medieval and early modern scholars treated reading as an interactive process, annotating books with enthusiasm. It is not unusual to see a manuscript or an early printed book with numerous notes written in different hands. Indeed, books were often written or printed with a generous margin to facilitate this. Similarly, it was common for an owner to write inscriptions, which could be as simple as a signature or something more complex, to show ownership. As a book passed between owners, the new owner might overwrite or scribble over the previous owner's signature. This left a trace of the passage of ownership that now provides an important contemporary record of the use and history of a book (Jackson 2001).

It is possible to image overwritten signatures using multispectral imaging, and two representative samples are described here. First, a copy of Otto van Veen's *Amorum Emblemata*, a book of emblems (each consisting of image, quotation and verse) about love, printed in 1608, which is believed to have been owned by the Elizabethan and Jacobean playwright Ben Jonson. It has three areas on the title page where previous inscriptions have been overwritten (figure 2.6). One is believed to include Ben Jonson's name and the other two have not previously been deciphered. Second is a copy of a short treatise on parts of Pliny's *Naturalis Historia*, printed in 1548 and owned by the Royal College of Physicians (Ryff 1548). It has an inscription reading 'Nicolaus Saunderus' dated 1584, which is clearly written on top of a previous inscription that is now illegible.

Both books were imaged using multispectral imaging, with image processing carried out as described previously. Where possible, both sides of a sheet are imaged to identify any instances where text that is printed on the back side is visible from the front (as was the case in the music manuscript described in the introduction).

It was possible to recover the three areas of overwriting on *Amorum Emblemata*. The underwriting is still difficult to decipher, but given knowledge of the context, the first is believed to read '*tamquam explorator*', a quotation from Seneca meaning 'as an explorer' and written by



**Figure 2.6** A photograph of the title page of *Amorum Emblemata* (OGDEN A 292) showing three different overwritten inscriptions.

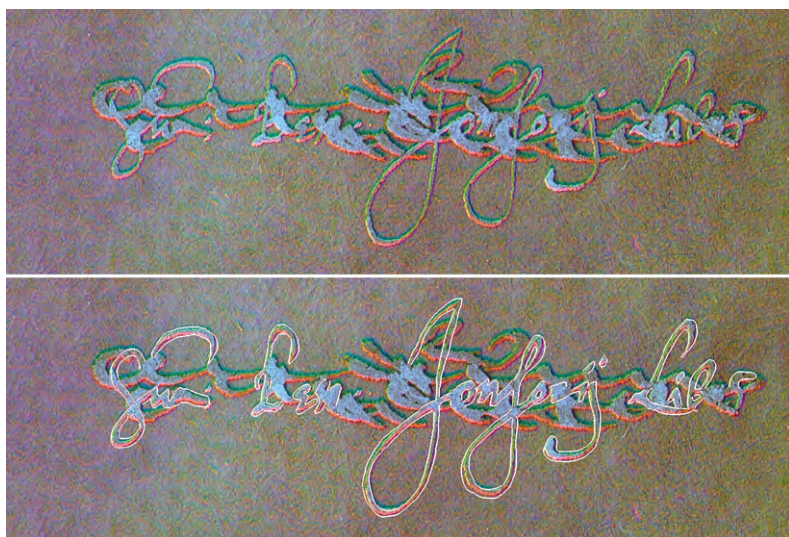
Credit UCL Special Collections/Cerys Jones.

Ben Jonson as a motto in several of his books to indicate his ownership. The second is likely to say ‘*Sum Ben Jonsonij Liber*’, or ‘I am Ben Jonson’s book’ (figure 2.7).

The third is more challenging, but with knowledge that the author’s dedication, printed on the following pages, is to Philip Herbert, Earl of Montgomery (1584–1650), and his older brother William Herbert, 3rd Earl of Pembroke (1580–1630),<sup>4</sup> both of whom provided patronage to Jonson in many ways (and that a manuscript inscription in an early modern hand has been added following the statement of dedication to read ‘& of thy noble vou[ch]sake’), it is possible to surmise that it says:

D.  
ex Philippi { . } o { . } i { . } iss { . } comitis Mont-  
gomerij Musaeo.

or ‘[Gift] from the library / study / collection<sup>5</sup> of Philip { . . . } Earl of Montgomery’ (figure 2.8). *Mont-gomerij* is split across two lines, and the



**Figure 2.7** Principal component analysis revealing inscription ‘*Sum Ben Jonsonij Liber*’ that has been overwritten (top), with underwriting highlighted by outlining it (below).

Credit: UCL Special Collections/Cerys Jones.



**Figure 2.8** Principal component analysis revealing inscription ‘*D. Ex Philippi Comitis Mont-Gomerij Musaeo*’ that has been overwritten (top), with underwriting highlighted by outlining it (below).

Credit: UCL Special Collections/Cerys Jones.

missing word may be ‘nobiliss.’ or a similar abbreviation for ‘nobilissimi’, giving ‘Philip, most noble Earl of Montgomery’. The improved visibility of the inscriptions suggests that all three are in the same hand. Matching this with known inscriptions by Ben Jonson, we are now more confident that the book was indeed owned by him and contains his motto as well as his name. We may also have revealed evidence that this copy was a gift to, or purchase for, Jonson from Philip of Montgomery (Jonson’s *Timber; or discoveries made upon men and matter*, published posthumously in 1641, notes that William’s patronage included £20 a year to buy books for Jonson). While the three inscriptions discussed here are crossed through (with the exception of the word ‘musæo’), the lines ‘the gyfte of one whose death I moane’ are copied repeatedly into the book elsewhere, in an early modern hand, and are not crossed through. Might these refer to the death of William, or later death of Jonson, or the even later death of Montgomery?

The undertext beneath ‘Nicolaus Saunderus’ on *Naturalis Historiae Commentarius* was also difficult to read after enhancement (figure 2.9), but after discussion with Katie Birkwood, Rare Books and Special Collections Librarian at the Royal College of Physicians, we believe the underwriting says ‘Joannes Dee 1562 Antwerpiae’. This supports the belief that the book was owned by John Dee (1527–1608/9), an Elizabethan and Jacobean scientist and astrologer. The Royal College of Physicians holds several books of his that bear his partially erased or overwritten signature, often overwritten by the name of Nicolas Saunder who obtained books from Dee, possibly by theft (Jones 2016). Imaging was able to support other evidence, including annotations in his hand



**Figure 2.9** Photograph of title page showing area where ‘Nicolaus Saunderus’ has been written over an earlier inscription (top) and principal component analysis that attempts to enhance the earlier inscription (below).

Credit: UCL Special Collections/Jieran Sun.

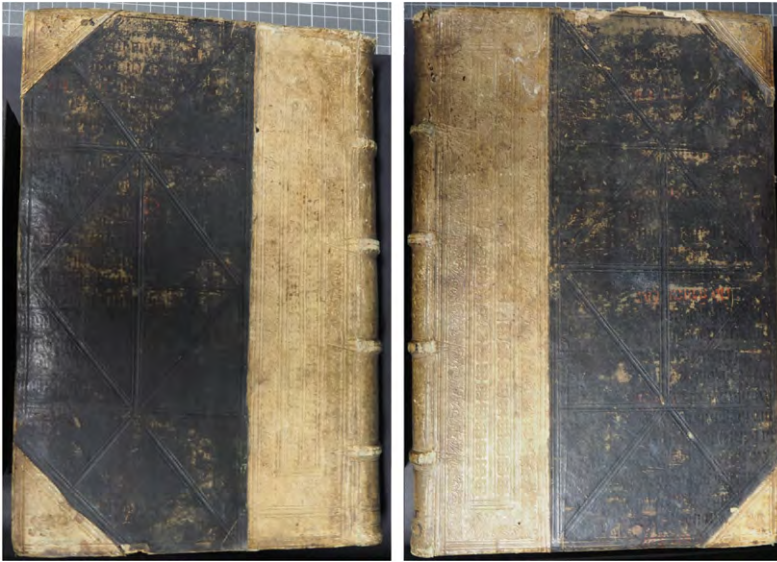
elsewhere in the book, that this copy of *Naturalis Historiae* was part of Dee's collection, either stolen or received by Saunder.

It is notable that the successful recovery of the underwriting on *Amorum Emblemata* and *Naturalis Historiae Commentarius* was not due to principal component analysis or even multispectral imaging per se. It was due to the excellent spatial resolution (32.5 pixels/mm) and the additional perceived contrast offered by false colour imaging. This, together with the relative lack of success of recovering the writing on other examples, is likely to be due to the ubiquitous use of iron gall ink. Iron gall ink, made from the galls of oak trees, was the most widely used ink in Europe for manuscripts from Roman times until the twentieth century. It darkens from light blue to brown-black over a few decades, but once darkened, the spectral signature of all types of iron gall ink is similar. We would not therefore expect the response of the under-writing to be significantly different from that of the ink used to obscure it, and, therefore, we would not expect multispectral imaging to be particularly successful at separating the undertext from the overtext.

## Imaging the binding of a book

*Exoticorum libri decem* (Clusius 1605) is a book compiled by the pioneering sixteenth-century botanist Carolus Clusius, including both his own works and new editions of other key works on natural history. It is an exhaustive description of animals and plants, illustrated throughout by woodcut prints. The full title is *Exoticorum libri decem: quibus animalium, plantarum, aromatum, aliorumque peregrinorum fructuum historiae describuntur*, or 'Ten books of exotica: giving accounts of animals, plants, spices and other fruits from distant lands'. The copy held by Special Collections is the first edition, printed in 1605, and has a contemporary half-binding of unstained vellum and stained re-used parchment over boards (figure 2.10). There is very faint evidence of writing on the binding and we used multispectral imaging to try to reveal more of the writing and determine what it says.

The standard imaging process described earlier was used with 17 images, followed by principal component analysis and some other image enhancement techniques. Unprocessed images offered some visible improvement in contrast, but not enough improvement that the writing became legible. Some of the principal components did significantly improve legibility and certainly uncovered more writing that was invisible to the eye. We generated false-colour images by selecting three principal

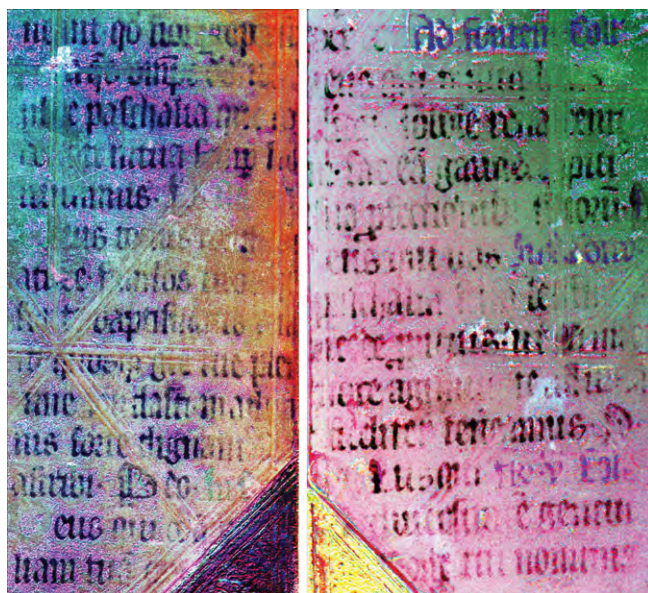


**Figure 2.10** A photograph showing the binding of *Exoticorum libri decem*, with a barely visible handwritten inscription.

Credit: UCL Special Collections/Cerys Jones.

component images and assigning them to the red, green and blue channels of a standard image and processed these further using a program called DStretch, which can increase colour contrast.<sup>6</sup> These did show more of the writing and had indications that some of the capitals were written in a different colour from the rest of the writing (figure 2.11). On both the front and back covers, we were able to detect a greater extent of writing than had previously been suspected, to identify the language as Latin, to identify the presence of different colour or ink and to begin to make out some letters and words (such as ‘*paschalia*’ at the top and ‘*Deus*’ at the bottom of the image on the left). However, to read, understand, date and identify the manuscript text will need a palaeographer who is familiar with writing of that period.

Even though we have so far been unable to read and identify the writing on the binding of the book, we have been able to determine that the book was bound in an earlier manuscript. This was suspected but as the writing is almost imperceptible to the eye, our confirmation is valuable. Revealing this previously unconfirmed history of the book has changed the way that it is handled and cared for. By growing our understanding of the history and provenance of the book, it is possible to



**Figure 2.11** Principal component analysis, allowing some of the inscription to be read, and showing that more than one ink is present.

Credit: UCL Special Collections/Cerys Jones.

identify opportunities for further research directions to reveal more of the (currently) ‘invisible’.

This example also further demonstrates the importance of bringing together a multidisciplinary team to tackle questions around these objects. In this case, librarians and archivists who understand the books and their context, imaging scientists who can create the clearest possible images of the writing, and classical, medieval or early modern scholars such as palaeographers and historians who can read and interpret the writing all had important roles to play. Even then, palaeography and history offer alternative contextual and interpretative insights, and pooling interpretations and discussing openly what each discipline enables us to see in the images has proved central to the work revealing more of the invisible.

## Imaging illuminations

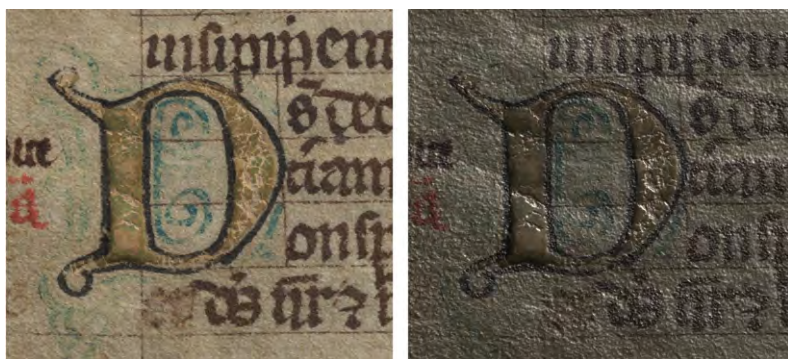
Illuminated letters were used in high-profile medieval manuscripts, especially religious texts. [MS FRAG/LAT/28](#) is a fourteenth-century

psalter, or psalm book, written on parchment. Only the bottom half of the leaf remains and includes parts of Psalms 48 and 49. It is believed to have been used for private devotional use and has faint marginal annotations. The text is in Latin, mainly in iron gall ink, with some letters in red to denote the start of a new line of the psalm. However, the most striking feature of the fragment is an illuminated initial 'D' in gold leaf, the height of three lines of text, with some faded ink decorations around it, indicating the start of the 49th Psalm. The gold leaf is extensively degraded, with the underlying parchment visible in places. It was about to be restored and we were asked to image it beforehand in the hope that imaging would help to guide the restoration process.

One might expect gold leaf to be bright and reflective. However, the lighting for the multispectral imaging system is arranged so that the manuscript is illuminated from a 45-degree angle, so that any direct, specular reflections would also occur at 45 degrees and therefore not be detected by the camera. Such reflections might be unusually bright, but would carry information about the wavelength of the illuminating lights rather than the material of the object itself. The gold leaf therefore appeared dark in the images, especially at shorter wavelengths where the parchment fluoresced and so appeared light. Other than providing high-resolution images, there was little additional information provided by multispectral imaging.

However, the flaking surface of the gold leaf offered some 3D surface structure, suitable for reflectance transformation imaging, so we carried out this imaging modality on the illuminated letter 'D' as well as multispectral imaging. The interactive viewer (RTIViewer, available from <http://culturalheritageimaging.org>) allows the virtual light source to be moved over the surface of the image, enabling the viewer to enhance the shadows and therefore the visualisation of the surface interactively. It also offers different viewing options, one of which is 'specular enhancement', which emphasises the areas that reflect light most strongly such as the gold (figure 2.12).

The images we obtained will be useful during the restoration process. We will train the conservators in the use of RTIViewer, so that they can interact with the RTI image themselves. The multispectral images gave excellent delineation of the edges of the remaining gold leaf flakes, mainly due to the fluorescence of the underlying parchment. The interactivity allowed by RTI enables the user to explore the surface structure of the gold leaf in detail, to gain an impression of the level of damage and an indication of how well the remaining gold flakes are adhered to the surface. We aim to repeat the imaging following the



**Figure 2.12** Reflectance transformation image of the gold illuminated letter ‘D’. This shows two snapshots taken from the interactive viewer, visualised using two of the standard options available in RTIViewer, ‘Default’ (left) and ‘specular enhancement’ (right).

Credit: UCL Special Collections/Jieran Sun.

conservation treatment so that we can compare multispectral and RTI images of the illuminated letter before and after restoration.

## Conclusion

In this chapter, two examples of advanced imaging methods applied to rare books and archival documents have been presented, together with a number of different case studies where these techniques have been used to image manuscripts and books. This work has revealed previously unknown attributes and insights, which have increased our knowledge of these objects and informed their curation, storage and interpretation. Most commonly, advanced imaging is used to examine iconic objects (e.g. [Bearman and Spiro 1996](#); [Easton et al. 2003](#); [Earl et al. 2010](#)), whereas here we use it to examine less high-profile items in a university’s historic collection, thereby gaining insights into new pieces and further revealing that which has been invisible.

However, it is clear that imaging in these cases has not been transformative. In most cases, it has confirmed information that already existed or added incrementally to existing information and understanding. This should not be surprising, as the time, effort and resources required to image items means that advanced imaging tends to be applied to items

that are already considered important and so have been previously studied.

The co-location of the Digitisation Suite with Special Collections at UCL has allowed a degree of experimentation that might be difficult to achieve otherwise. Working together in a university setting has meant that students have been able to carry out imaging, which means that costs are significantly reduced. Even so, access to advanced imaging is still limited, so choices need to be made about the allocation of resources. Sometimes, indeed often, imaging might not lead to new knowledge and it must be accepted that speculative studies will not always lead to successful outcomes and might be perceived by some, in this respect, as wasted effort. To maximise the likelihood of success, it is necessary to build relationships based on trust, and for imaging scientists, librarians and archivists to have detailed, open discussions about the imaging. In our experience, a multi-disciplinary collaboration such as this is only successful when both parties gain from the project and when both parties are willing to attempt to understand the whole of the challenge.

Reports on advanced imaging tend to emphasise new discoveries about the text of a document, but we have found that equally important is information that is of value to conservators. Imaging could be used to establish the condition of an item prior to conservation and provide a robust record of the effect of conservation. It can also guide the conservator, but again this needs close collaboration between imager and conservator.

Even when imaging does generate new and useful information, it is not straightforward to integrate it into standard library catalogues so that it can be found by users searching the system. Images, especially complex, multi-dimensional images such as those generated by MSI and RTI, cannot easily be stored, recovered, viewed and examined using standard library and archives software. This problem becomes even more intractable when the images are associated with complex metadata. This remains an unsolved problem, despite the development of some standard image interfaces such as IIIF.<sup>7</sup> This is not only a problem for advanced imaging, but also for more routine digitisation. We hope that any solution that is developed, which allows digitised images and updatable metadata to be integrated with their physical objects' updatable catalogue records, is sufficiently flexible to also allow more complex image types to be recorded. It is likely that the demand for systems for flexible archiving that can handle a wide range of potentially user-defined datatypes will increase, requiring a step increase in digital storage and presentation

requirements. Such a system should offer the user information not only about the history and content of a document, but also its materiality and physical attributes. As with the physical collection, building a rich collection of images of the physical is a way of building information whose relevance may only be identified and understood far in the future, or by researchers from very different disciplines. Because the visual, verbal and material amass to inform us about heritage objects, there is value in picturing the invisible even when we cannot read it.

We believe that advanced imaging can play a role in smaller museums and archives, by providing information about the history of an item, its curation and its cataloguing. However, the resource requirements are significant and the techniques must be used realistically. We suggest that if a library or archive was to have access to advanced imaging, the imaging would be deployed most effectively following discussion between the curator and imaging scientist, when the imaging is aimed at answering specific questions and when staff responsible for cataloguing are fully involved at an early stage.

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## Notes

- 1 <https://www.ucl.ac.uk/library/special-collections/>.
- 2 <https://www.ucl.ac.uk/library/special-collections/a-z/ogden-library>.
- 3 <https://www.rcplondon.ac.uk/education-practice/library/historical-research-materials>.
- 4 We are grateful to Lucie Grange-François, UCL BASc visiting student, for linking dedication and inscription as part of an undergraduate project.
- 5 Literally, 'place dedicated to the muses' and used in particular of the Hellenistic library and scholarly academy at Alexandria, but here most likely Anglicised Neo-Latin for 'museum' used in sense 2.a. ('collection') or 1.b. suggested in the *Oxford English Dictionary* (3rd edition 2003): 'a scholar's study', for which the dictionary's first quotation comes from letters published in 1645 by a former acquaintance of Jonson: 'To my honoured friend and fa. Mr. B. Johnson ... I thank you for the last *regalo* you gave me at your *Musæum*, and for the good company'.
- 6 Available from <https://www.dstretch.com>
- 7 <https://iiif.io/>.

## References

- Bearman, Gregory H. and Sheila I. Spiro. 1996. 'Archaeological applications of advanced imaging techniques', *Biblical Archaeologist* 59: 56–66.
- Casini, Andrea, Franco Lotti, Marcello Picollo, Lorenzo Stefani and Ezio Buzzegoli. 1999. 'Image spectroscopy mapping technique for noninvasive analysis of paintings', *Studies in Conservation* 44: 39–48.
- Cosentino, Antonino. 2014. 'Identification of pigments by multispectral imaging: A flowchart method', *Heritage Science* 2: 8.
- DiBiasie Sammons, Jacqueline F. 2018. 'Application of Reflectance Transformation Imaging (RTI) to the study of ancient graffiti from Herculaneum, Italy', *Journal of Archaeology Science: Reports* 17: 184–94.
- Dillon, Catherine, Nancy Bell, Kalliopi Fouseki, Pip Laurenson, Andrew Thompson and Matija Strlič. 2014. 'Mind the gap: Rigour and relevance in collaborative heritage science research', *Heritage Science* 2: 11.
- Earl, Graeme, Kirk Martinez and Tom Malzbender. 2010. 'Archaeological applications of polynomial texture mapping: Analysis, conservation and representation', *Journal of Archaeology Science* 37: 2040–50.
- Easton, Roger L., Keith T. Knox and William A. Christens-Barry. 2003. 'Multispectral imaging of the Archimedes palimpsest'. In: *32nd Applied Imagery Pattern Recognition Workshop, 2003. Proceedings*, 111–16. Washington DC: IEEE.
- Giacometti, Alejandro, Alberto Campagnolo, Lindsay MacDonald, Simon Mahony, Stuart Robson, Tim Weyrich, Melissa Terras and Adam Gibson. 2017. 'The value of critical destruction: Evaluating multispectral image processing methods for the analysis of primary historical texts', *Digital Scholarship in the Humanities* 32(1): 101–22.
- Gibson, Adam, Kathryn E. Piquette, Uwe Bergmann, William Christens-Barry, Graham Davis, Marco Endrizzi, Shuting Fan, Sina Farsiu, Anthony Fitzgerald, Jennifer Griffiths, Cerys Jones, Guorong Li, Phillip L. Manning, Charlotte Maughan Jones, Roberta Mazza, David Mills, Peter Modregger, Peter R. T. Munro, Alessandro Olivo, Alice Stevenson, Bindia Venugopal, Vincent Wallace, Roy A. Wogelius, Michael B. Toth and Melissa Terras. 2018. 'An assessment of multimodal imaging of subsurface text in mummy cartonnage using surrogate papyrus phantoms', *Heritage Science* 6: 7.
- Jackson, H. J. 2001. *Marginalia: Readers writing in books*. New Haven; London: Yale University Press.
- Jones, Cerys, Christina Duffy, Adam Gibson and Melissa Terras. 2020. 'Understanding multispectral imaging of cultural heritage: Determining best practice in MSI analysis of historical artefacts', *Journal of Cultural Heritage* 45: 339–50. <https://doi.org/10.1016/j.culher.2020.03.004>
- Jones, Roger. 2016. 'Exhibition: Scholar, courtier, magician: The lost library of John Dee: Master of divine secrets', *British Journal of General Practice* 66(647): 317.
- Liang, Haida. 2012. 'Advances in multispectral and hyperspectral imaging for archaeology and art conservation', *Applied Physics A* 106: 309–23.
- MacDonald, Lindsay W., Erica Nocerino, Stuart Robson and Mona Hess. 2018. '3D reconstruction in an illumination dome', *Electronic Visualisation and the Arts*: 18–25.
- Malzbender, Tom, Bennett Wilburn, Dan Gelb and Bill Ambrisco. 2006. 'Surface enhancement using real-time photometric stereo and reflectance transformation', *17th Eurographics Symposium on Rendering Techniques*: 245–50.
- Marengo, Emilio, Marcello Manfredi, Orfeo Zerbinati, Elisa Robotti, Eleonora Mazzucco, Fabio Gosetti, Greg Bearman, Fenella France and Pnina Shor. 2011. 'Technique based on LED multispectral imaging and multivariate analysis for monitoring the conservation state of the Dead Sea Scrolls', *Analytical Chemistry* 83: 6609–18.
- Ogden, Charles. 1937. *Basic English and Grammatical Reform*. Cambridge: Orthological Institute.
- Terras, Melissa. 2015. 'Cultural heritage information: Artefacts and digitization technologies'. In: *Cultural Heritage Information*, edited by G. Chowdhury and Ian Ruthven, 63–88. London: Facet.
- Tonazzini, Anna, Emanuele Salerno, Zienab A. Abdel-Salam, Mohamed Abdel Harith, Luciano Marras, Asia Botto, Beatrice Campanella, Stefano Legnaioli, Stefano Pagnotta, Francesco

Poggialini and Vincenzo Palleschi. 2019. 'Analytical and mathematical methods for revealing hidden details in ancient manuscripts and paintings: A review', *Journal of Advanced Research* 17: 31–42.

## Collection items


- Clusius, Carolus. 1605. *Caroli Clusii Atrebatensis ... Exoticorum libri decem quibus animalium, plantarum, aromatum, aliorumque peregrinorum fructuum historiae describuntur* ([Leiden?]: Ex officinâ Plantinianâ Raphelengii). London, UCL Special Collections, STRONG ROOM HNHS FOLIO 1605 L2 (barcode UCL0015382).
- Ryff, W. H. 1548. *In Caii Plinii Secvndi Natvralis historiae argutissimi scriptoris I. & II. cap: libri XXX. commentarius ... cvi praeterea adiecta est de fascinationibus disputatio elegans & erudita* (Wurzburg: per Ioannem Mylium). London, Royal College of Physicians, D1/19-c-27 (barcode 9978).
- van Veen, Otto. 1608. *Amorum emblemata* (Antwerp: venalia apud autorem) London, UCL Special Collections, STRONG ROOM OGDEN A 292 (barcode UCL0013661).
- Fragment of a noted missal. Thirteenth century. Manuscript on parchment. London, UCL Special Collections, MS FRAG/MUSIC/5.
- Fragment of a Psalter. Fourteenth century. Manuscript on parchment. London, UCL Special Collections, MS FRAG/LAT/28.
- Two fragments of a Hebrew manuscript. Unknown date. Manuscript on parchment. London, UCL Special Collections, MS FRAG/HEB/1.

*Picturing the Invisible* presents different disciplinary approaches to articulating the invisible, that which is not known or that which is not provable. The challenge that we have seen is how to articulate these concepts, not only to those within a particular academic field but beyond, to other disciplines and society at large. As our understanding of the complexity of the world grows incrementally, so does our realisation that issues and problems can rarely be resolved within neat demarcations. Therefore, the importance of finding means of communicating across disciplines and fields becomes a priority. Whilst acknowledging the essential importance of the specialist academic, the capacity to understand other disciplines, their priorities, methodologies and even the language used can become crucial in being an effective instrument for change.

This book brings together insights from leading academics from a wide range of disciplines including Art and Design, Curatorial Practice, Literature, Forensic Science, Medical Science, Psychoanalysis and Psychotherapy, Philosophy, Astrophysics and Architecture with a shared interest in exploring how, in each discipline, we strive to find expression for the invisible or unknown, and to draw out and articulate some of the explicit and tacit ways of communicating those concepts that transcend traditional disciplinary boundaries.

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