

# Near-Infrared Raking Reflectance Imaging of Stylus Marks in Renaissance Drawings: Distinguishing Media, Relief, and Sequence.

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## Abstract

*This study considers near-infrared raking reflectance imaging as a way to record incised lines, pricked holes, and other shallow stylus marks in drawings on paper. Such traces can clarify how a design was constructed, revised, or transferred between supports, but they are often difficult to interpret when drawing media visually compete with surface relief. Standard near-infrared reflectance imaging, typically recorded with symmetrical bilateral copy lighting, can reduce the visibility of some drawing media but does not strongly describe shallow deformations in the paper plane. Visible raking illumination\* emphasizes relief, yet visible media may remain dominant. Imaging experiments on a group of Renaissance drawings suggests that near-infrared, with a raking illumination geometry can help distinguish material deposits from impressed or incised marks, particularly where a stylus line diverges from adjacent media. The method also draws attention to a limitation in technical-imaging terminology: there is no standardized naming convention or prescribed order of terms for describing new imaging techniques or novel combinations of established methods. This paper proposes “near-infrared raking reflectance” as a description of the condition examined here and considers how recording illumination wavelength, geometry, and radiation mode in that order, may support more consistent documentation.*

*\*Although conservation imaging often reserves “light” and “illumination” for the visible spectrum and uses “radiation” or “irradiation” more broadly outside it, this paper uses “illumination” when referring to angle and geometry to avoid confusion with “irradiation,” which can imply exposure dose or duration rather than lighting direction.*

## Motivation

Stylus marks are physical events with disproportionate interpretive weight depending on the imaging or viewing method. They may register the pressure of a drawing instrument; the passage of a blind stylus used for planning or transferring a design from one sheet to another. Each possibility belongs to a different operation: drawing, revising, copying. On the sheet under consideration, however, these operations may or may not occupy the same line. Their identification depends on a chain of comparison: mark against medium, impression against contour, drawing against related drawing, and surface evidence against the known routes by which a composition moved.

Conservation examination in preparation for the exhibition Raphael: Sublime Poetry at The Metropolitan Museum of Art (2026), made the difficulty of recording and visualizing such marks immediate. In preparatory drawings associated with Raphael and his circle, established imaging methods did not always

separate transfer evidence from adjacent media. Ink, chalk, and wash could occupy the same visual field as a shallow deformation in the paper. The question that followed was procedural: what would become visible if near-infrared radiation were directed across the sheet at a low angle? Could this arrangement distinguish the drawn line from the impressed one?

A survey of bibliographic references was undertaken alongside the practical imaging tests to situate the method within existing precedents. Only two published examples of near-infrared raking reflectance imaging were identified, and the technique was absent from the conservation-imaging tables and taxonomies consulted.

## Problem

These marks can be difficult to document because they are often slight and visually entangled with surrounding media. Their visibility depends on the density of adjacent material, the texture and tone of the paper, and the direction from which the sheet is illuminated. Photomicrography can help to amplify the difference, though the field of view is very limited (Fig. 1).

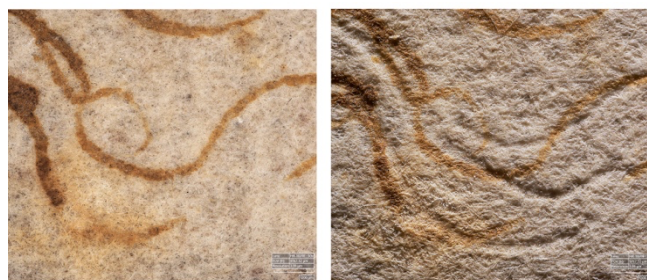


**Figure 1.** 30x Photomicrographs: Raphael, *Lucretia*, 1508-10. The Metropolitan Museum of Art, New York, Purchase, Lila Acheson Wallace Gift, 1997 (1997.153). Left: visible normal reflectance. Right: visible raking reflectance

The difficulty is also terminological. In multispectral imaging, the various named techniques are often non-conforming. If we look at all recorded types of infrared imaging: spectral range, geometry, and radiation mode, are often ordered differently. “Reflected infrared” is ordered radiation mode first, then illumination wavelength; “infrared reflectography” uses illumination wavelength, then radiation mode; “transmitted infrared”, radiation mode, then illumination wavelength; “infrared luminescence” now uses recorded wavelength, then radiation mode; “infrared reflectography luminescence” seems to be a logical progression from infrared luminescence, however, by listing two conflicting radiation modes is descriptively unclear. The most descriptive terms are: “ultraviolet-induced infrared luminescence”, and “visible-induced infrared luminescence”, by listing illuminated

wavelength, recorded wavelength, then radiation mode. “Reflected infrared” is an umbrella term which should include the various illumination geometries, recorded wavelengths, and radiation modes possible. Instead, it is positioned as a stand-alone category and refers to a near-infrared reflectance image made under normal, or standard copy lighting. When illumination geometry is mentioned in this literature, it is also positioned as a stand-alone category, e.g. “raking light”, and is defined as recorded under *visible* illumination [3, 9, 11, 15]. Webb’s work, published in *Conservation 360* has a comprehensive table that aligns these established technique names with other sources [15]. While alignment is necessary, an infrared reflectance image made with raking illumination sits awkwardly between these established names. To write a paper on a technique, you first need to name it. Cosentino identifies “raking with infrared light” as useful for revealing shallow incisions in mural paintings [3]. Furukawa and colleagues likewise showed that “oblique near-infrared illumination” can reveal writing-pressure indentations and support their measurement through shape-from-shading analysis [6]. These examples show that the evidentiary value of raking changes with surface morphology, radiation source, and material response. They also introduce another view of an inconsistent *ordering of terms* in technique naming.

For clarity in discussion and metadata entry, these conditions may be recorded separately:

- 1. Illumination wavelength:** ultraviolet, visible, near-infrared, or short-wave infrared. Exact nm range can be specified.
- 2. Illumination geometry:** symmetrical bilateral copy lighting, raking, coaxial, specular, diffuse, or transmitted
- 3. Recorded wavelength** (optional for clarity, most used for luminescence imaging): ultraviolet, visible, near-infrared, or short-wave infrared.
- 4. Radiation mode:** reflectance, transmission, or luminescence.

The long-form of this technique would therefore be named: near-infrared raking, near-infrared reflectance. If we decide that number three, recorded wavelength, should be reserved for luminescence mode only, we can therefore call the technique: near-infrared raking reflectance. This is not a proposed replacement for established terminology. It instead acts as an exercise in testing the ability of current terms for expansion—to include more modalities in the future. Further, when recording metadata associated with the image files, this separation of terms helps in searchability and preservation. A file tagged with “reflected infrared” and “raking light” can confuse future users of the combination used here. Separating illumination wavelength, illumination geometry, recorded wavelength, and radiation mode, would make the image easier to understand later, especially when files move between systems or are used by researchers who were not present when they were made.

## Methodological Context

Infrared radiation was identified by William Herschel in 1800 as extending beyond the red end of the visible spectrum [9]. Its importance in art examination lies in the differing ways materials absorb, reflect, and transmit radiation. Infrared-sensitive photographic film entered museum laboratories in the early twentieth century alongside X-radiography and ultraviolet examination. These early methods could distinguish some drawing materials from their support or from overlying paint, although their usefulness was limited by the spectral sensitivity of film, up to approximately 900 nm.

In the 1960s, J. R. J. van Asperen de Boer extended infrared examination through “infrared reflectography”, using electronic systems with lead-sulfide detectors and vidicon technology to view a “reflectogram”. This extended imaging farther into the infrared than photographic film, up to 2500 nm, allowing some pigments to become comparatively transparent [13, 14]. Other detector materials with similar sensitivity, including PtSi and InGaAs, were later introduced. Silicon-based CCD and CMOS sensors, with suitable modification and filtration, enabled higher spatial resolution and made infrared imaging more accessible, though their spectral response generally ends near 1000–1100 nm [2, 15]. This history has shaped the current terminology. “Infrared reflectography” often refers to imaging with PtSi, PbS, or InGaAs systems, while “reflected infrared imaging” is commonly used for silicon-based imaging. Naming a method based on its detector material has created some confusion, most notably when listing new methods. In common speak these historical terms may prevail, but for clarity in articles and journals the preferred terms should be near-infrared reflectance instead of reflected infrared, and wide-band infrared reflectance in lieu of infrared reflectography, since this imaging method overlaps both near and shortwave infrared. Specifying the bands would be best practice.

Raking illumination has its own history within technical photography, where light positioned at a low angle to the surface emphasizes irregularities through directional shadow and highlight. It has conventionally been used to register texture, deformation, incisions, and other relief-related features [3, 9, 11]. In much conservation literature and documentation practice, however, raking remains organized separately from spectral modes such as infrared and ultraviolet [2, 4, 9]. Together, these histories establish the technical basis for using near-infrared raking reflectance to examine paper-based works.

## Approach

The method was tested on Renaissance drawings in which transfer evidence had already been suspected through close examination, prior technical study, or comparison with related works. Each drawing was examined under multiple illumination conditions, including visible, ultraviolet, and near-infrared with standard copy lighting, raking, axial specular, and transmitted illumination. The approximate angle and working arrangement were kept consistent across the examined works. Because raking illumination is directional, the appearance of a mark changes according to the orientation of the light source. Illumination direction was therefore treated as an interpretive variable.

For this study, a modified Canon 5DSR with full spectrum conversion (270–1100nm) was used. LED light fixtures designed by The Metropolitan Museum of Art were used as the illumination source [7]. These ISO 3664-compliant, linear, and rotating lights have seventy-two LEDs for each configuration, including a visible white, 365 nm ultraviolet, and 950 nm infrared radiation channel. Different combinations of filters were added to the camera lens: a Coastal Optics 60 mm apochromatic lens was fitted with an IDAS-UIBAR III (400–680 nm) for visible light imaging, and an Xnite 830 (830–1100 nm) for near-infrared imaging.

All image files underwent flat-field correction using a reference image of an even background recorded under the same optical and illumination conditions. The correction compensated for spatial variation present in the reference field, including uneven illumination and optical falloff. For raking images, the reference field recorded the spatial falloff associated with the low-angle source. Correction reduced this background variation without removing the shadows and highlights generated by the drawing itself, which remained as deviations from the reference field. Raking illumination geometry was adjusted so that the difference across unmarked paper did not exceed  $\Delta L^* 20$  in visible light files and 1.5 stops in linear near-infrared files.

## Findings

Over thirty drawings associated with Raphael and his circle were examined in various collections including: The Metropolitan Museum of Art, Ashmolean Museum, Windsor Castle, and The British Museum, in which transfer marks had been suspected through close examination or prior technical study. The most useful results occurred where a shallow impression and a drawn contour occupied the same region of the sheet but did not fully coincide. Under normal near-infrared symmetrical reflectance, some media became less prominent, yet the paper plane remained comparatively flat (Fig. 2).



**Figure 2.** Detail: Raphael, *Lucretia*, 1508-10. Left: visible normal reflectance. Right: near-infrared normal reflectance.

Under visible raking reflectance, relief was more apparent, but ink, chalk, or wash could remain visually dominant. In the near-infrared raking images; some media receded while the paper surface became more legible. This being the major advantage of this technique. Interestingly, the near-infrared raking images lost some visibility of the infrared absorbing media that reads very clearly in normal reflectance mode. This reduced prominence does not necessarily indicate diminished absorption. Instead, grazing geometry redistributes the reflected signal across the paper surface. Local changes in slope, fiber orientation, and indentation introduce directional shadowing and scattering that can outweigh the diffuse

tonal contrast of the drawing medium. The resulting image privileges surface displacement, allowing impressed marks to become more legible where they diverge from adjacent media. This further helped visualize the separation of media and impression (Fig. 3).



**Figure 3.** Detail: Raphael, *Lucretia*, 1508-10. Left: visible raking reflectance. Right: near-infrared raking reflectance.

Where an impressed line followed a drawn contour closely, the impression may have resulted from pressure applied during drawing. Where the impression departed from the contour, continued beyond it, or crossed it without corresponding media, the difference raised another possibility: either the media had been lost over time or that the sheet had been marked by blind stylus during planning or transfer. In several drawings, the difference was not dramatic at first glance. It became visible in the mismatch between two lines: one carrying media; the other a deformation of the paper's surface. In the drawing used as a visual example for this paper, blind stylus marks appeared in relation to carbon-based media visible on the verso under visible transmitted light imaging (Fig. 4).



**Figure 4.** Raphael, *Lucretia*, 1508-10. Visible transmitted.

Read together with the verso evidence, this relation supported the interpretation of the incisions as transfer marks, not pressure traces associated with the initial drawing process [1]. Pricked holes produced less consistent results. Some became legible in near-infrared raking reflectance because their edges generated directional shadow. Others remained more clearly described by visible raking or transmitted illumination, particularly where the relevant evidence was perforation, thinning, or a local change in paper density. These negative cases were equally instructive. Where an under drawing was visible in near-infrared imaging, but no incision or pricking was present, raking illumination often contributed only surface texture. In such drawings, the added relief did not change the interpretation, except to confirm an absence of indentation. Near-infrared raking reflectance was most consequential when the question concerned a deliberately impressed feature: a stylus line, an incised contour, a prick, or another deformation that was difficult or impossible to see or understand without changing the relative appearance of the various intentional marks, both blind or media. This relation of marks could clarify sequence.

In addition to viewing the results of each image independently, false color composites were registered to clarify where their information diverged. In addition to a conventional false-color infrared composite that distinguishes materials by spectral behavior, I created a second modified composite that incorporates a dark-pixel trace from the near-infrared raking image to register instances of blind marking and indentation. In these composites, cyan corresponded to infrared-absorbing carbon underdrawing, red to iron gall ink, and dark blue to blind indentations. This approach made it possible to visualize, within a single image, the relationship between deposited media and impressed marks in the support (Fig. 5).



**Figure 5.** Raphael, *Lucretia*, 1508–10. Left: false-color infrared composite. Right: false-color infrared raking composite.

## Conclusion

Near-infrared raking reflectance shows how a change in imaging arrangement can alter the evidence available in a drawing. This imaging modality can separate a drawn line from an impressed one and bring the relationship between media, paper deformation, and transfer into a clearer view. In Renaissance drawings, a sheet is not simply a field of visible marks. It is a worked surface: pressed, pierced, redirected, and sometimes made to carry an image elsewhere. This method does not reveal a hidden drawing so much as shifts the attention from media to deformation which can significantly aide in understanding various campaigns of mark

making. Careful comparison across multiple imaging methods is imperative for accurate interpretation. For works on paper and parchment, it has proven to be especially useful and has become part of the Paper Conservation Department's standard imaging workflow. It contributes not only to render shallow relief, but also a vocabulary through which that evidence can be consistently recorded, compared, and interpreted.

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