

Recovery of handwritten text from the diaries and papers of David Livingstone

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Manyema Field Diary, 1870-1871



Envelopes

Historical Significance

- Tropical diseases
- African slave trade
- Just before Stanley

Ran out of paper, ink

- Newspapers
- Sermons
- Envelopes



Sermons



Newspapers

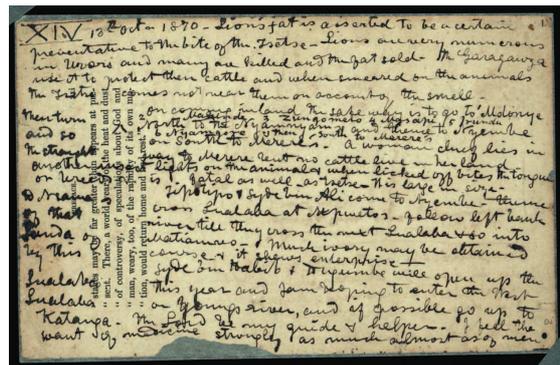
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Outline

- **David Livingstone**
 - Famous missionary from Scotland
 - Writings influenced public opinion of African slave trade
- **Multi-spectral Imaging Team**
 - Recovered erased text from Archimedes Palimpsest
 - Imaged Livingstone's diaries at National Library of Scotland in June/July 2010
- **Image Processing Techniques**
 - Principal Components Analysis (separates writing)
 - Spectral Ratios (suppress printed text)
 - Pseudocolor (distinguish ink that bled through paper)

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Many Leaves are Legible



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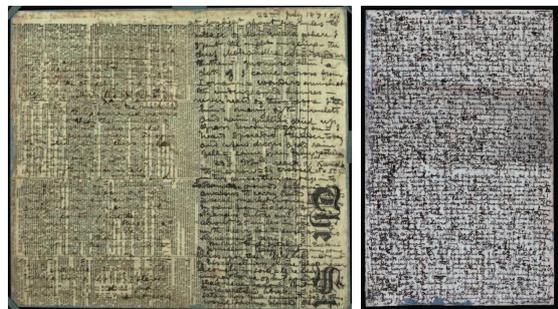
David Livingstone 1813-1873

- **Missionary in Africa**
 - 1841 arrives in South Africa
 - 1847 sets up mission by Zambezi River
- **First Expedition**
 - 1853 expedition into interior
 - 1855 discovers Victoria Falls
 - 1856 publishes *Missionary Travels*
- **Second Expedition**
 - 1858 official expedition into interior
 - 1864 expedition recalled after wife dies
- **Third Expedition**
 - 1866 seeks source of Nile
 - 1871 encounters H. M. Stanley in Ujiji
 - 1873 dies of malaria in Zambia



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Many are Illegible



Fading ink -- interference from printed text

Bleed-through from other side

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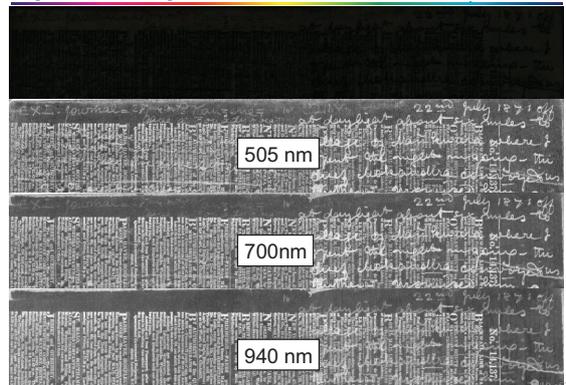
Multispectral Imaging Team



Doug Emery	Roger Easton Jr.	Bill Christens-Barry	Mike Toth	Keith Knox	Ken Boydston
Metadata	Image Processing	Lights	Management	Image Processing	Image Capture

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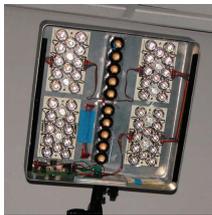
Spectral Dependence



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LED Illumination Panel

Ultraviolet	450 nm	Infrared
365 nm	465 nm	735 nm
	505 nm	780 nm
	535 nm	870 nm
	592 nm	940 nm
	638 nm	
	700 nm	

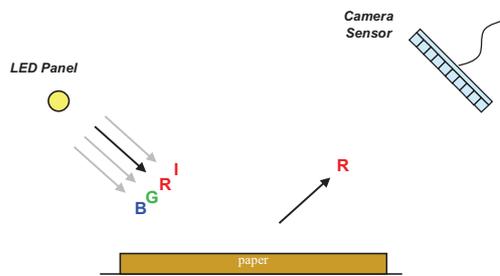


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Principal Components Analysis to Separate Writings

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LED Illumination



Images at every wavelength are in perfect registration

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Principal Component Analysis

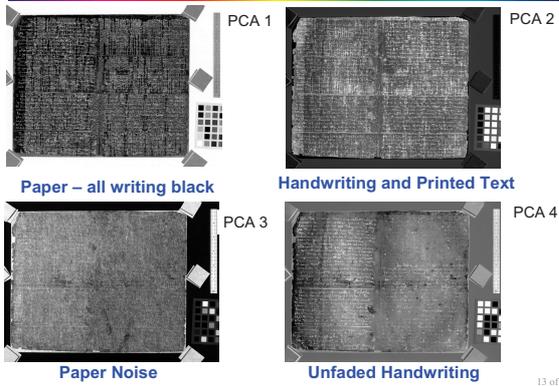
- **Data Set**
 - Perfectly registered data cube
 - 12 wavelengths, 365 nm – 940 nm
- **Principal Components Analysis**
 - Finds axes of maximum variation
 - Components ordered by significance
- **Separating the Writings**
 - Three kinds of writing – printed text, handwriting and bleed-through
 - Sometimes more than one ink
 - Different spectral variation for each writing
- **Application of PCA to data cube**
 - Goal is to isolate handwriting from printed text
 - PCA components seldom align perfectly with individual writings



Visible image of handwriting on newspaper

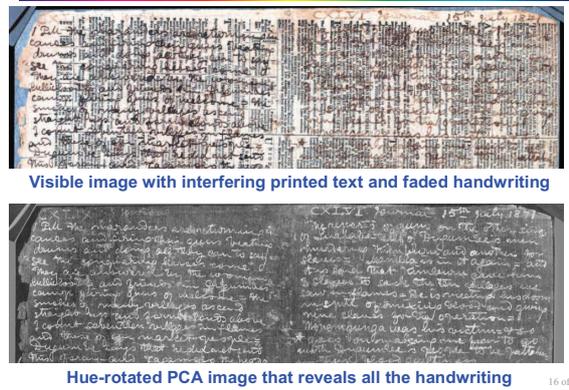
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Principal Components



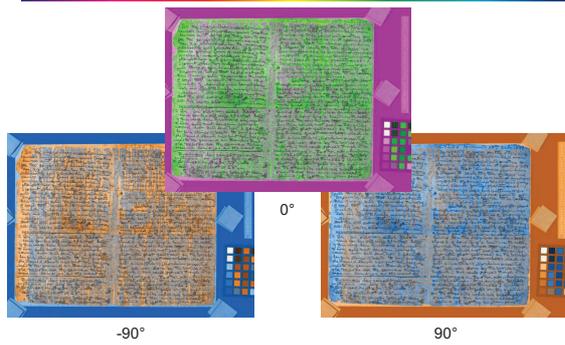
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Handwriting Recovered



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Hue Rotation



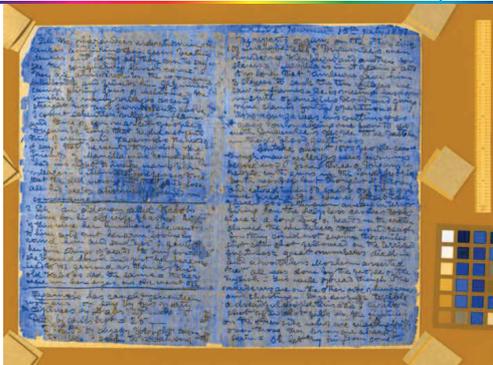
Insert PCA components 1 & 2 in a color image and rotate hue

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Spectral Ratios Suppresses Printed Text

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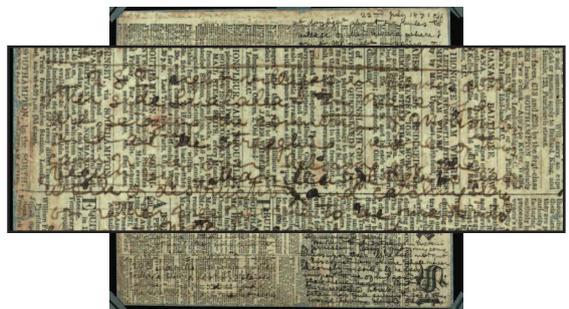
Hue Rotation



Choose hue angle that equates paper & text values in one color channel

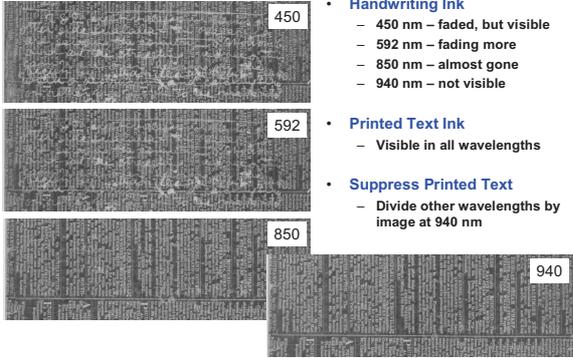
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Printed Text Interferes with Handwriting



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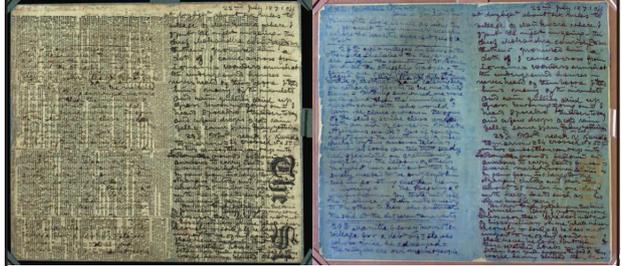
Spectral Dependence of Inks



- **Handwriting Ink**
 - 450 nm – faded, but visible
 - 592 nm – fading more
 - 850 nm – almost gone
 - 940 nm – not visible
- **Printed Text Ink**
 - Visible in all wavelengths
- **Suppress Printed Text**
 - Divide other wavelengths by image at 940 nm

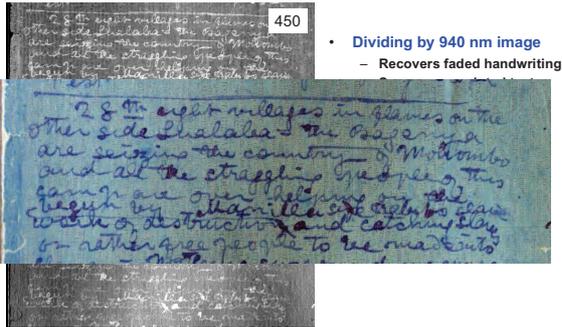
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Full Page Result



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Spectral Ratios



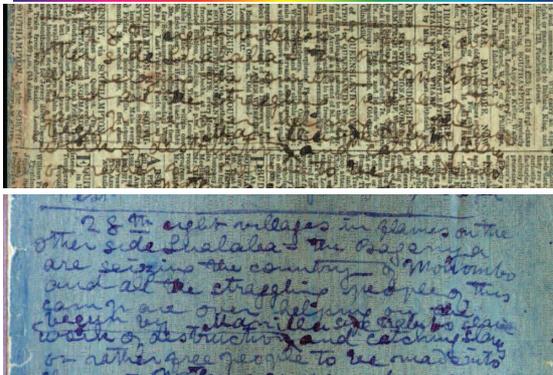
- **Dividing by 940 nm image**
 - Recovers faded handwriting

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Pseudo-color to Suppress Bleed-through

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Color Image, Spectral Ratio Comparison



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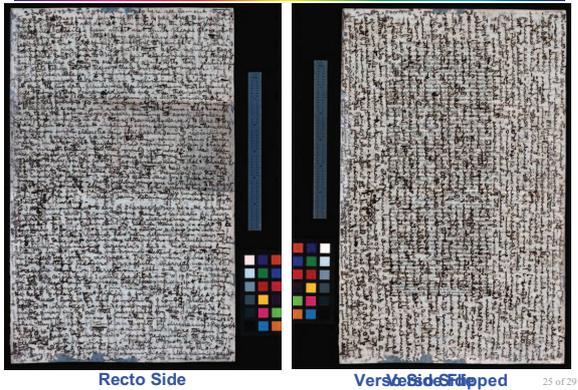
Ink Bleed Through



- Ink Bleed Through**
- Written on both sides
 - Ink bled through the paper
 - Handwriting hard to read

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Scan Both Sides of Page

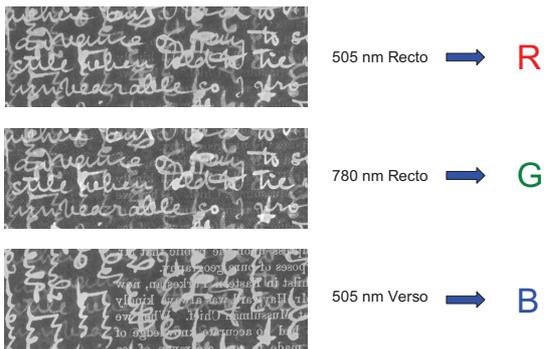


Summary

- **Principal Components Analysis**
 - Principal components not always aligned with writings
 - Hue rotation of color component image emphasizes writings
 - Method helps separate writings and recover handwriting
- **Spectral Ratios**
 - Handwriting ink is not visible in near infrared
 - Printed text is constant over the spectrum
 - Dividing by near IR image suppresses printed text
- **Pseudocolor**
 - Combine both sides of page in pseudocolor image
 - Uses color to distinguish writing from both sides

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Pseudocolor Combination



Acknowledgments

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 - David Livingstone Centre
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Comparison with Visible Image

