

Digital image processing and analysis

15. Multispectral imaging

Professor Ela Claridge
School of Computer Science

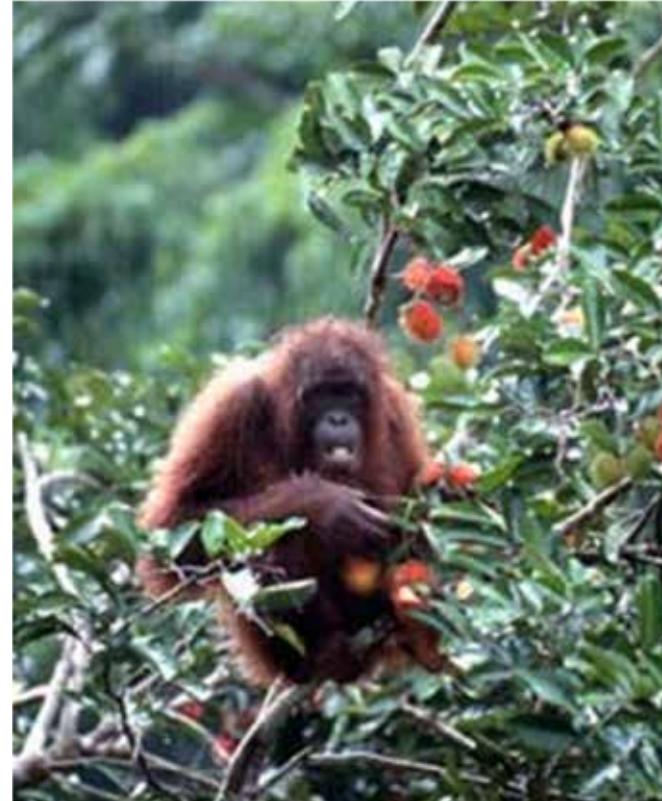
Previous lecture:

- Statistical shape models
 - What they are
 - What they are used for
- Principal Component Analysis (PCA)
 - What it is
 - How it is used for shape modelling
- Point distribution models
- Active shape models
- Active appearance models

In this lecture we shall find out about:

- Multispectral imaging
 - Why colour that we see does not always tell the full story
 - General principles of multispectral imaging
 - How to acquire multispectral images
 - Analysis and applications

What is perception for?

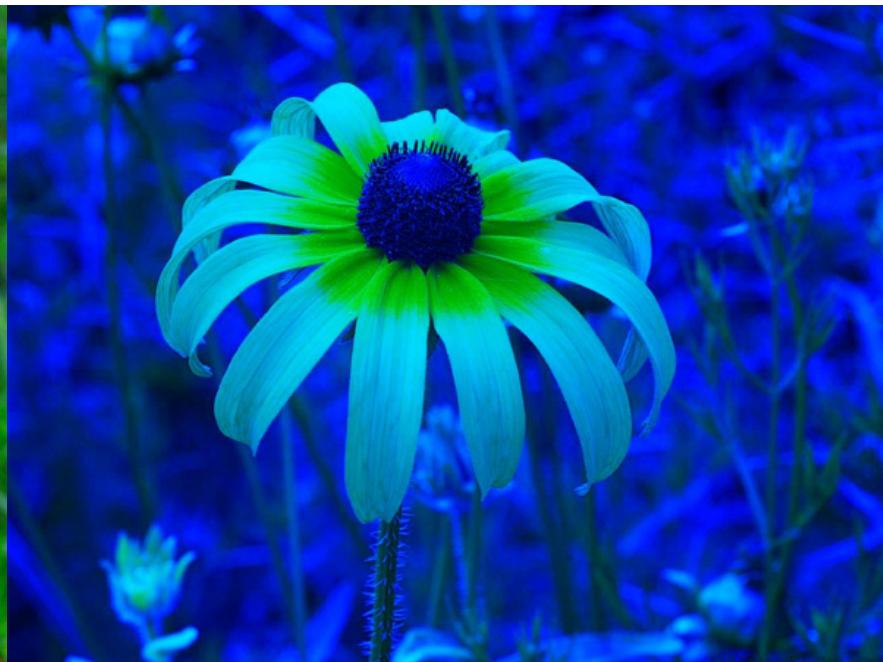


Quantitative imaging may lay beyond our perception

How bees see the world



Human vision
(RGB)



Simulated bee vision
(GB+UV)

<https://www.visualnews.com/2013/04/08/hidden-patterns-how-a-bee-sees-the-world-of-flowers/>

How birds see the world



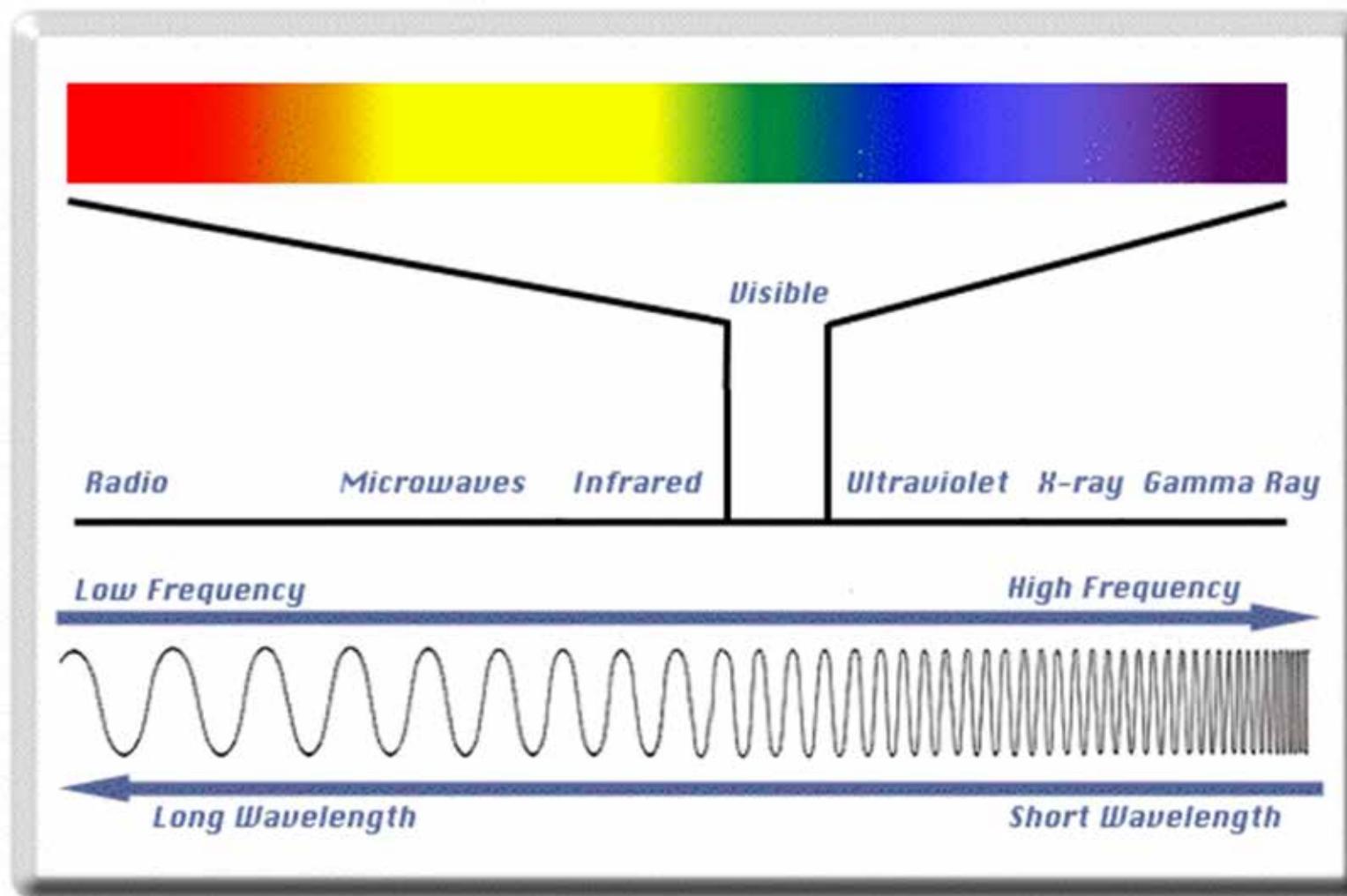
Human vision
(RGB)

UV vision
(Ultraviolet)

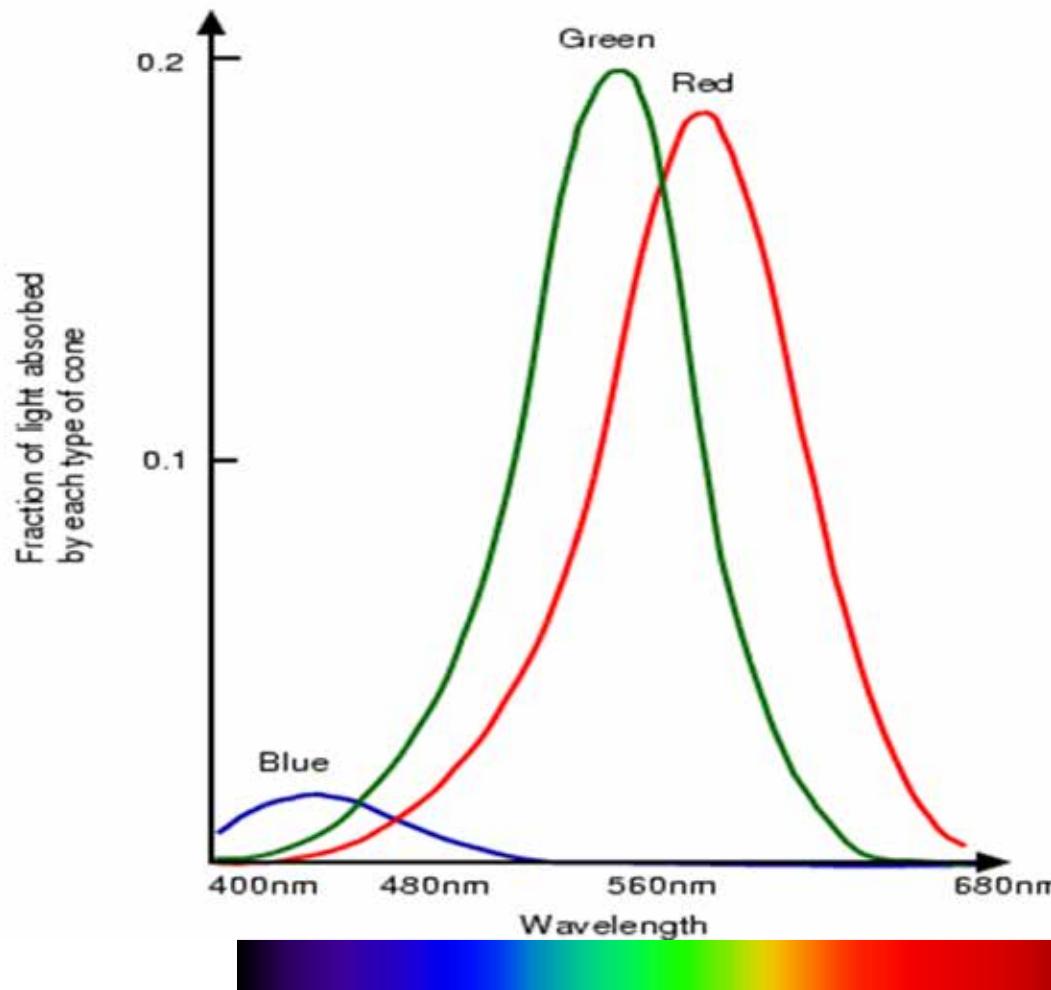
Simulated bird vision
(RGB+UV)

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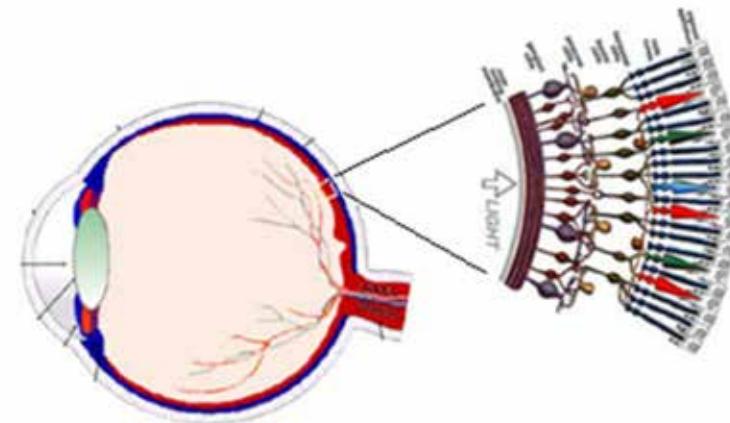
Light – a form of electromagnetic radiation



Spectral sensitivity curves for the retinal receptors

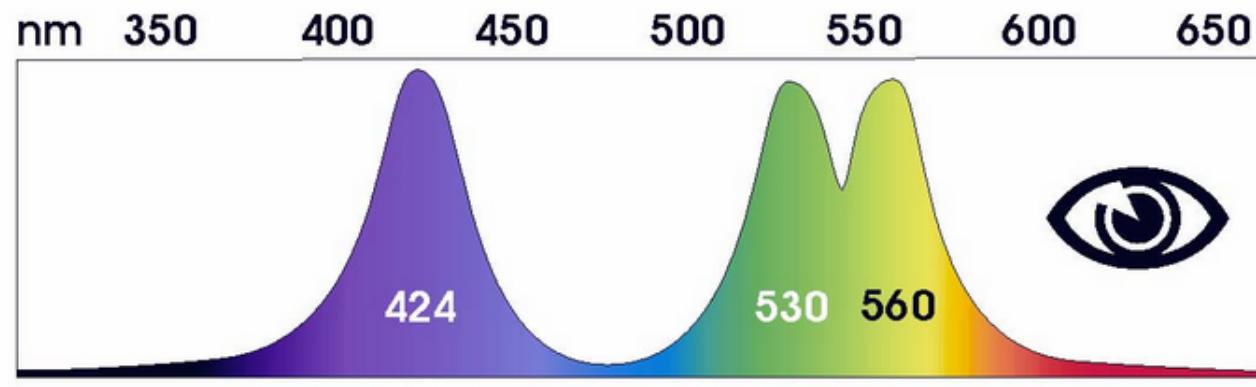


Change title

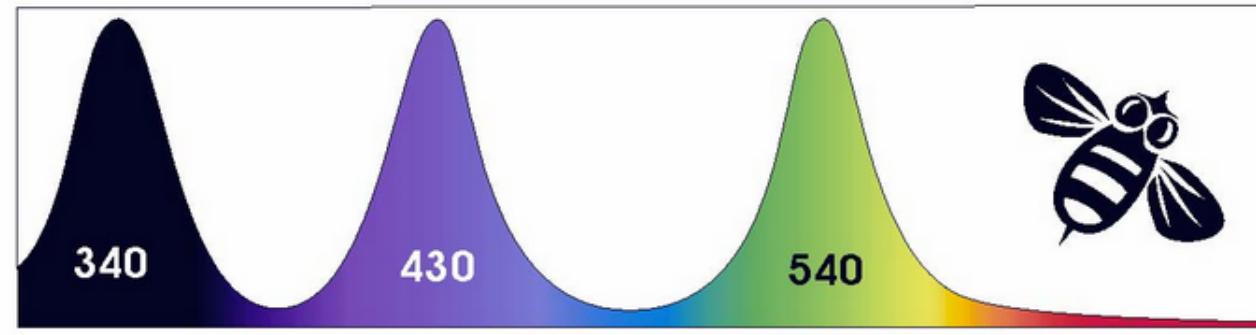


Spectra of different species vision

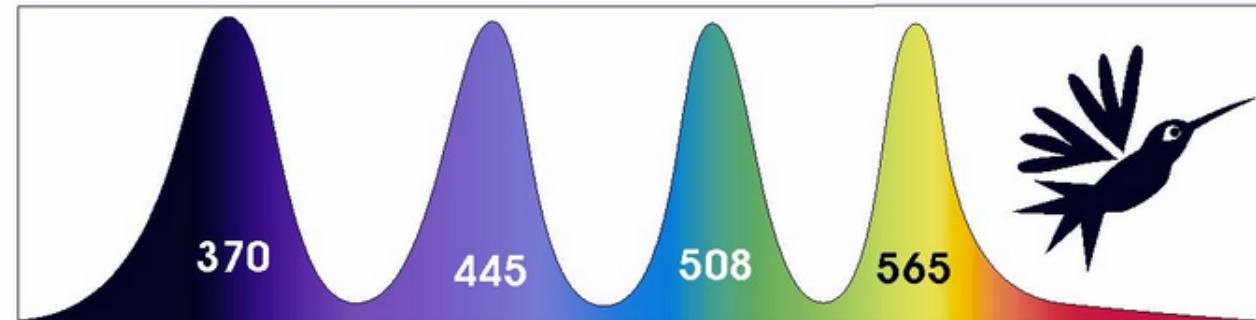
There are things we (humans) cannot see



Humans



Bees



Birds

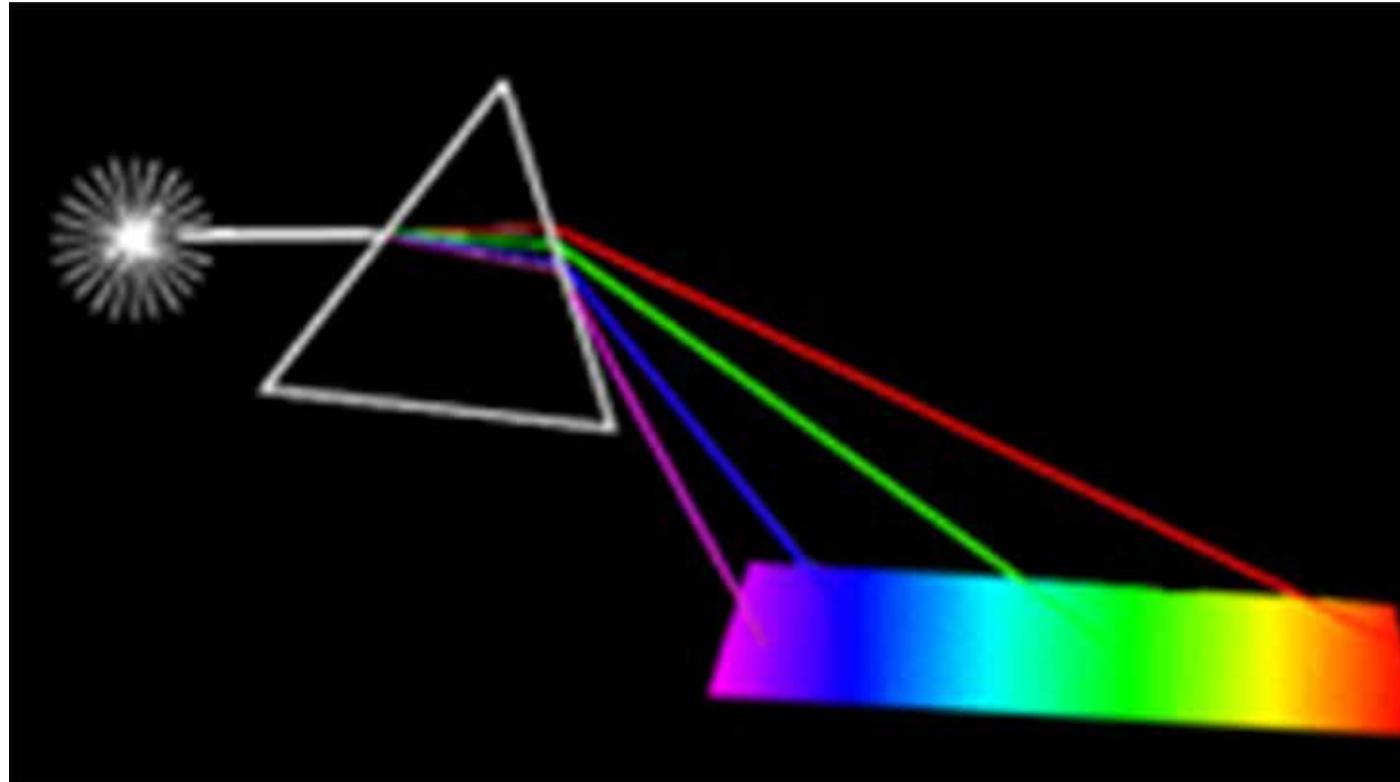
Colour perception - problems

There are things we cannot see



Colour perception – problems

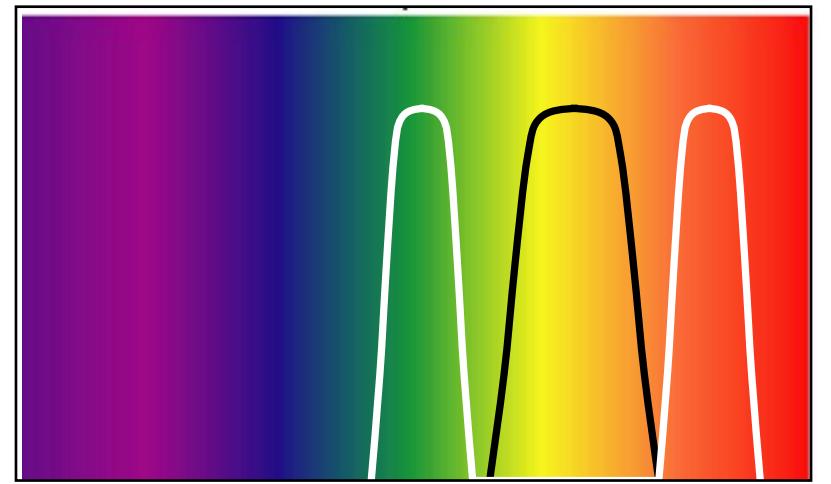
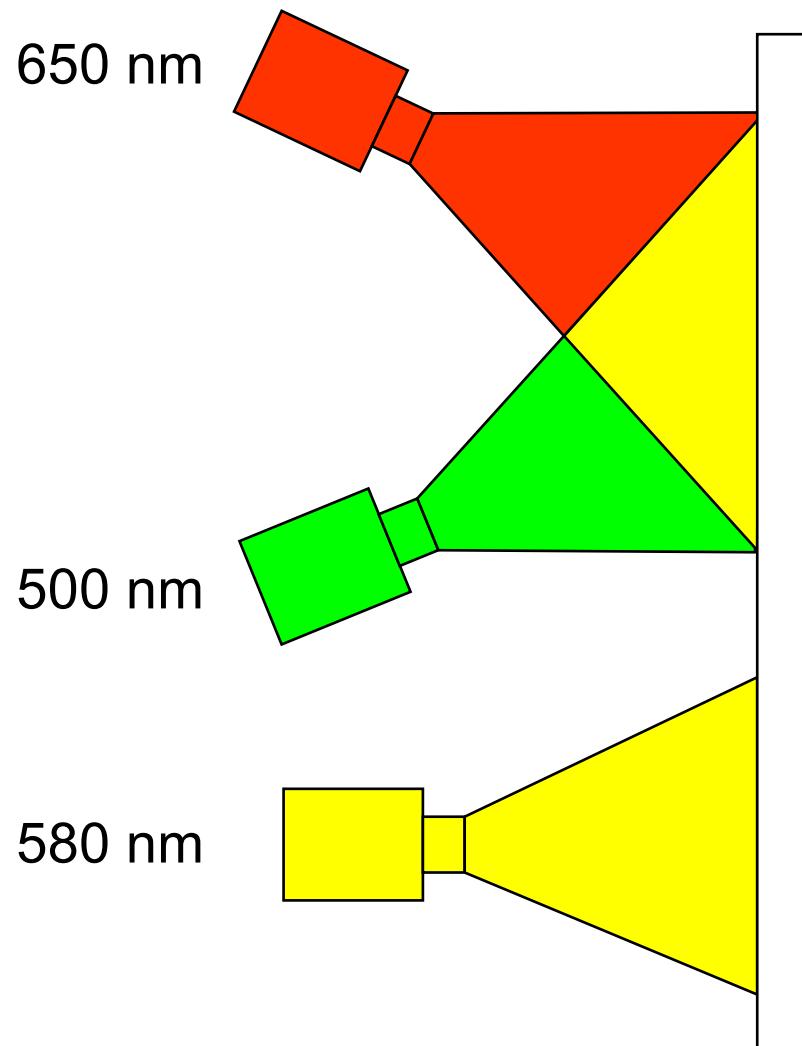
Inability to “unmix”



Inability to “unmix”

Colour perception – problems

Metamerism



Colour perception – problems

Metamerism

Indoors

Outdoors



Two colours that have different spectra look the same to the human eye.

They will appear differently in different illuminating conditions

Colour perception – problems

Colour constancy

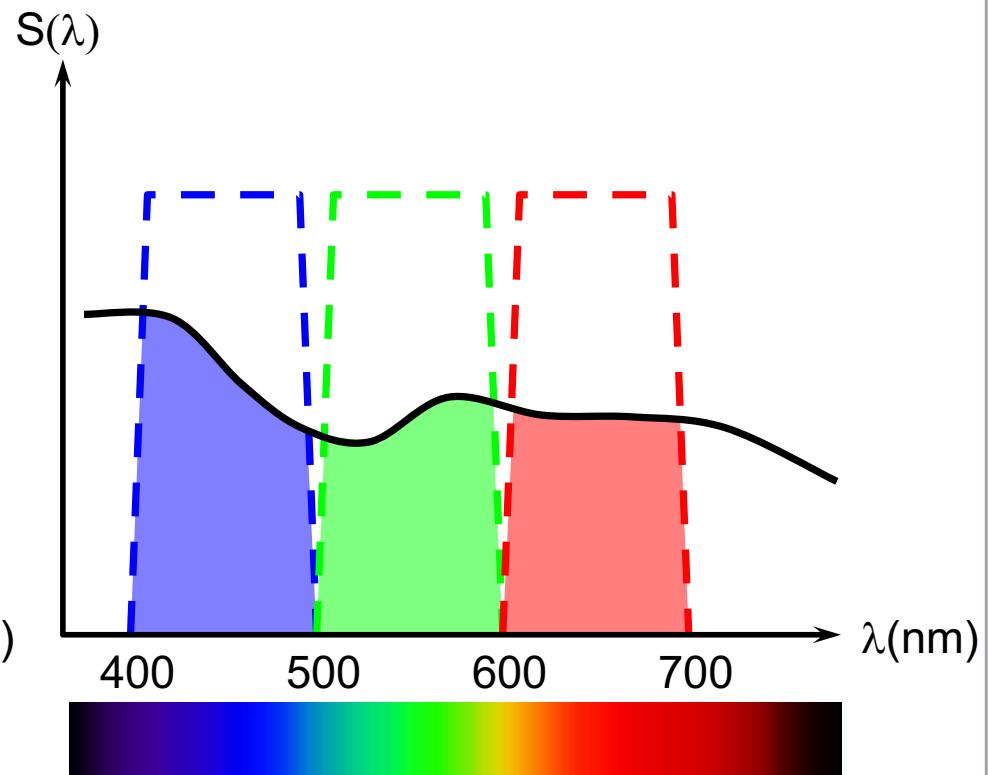
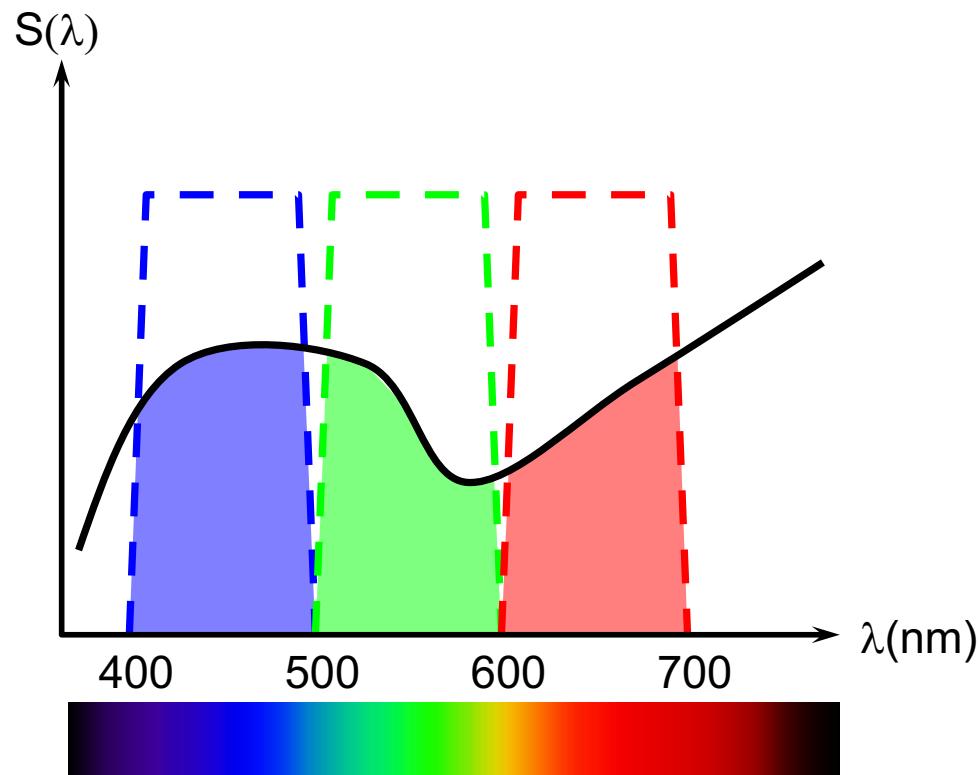


In these two pictures, the second card from the left seems to be a stronger shade of pink in the upper one than in the lower one. In fact they are the same colour (since they have the same RGB values), but perception is affected by the colour cast of the surrounding photo.

Source: Wikipedia

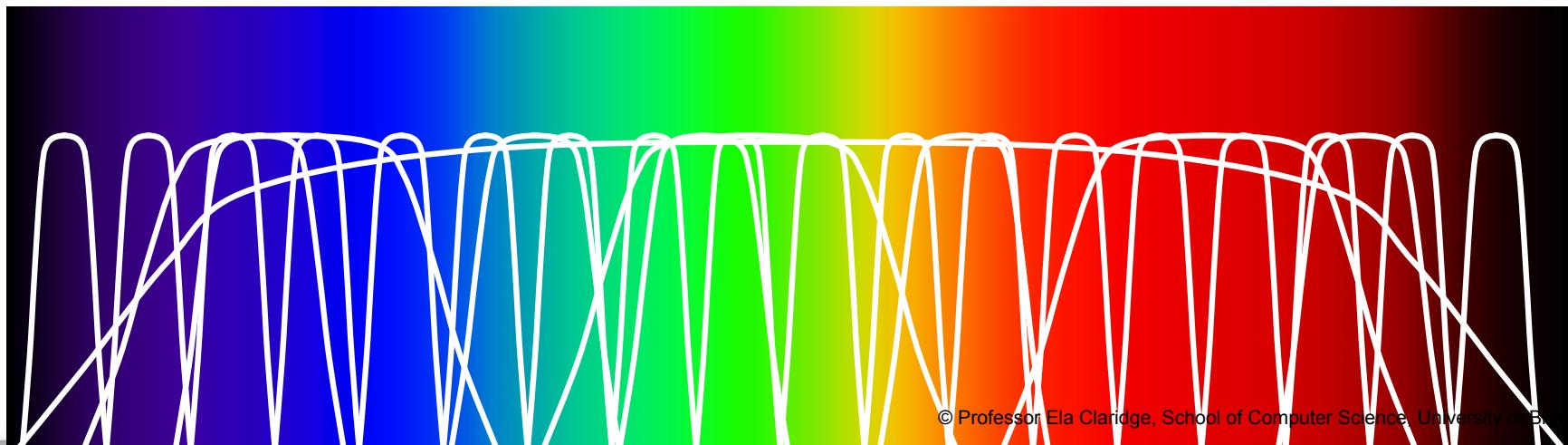
Sensors: limited spectral resolution

Both: human eyes and colour cameras



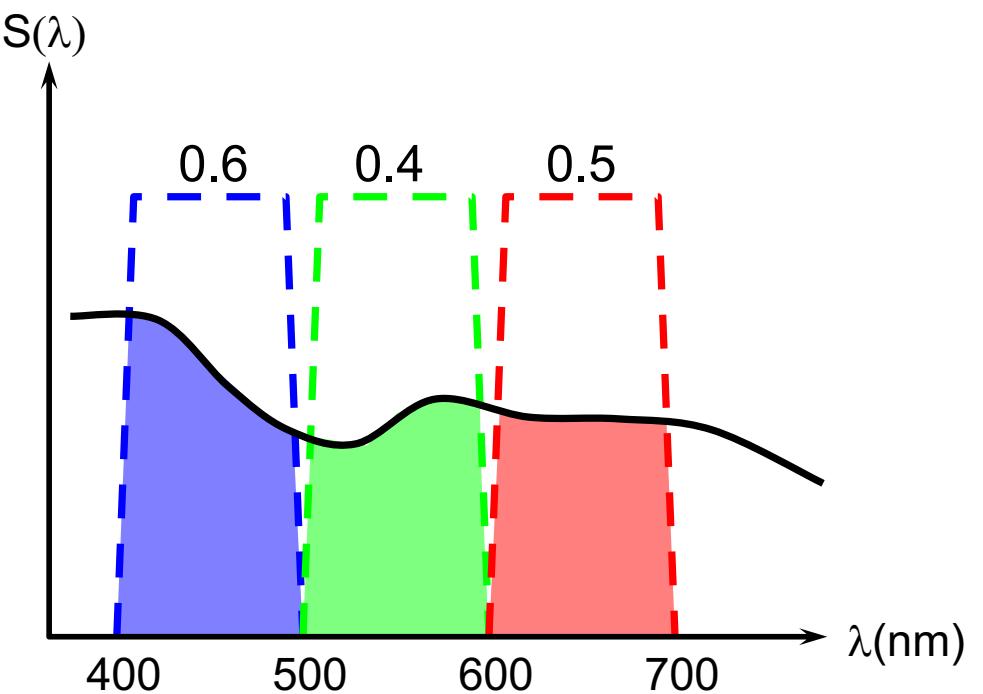
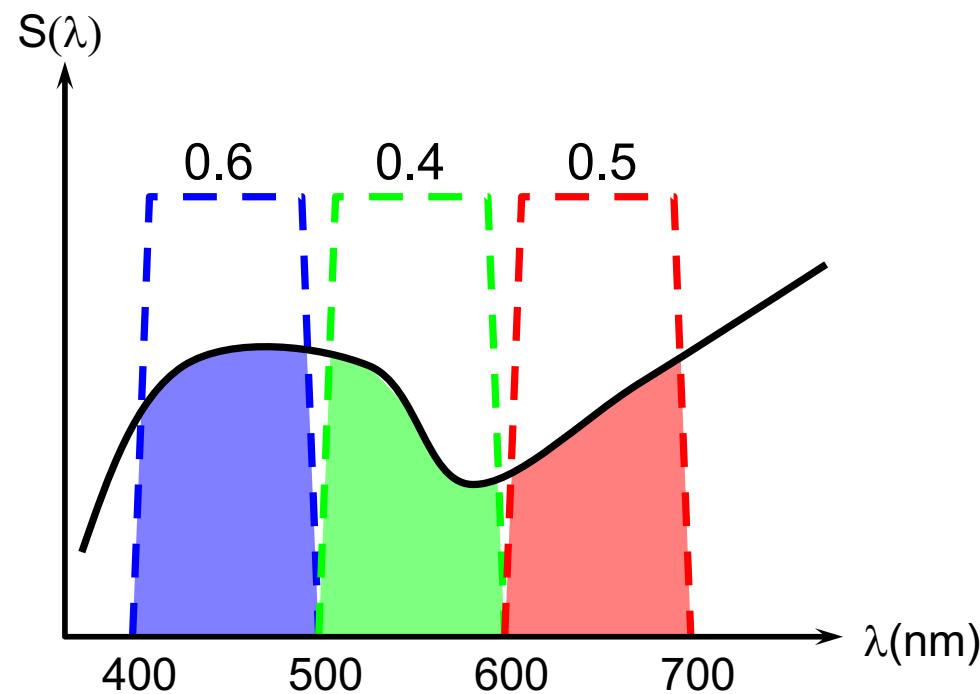
Multispectral and hyperspectral imaging

- Reflected, transmitted or emitted light collected by a camera forms an image
 - Monochrome (B/W) – collects all visible light
 - Colour – three broad bands (RGB)
 - Multispectral – several – several tens of bands (broad or narrow)
 - Hyperspectral – many (hundreds) narrow bands



Multispectral Imaging

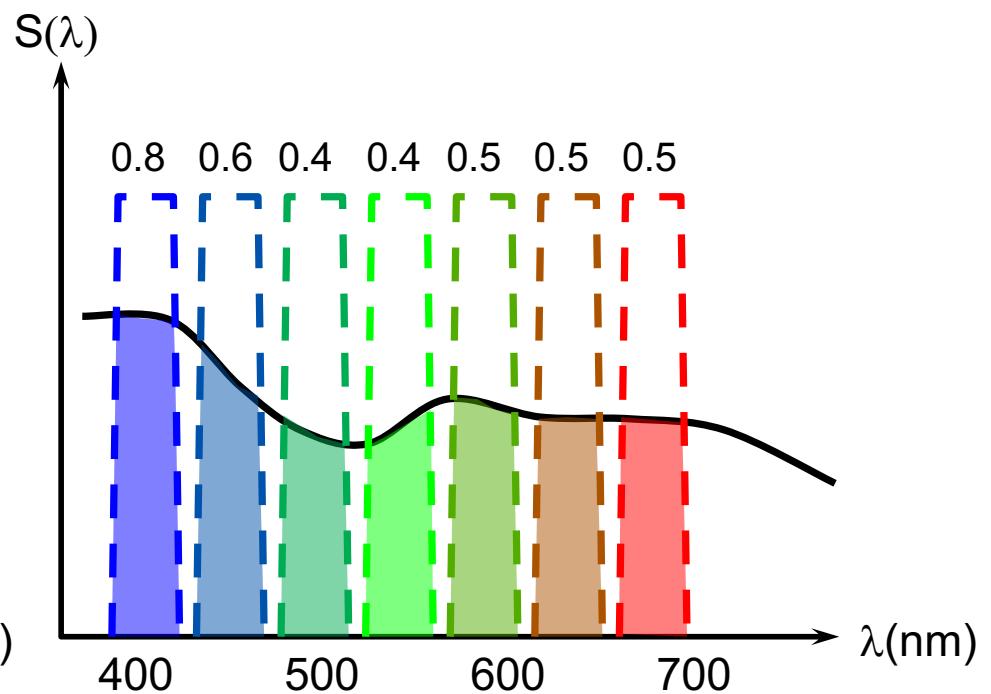
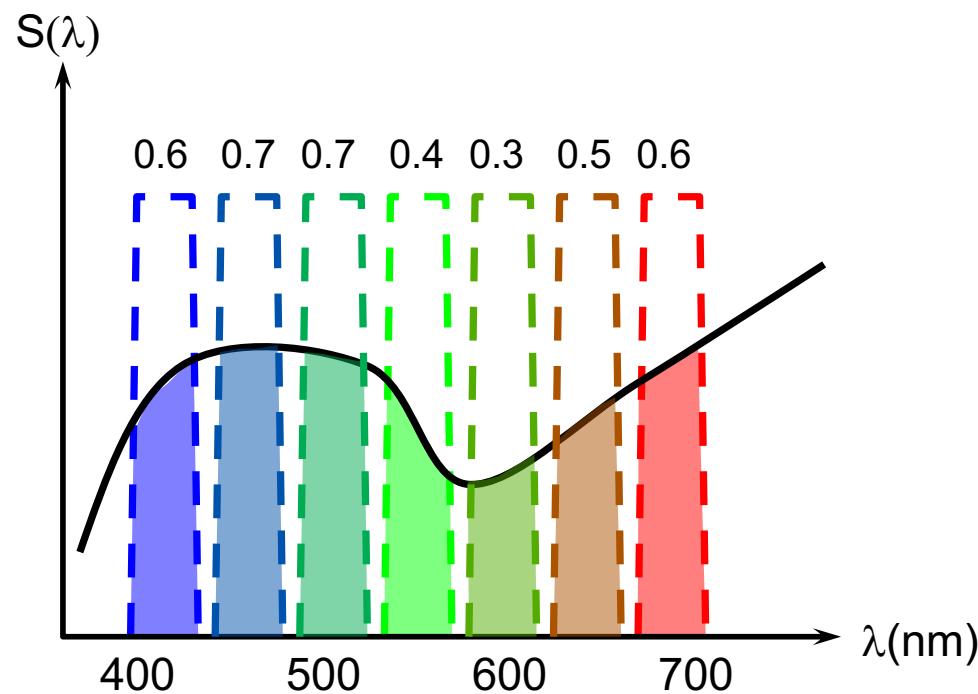
RGB – broad-band filters



The same RGB image values for different spectral reflectance

Multispectral Imaging

Narrow-band filters

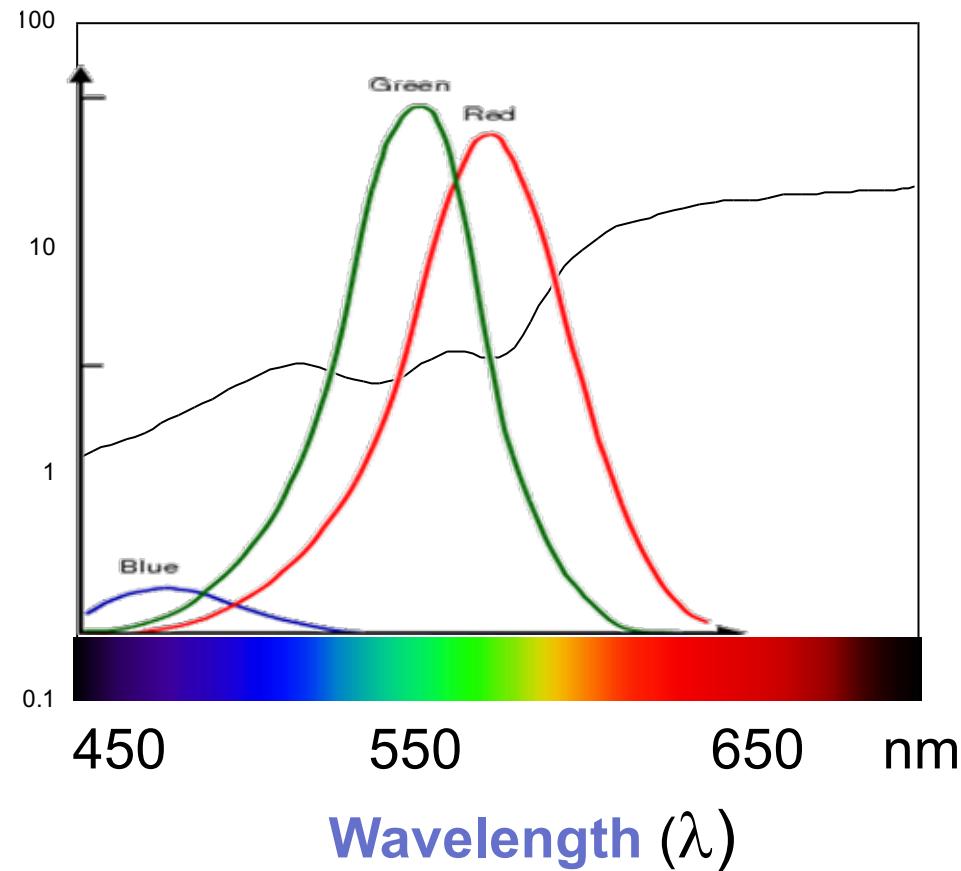


Different multispectral image values for different spectral reflectance

Why multispectral imaging?

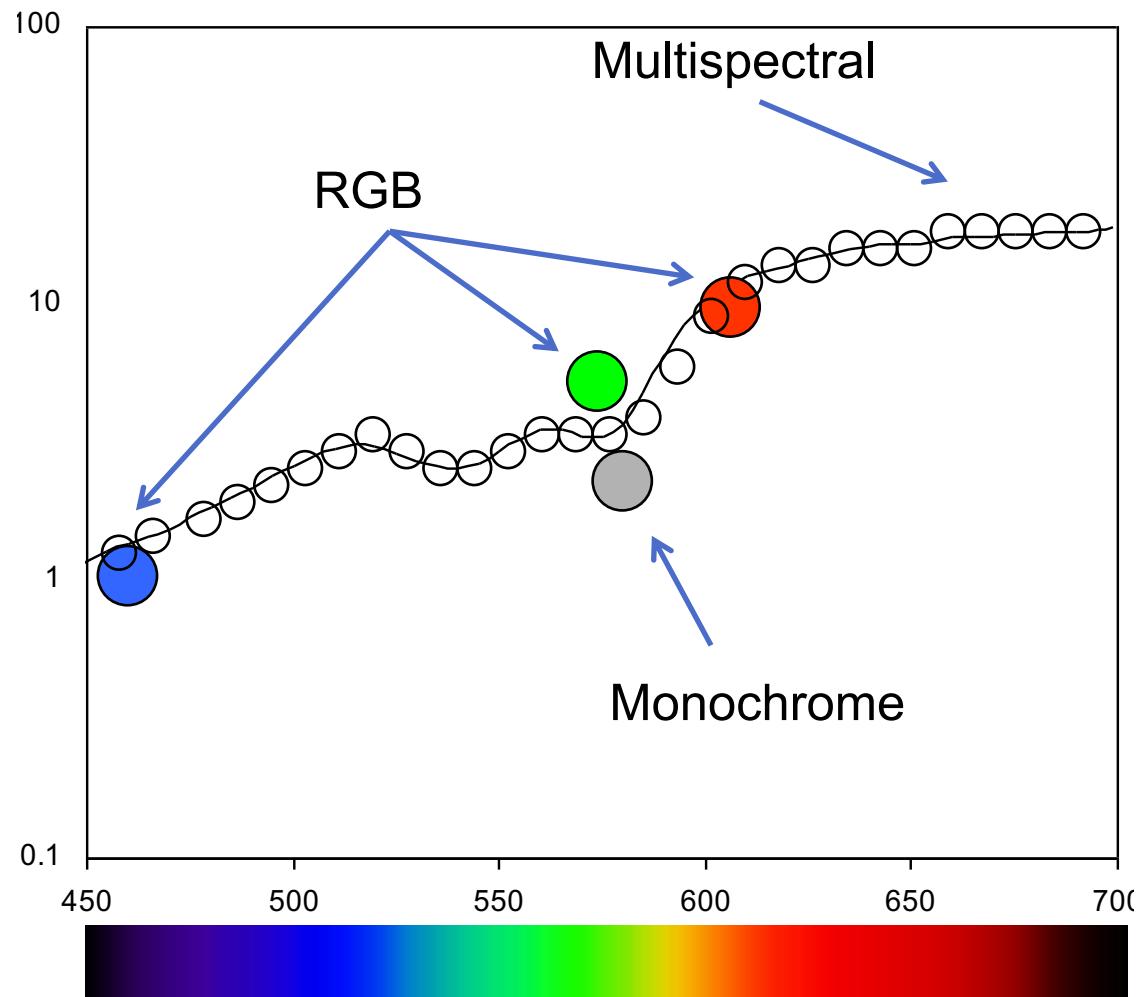
Richer interpretation

Example: spectral **reflectance** curve of the human skin



Why multispectral imaging?

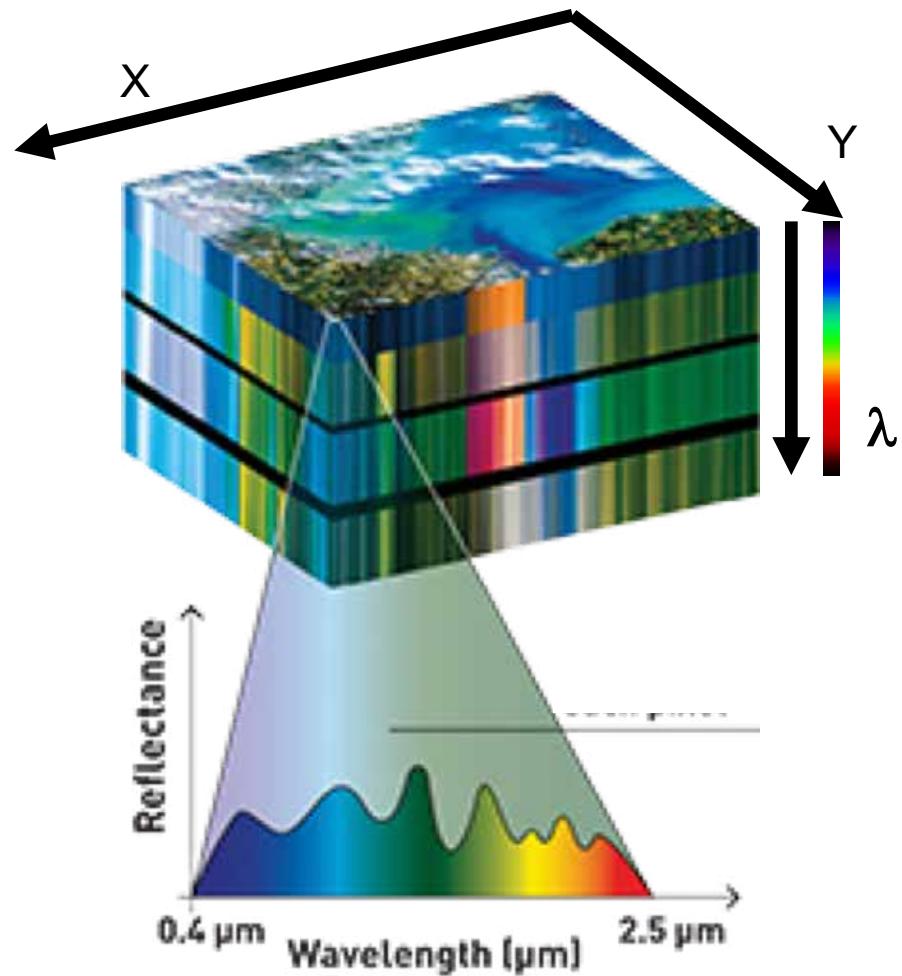
- Full representation of spectral properties
- Overcomes problems of human perception
- Extends human senses



Why multispectral imaging?

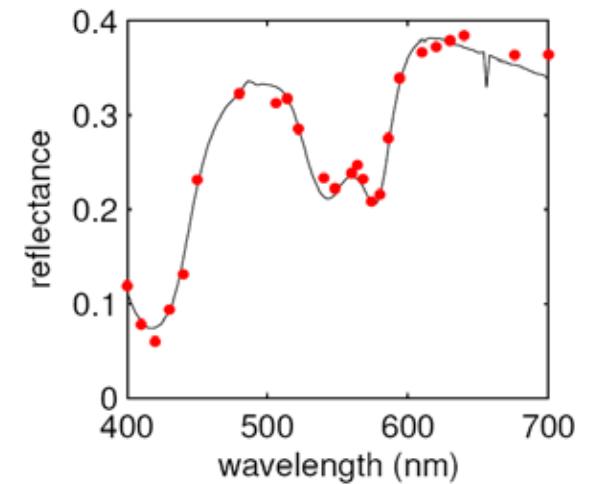
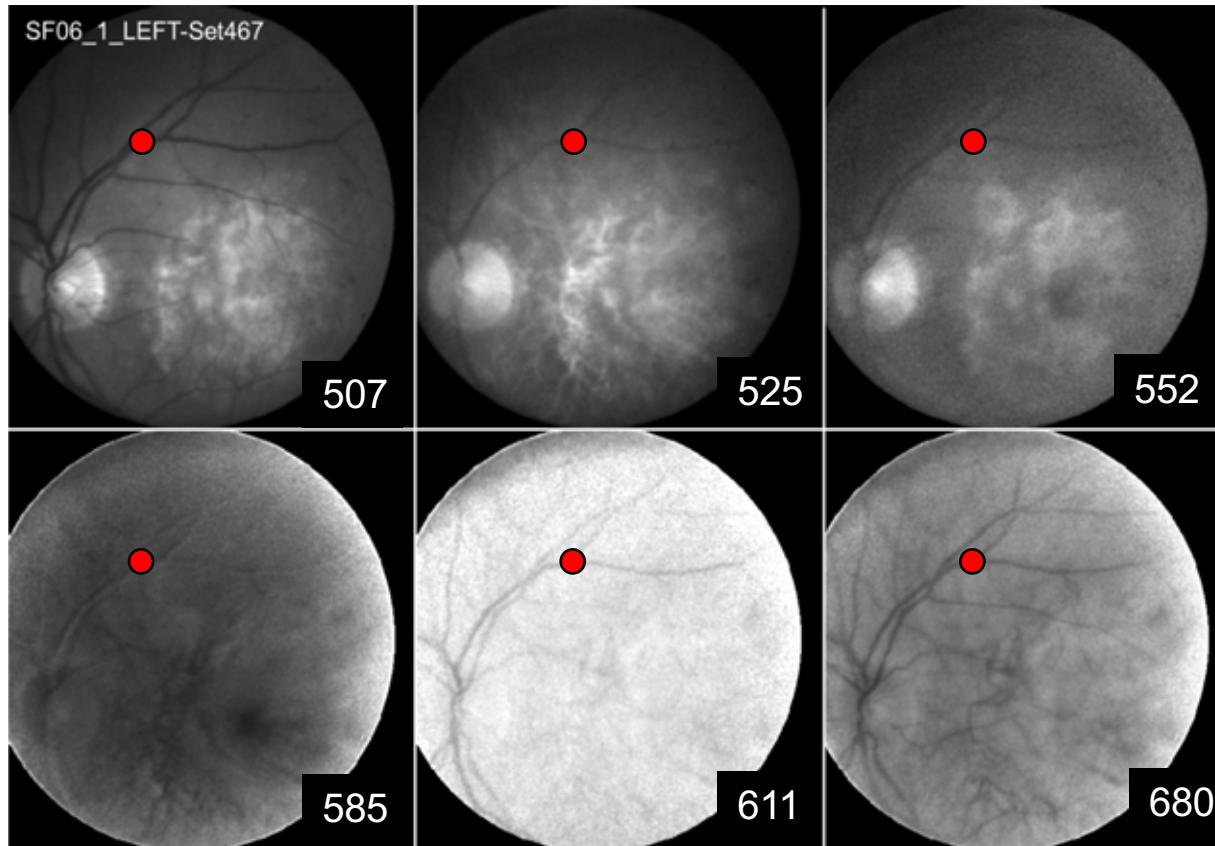
At the same time ...

- Full representation of spatial properties
- Overcomes the lack of spatial information in point spectroscopy



Hyperspectral cube
(lambda-stack)

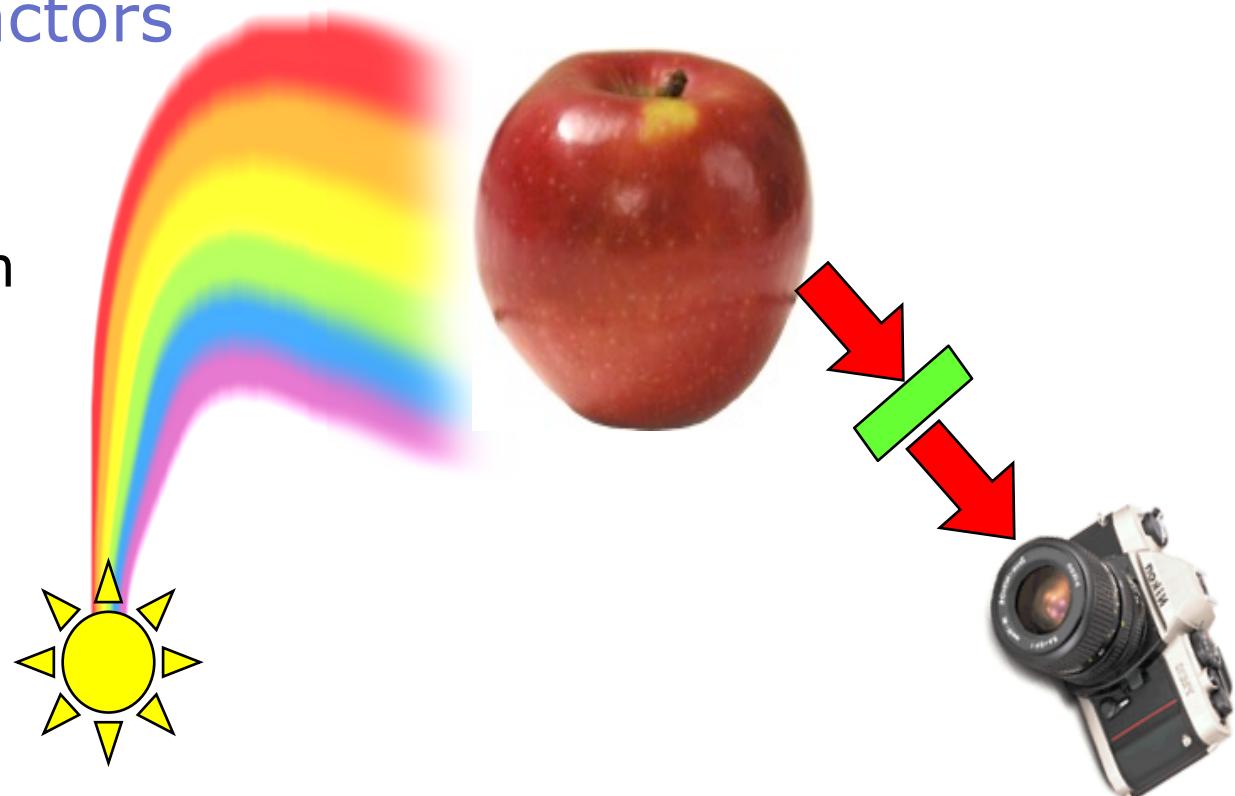
Multispectral image representation



What's in the image data?

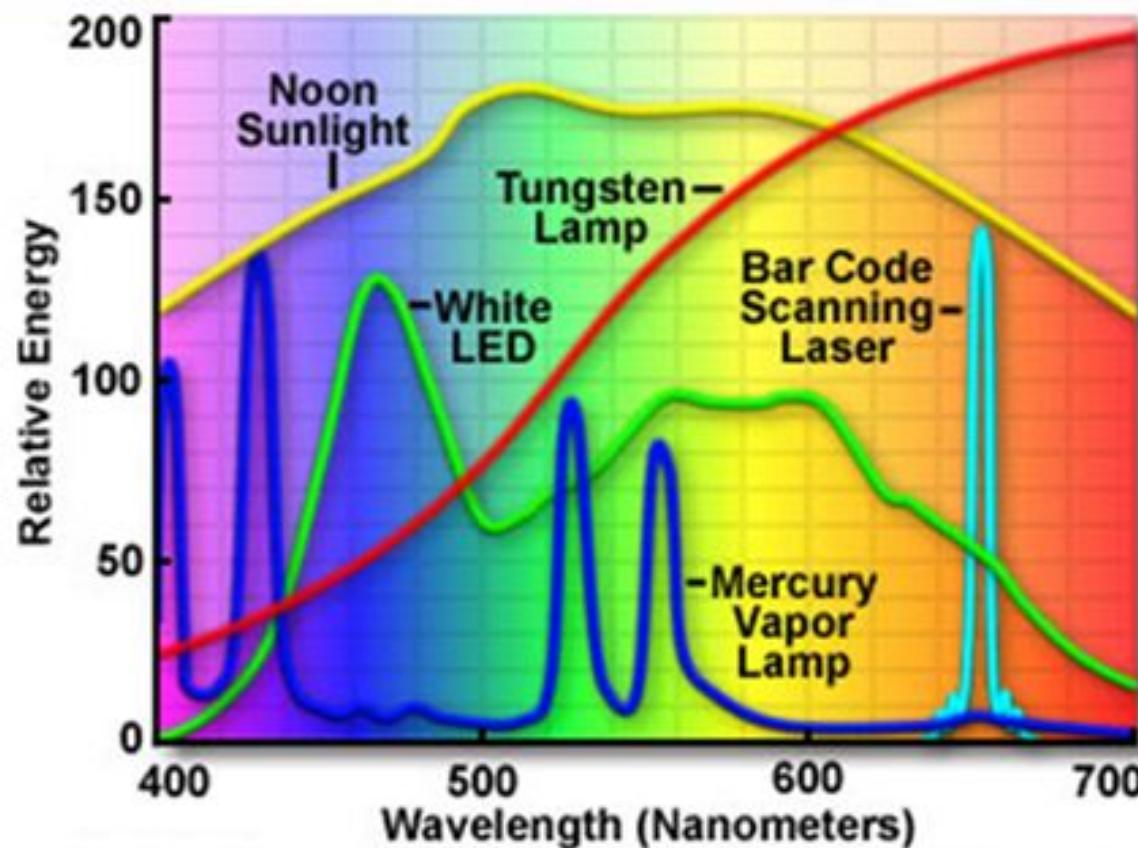
- Contributing factors

- Illumination
- Imaging system
- Object



What's in the image data? Different illumination

Spectra of common sources of visible light



(Source: Olympus America)

What's in the image data?

Camera sensors

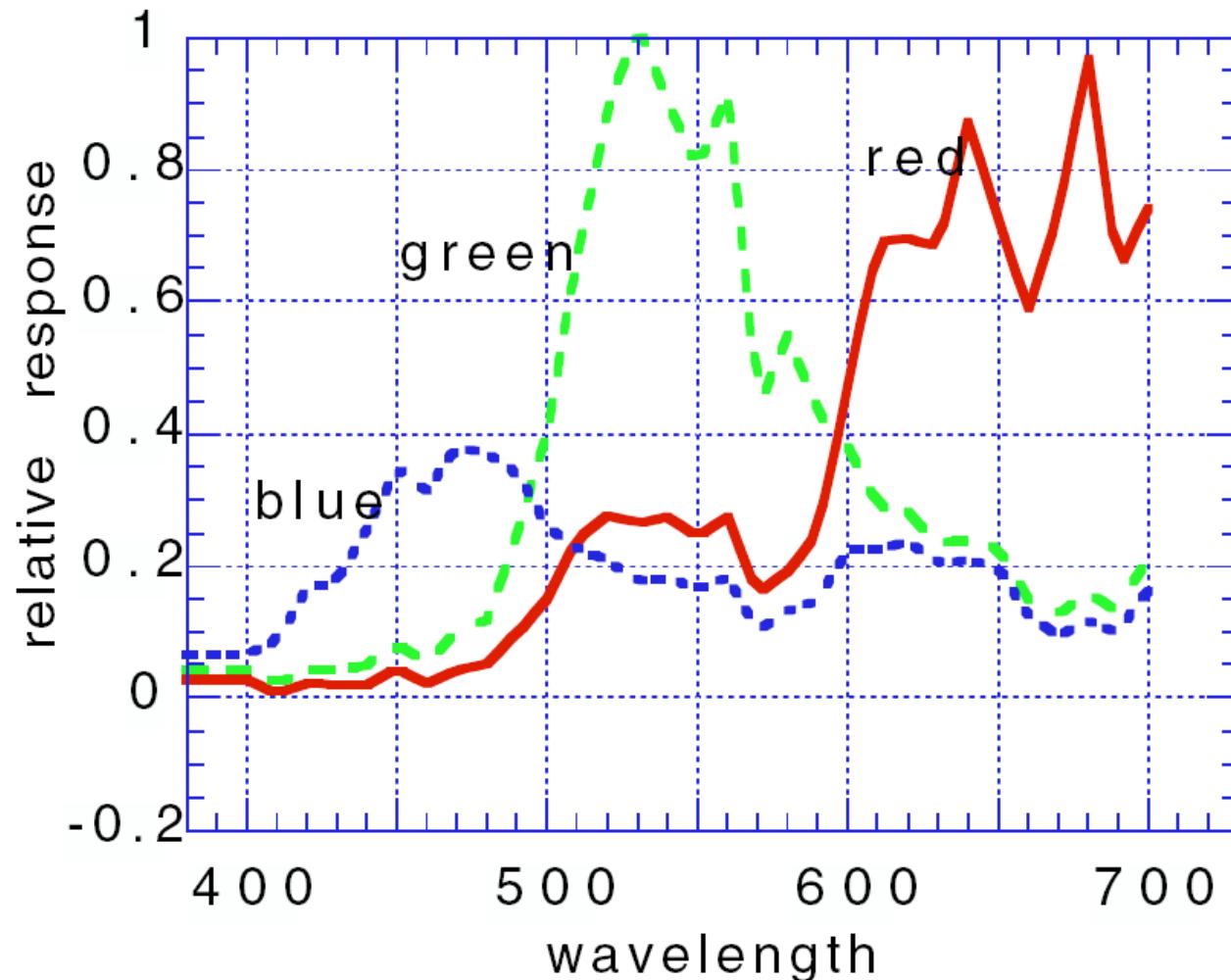
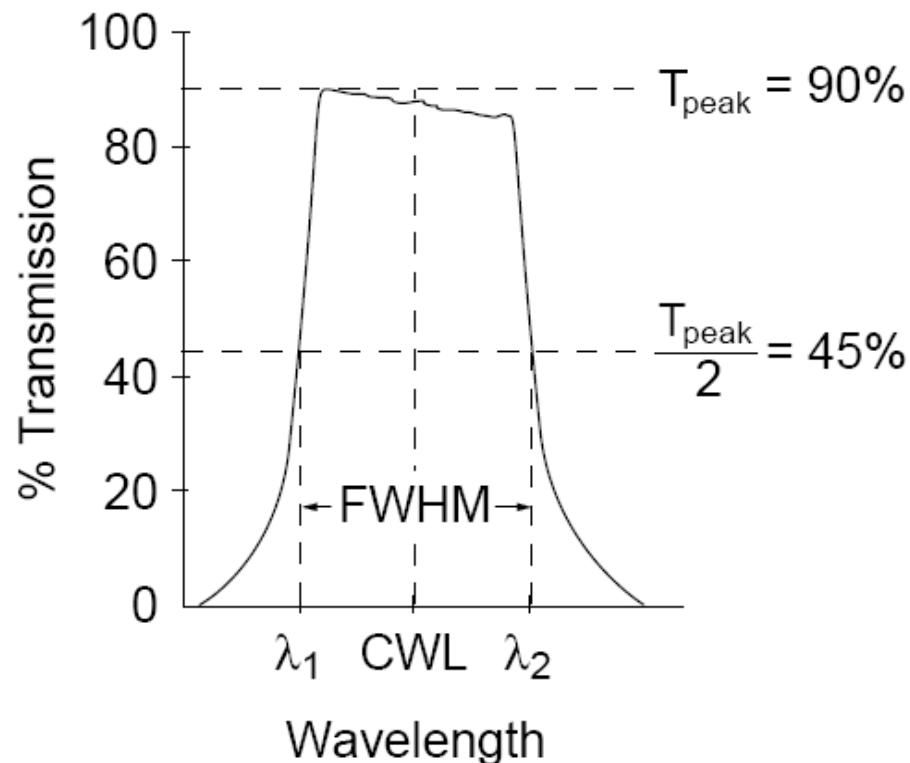


Figure 3. Spectral response of the Kodak KAF-1600C sensor used in the DCS-200 camera as supplied by Kodak

What's in the image data?

Imaging system filters

- A filter is a device which selectively transmits light having a particular range of wavelengths while blocking the remainder



What's in the image data? Calibration and normalisation

- To correctly interpret image data it is necessary to remove the effects of
 - Illumination
 - Imaging system / filters
 - Acquisition time
 - Aperture
 -
- Mathematical techniques for doing so are referred to as “calibration” and “normalisation”.

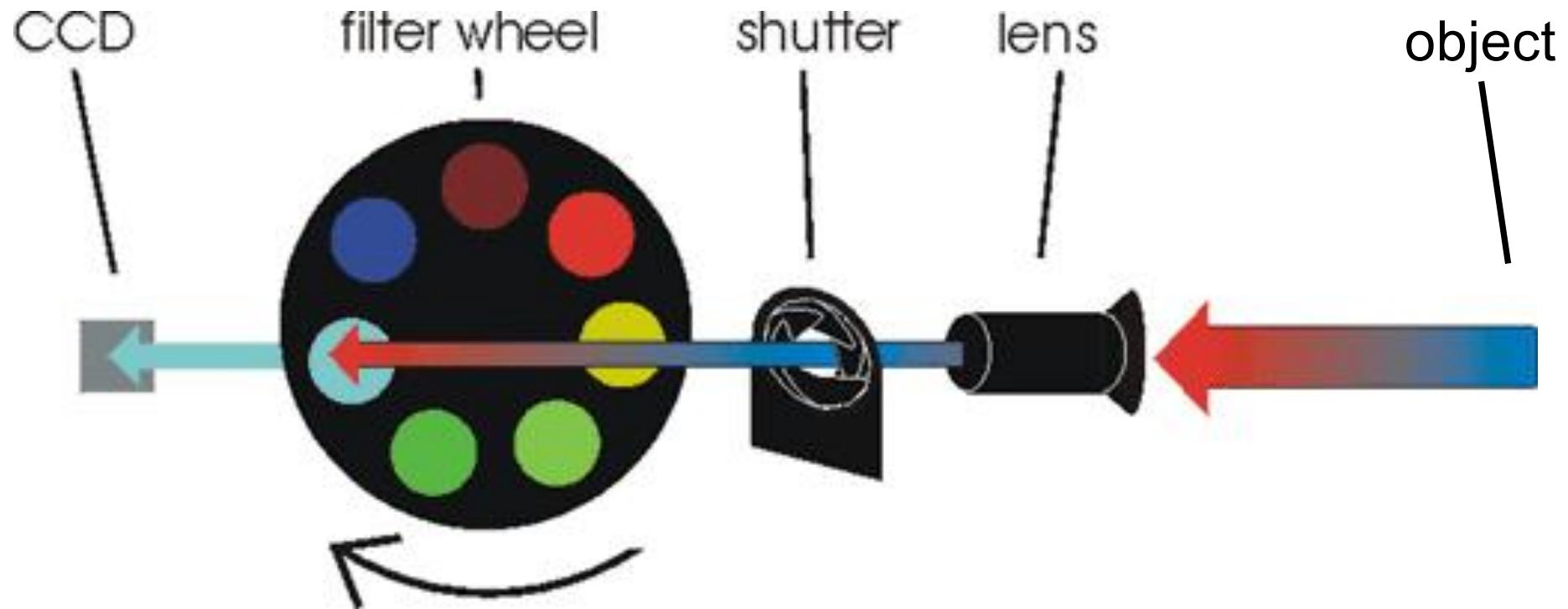
Acquiring multispectral images

Several ways of obtaining multispectral images

- Filter-based devices
 - Filter wheels
 - Programmable filters
- Diffraction-based devices
 - Pushbroom imaging
- Narrow-band illumination

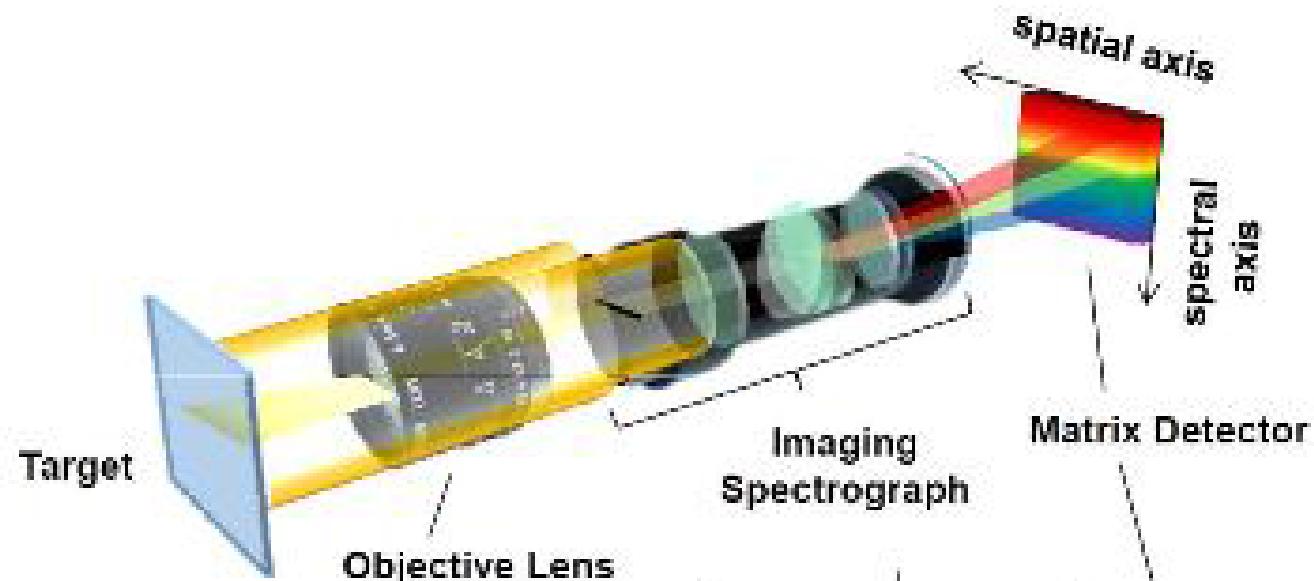
Acquiring multispectral images

Filter Wheel



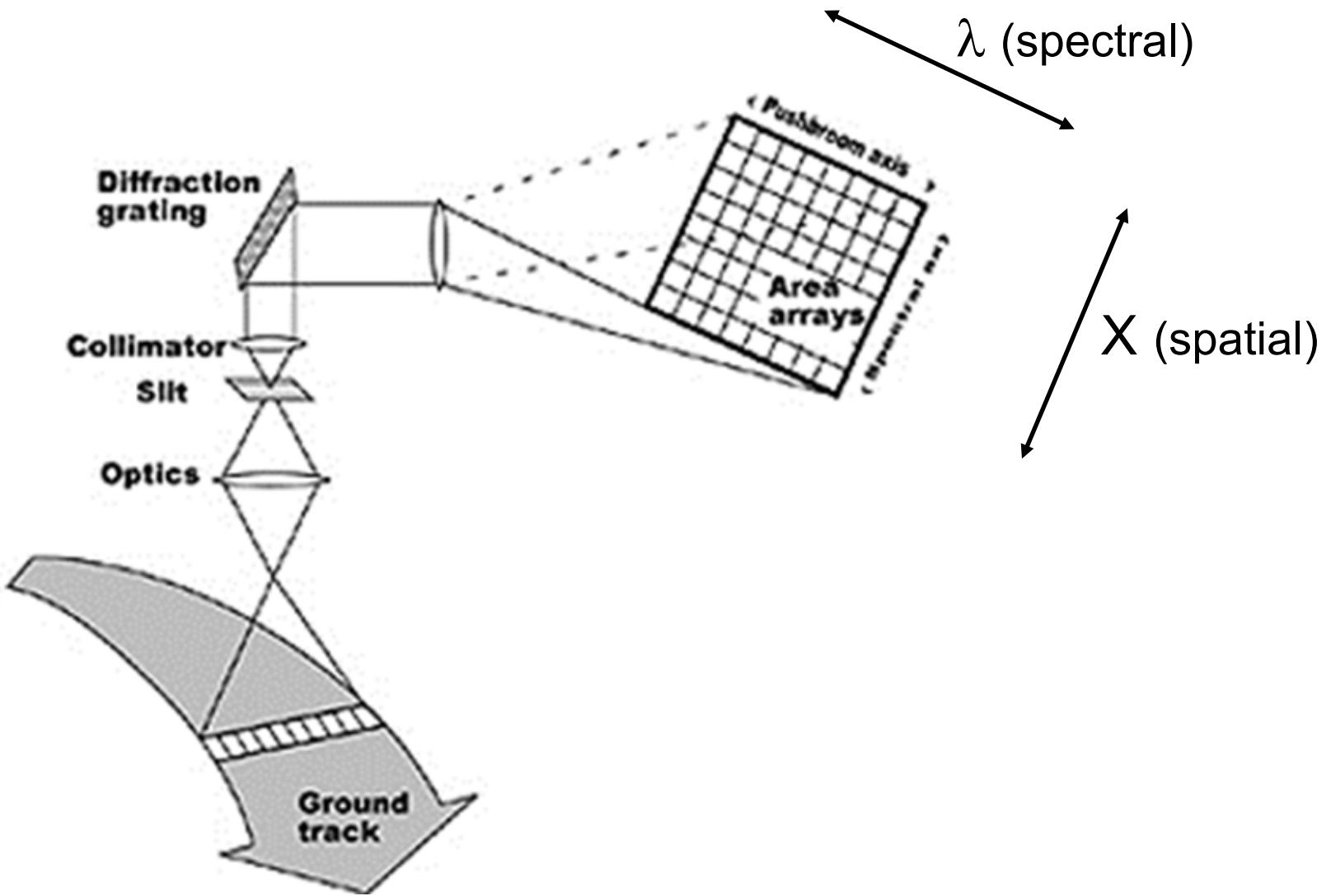
Acquiring multispectral images

Pushbroom



Acquiring multispectral images

Pushbroom



Source: <http://rst.gsfc.nasa.gov/Intro/pushbroomX.jpg>

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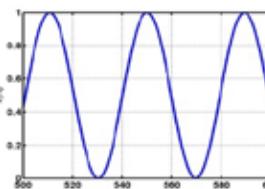
Acquiring multispectral images

Programmable Filters

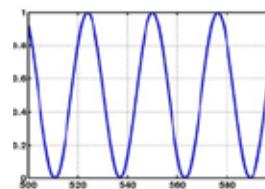
- Made of liquid crystal elements.
- By switching them on in different combinations, the filter can be configured to pass different wavebands.
- Can switch rapidly between bands to duplicate the effect of changing filters in the filter wheel.
- One programmable filter can mimic several hundred separate filters.



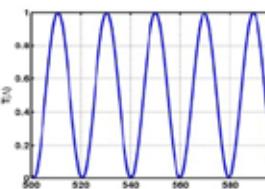
T1



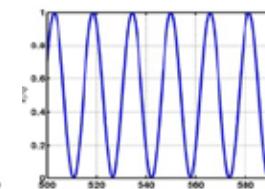
T2



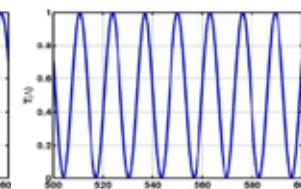
T3



T4

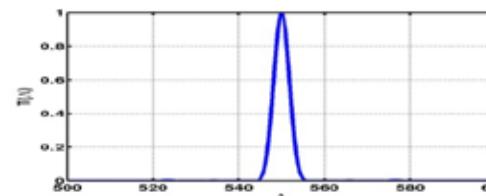


T5



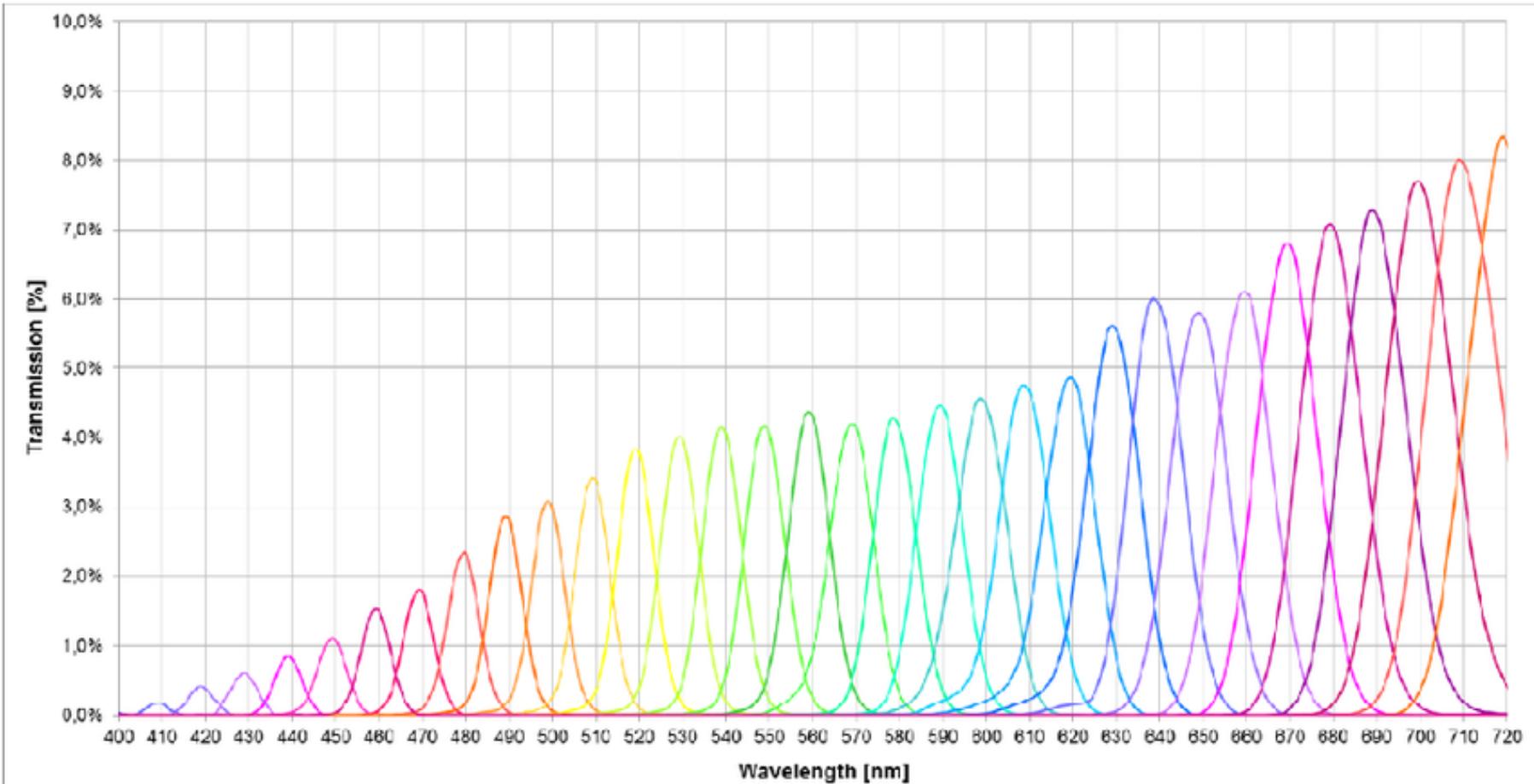
T6

$T1*T2*T3*T4*T5*T6$



Acquiring multispectral images

Programmable Filters



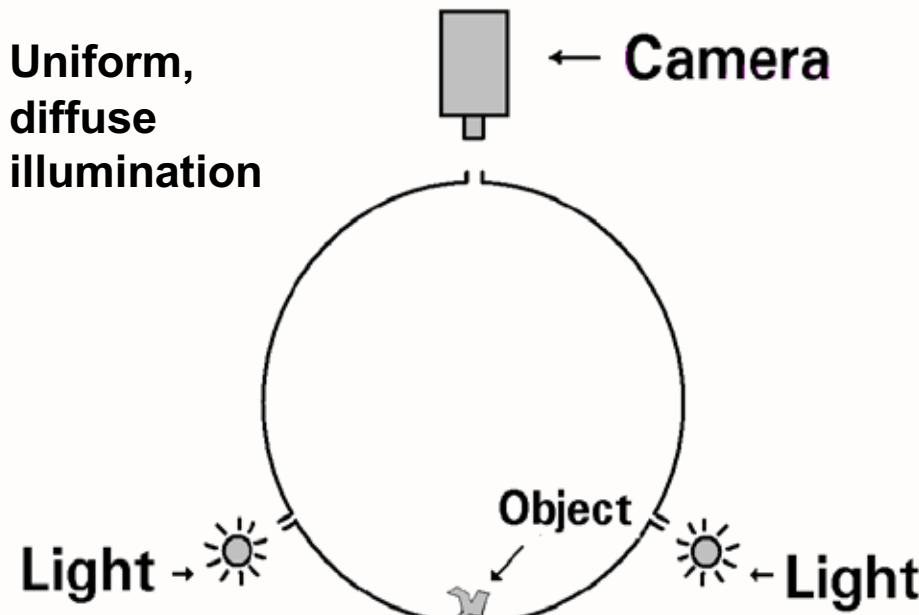
QE for VariSpec (C.R.I.) programmable filter

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Acquiring multispectral images

Narrow band illumination

Integrating sphere



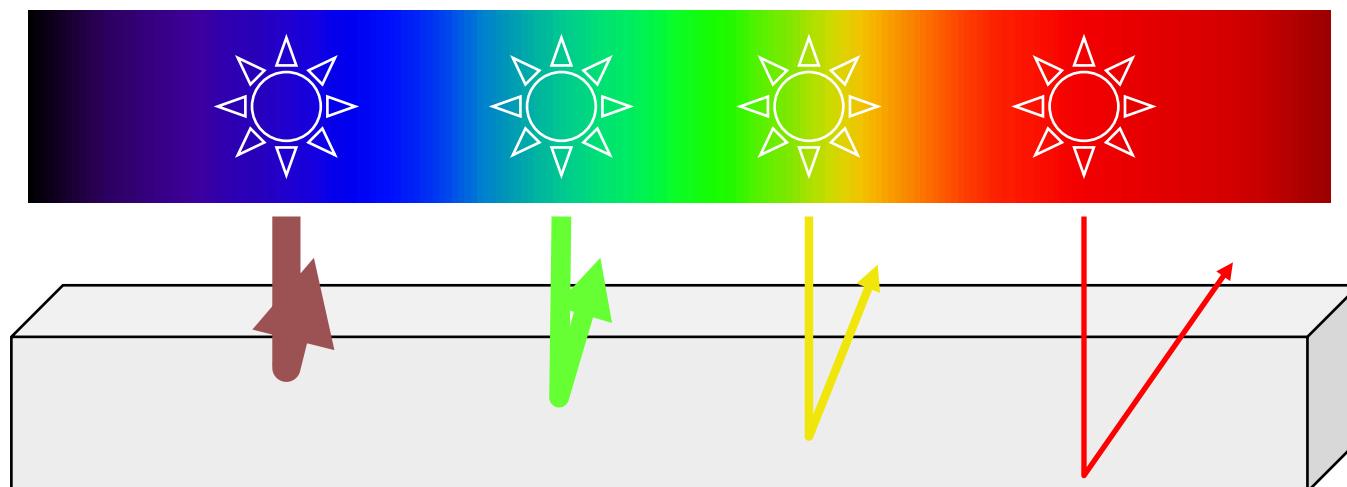
LEDs as light source



Multispectral image analysis

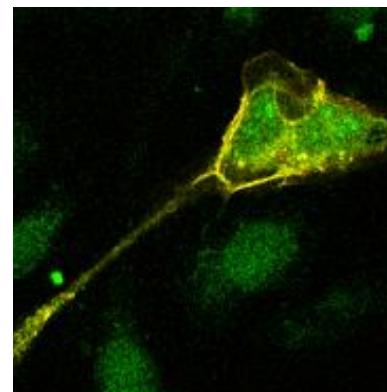
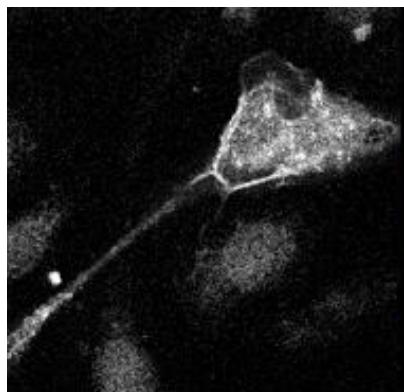
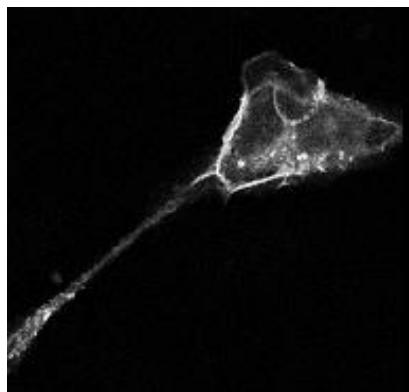
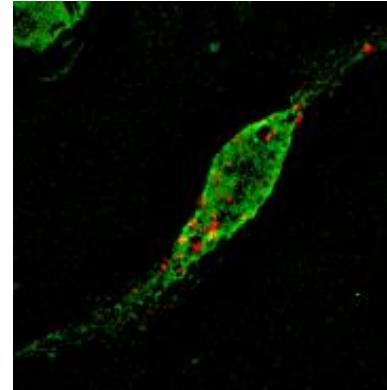
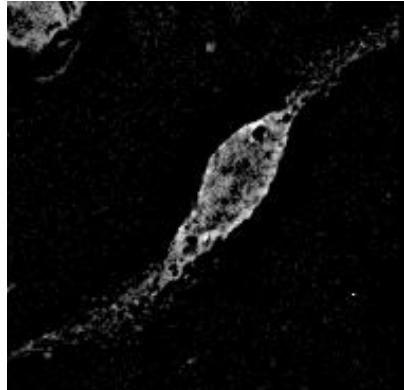
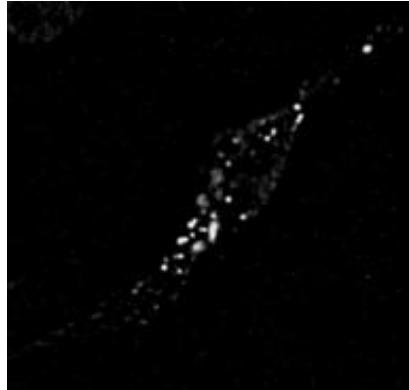
Measurable properties

- Reflectance
- Absorption
- Emission
- Depth of penetration



Kinds of applications

Visualisation



Proteins interacting

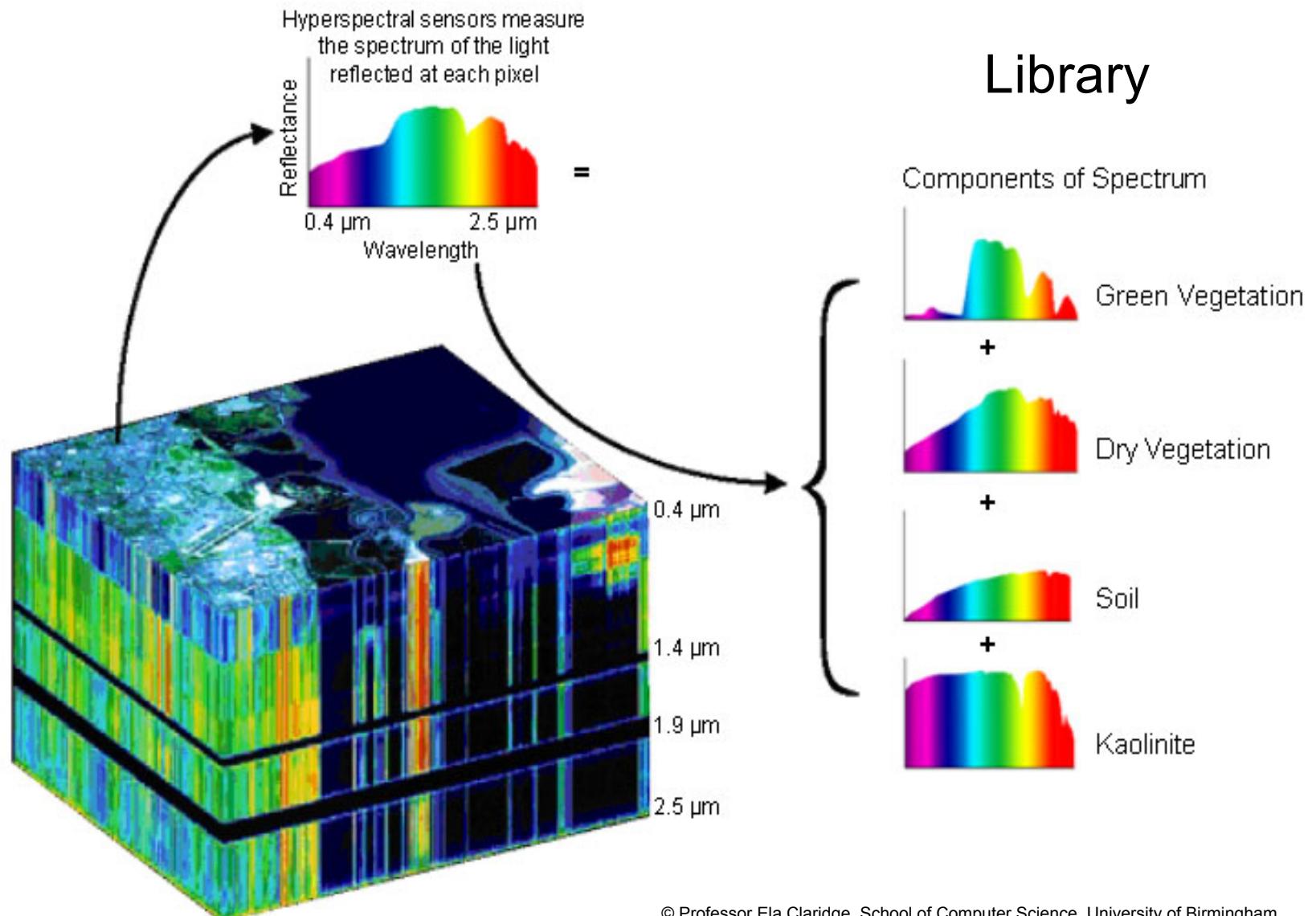
Fluorescence
levels imaged
through filter
centred at $\lambda 1$

Fluorescence at $\lambda 2$

$\lambda 1$ mapped to red
 $\lambda 2$ mapped to green
Where fluorescence is coincident at
 $\lambda 1$ and $\lambda 2$, we see yellow as
superposition of red and green

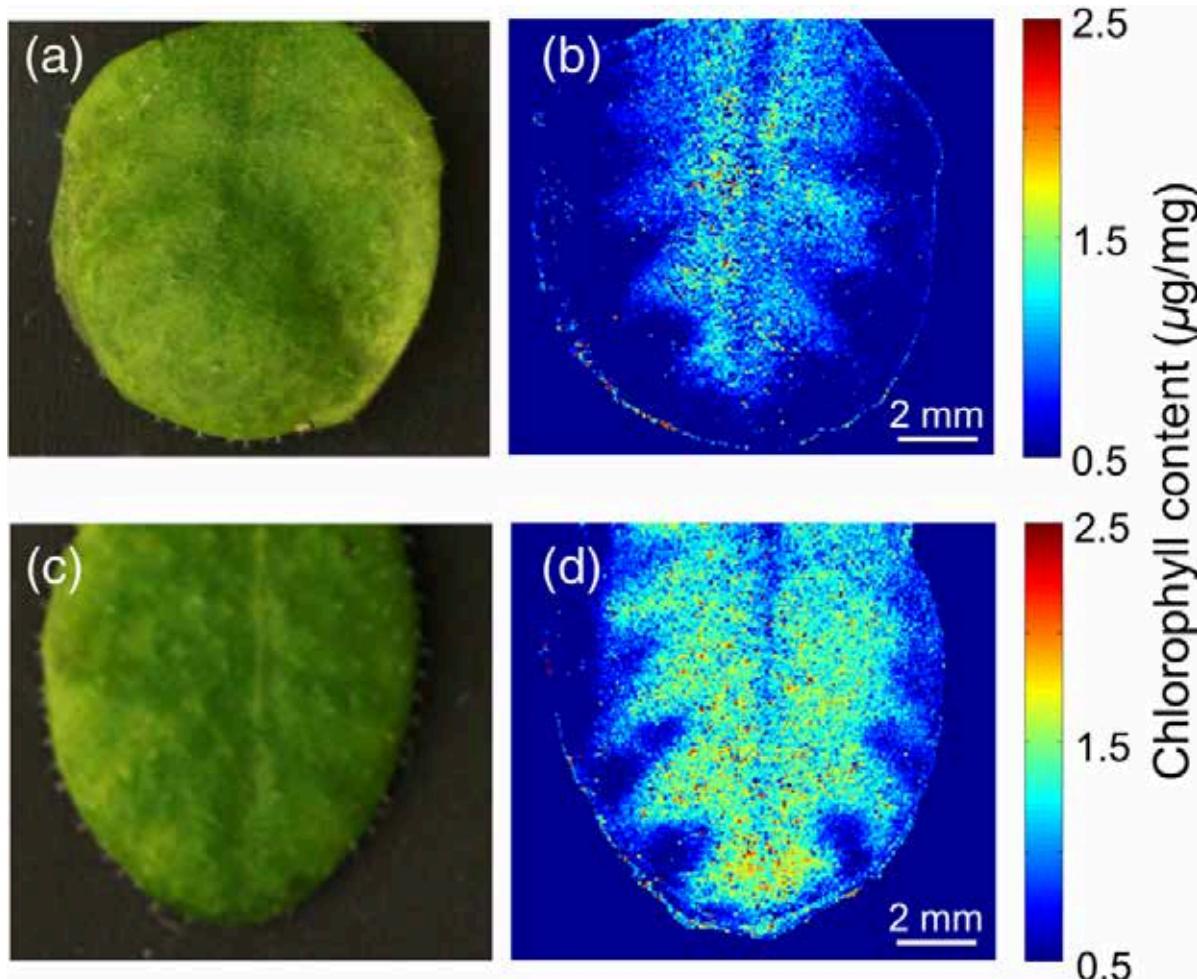
Kinds of applications

Classification



Kinds of applications

Quantitative analysis



http://biomedicaloptics.spiedigitallibrary.org/data/journals/biomedo/934852/jbo_21_1_016008_f003.png

Application areas

Arts



<http://thecreatorsproject.vice.com/blog/how-art-experts-discovered-a-hidden-portrait-beneath-a-picasso-masterpiece>

Application areas

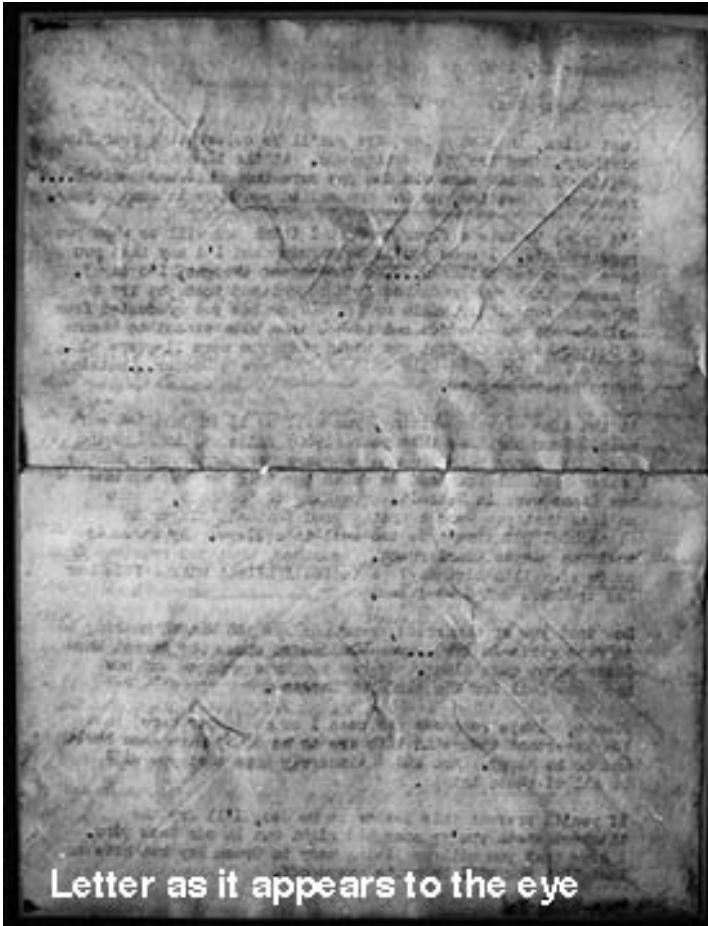
Archeology



In 1996, a Georgian scholar used ultraviolet light to read a Sinai palimpsest with an overtext in medieval Georgian. He found that the underlying text was written in Caucasian Albanian, and was the first example of a text written in this now-extinct language.

Application areas

Restoration



Dear Jim,
I hope you take big pleasure, finding your son
with the name Jim and would rather be
known as Jim or Edward. I seemed to mind
over because you feared being called Jim as
you got older and considered it a child's
name.
Older you will be - how you get this letter,
be the good Lord willing.
You are now in 5th grade and Mrs. Daniels
is your teacher. You have good of knowledge
and your teacher makes you do often work
of it. You had a fine report card the last period over
Dance, and I am friend of you. You are taking
Spanish, which I think is a right language
since you will meet many, you have braces
on your top teeth, a pinky shirt piece under
your coat has several spots. Your Dad and I, you
are great improvement, and feel I might have
made you a fine looking man.
You have quite turned the age wheel
in a bad combination with your sometime Dr. Derry
to fully realize your dearest girl - your best friend
several years back been Pat Sullivan -
By now you are too big to sit on my lap, but
remember the Friday night of our dancing and visit
to the beach.

**IR Luminescence restores
water damaged document**

<https://people.rit.edu/andpph/photofile-b/ir-letter-comparison-1.jpg>

Application areas

History



Multispectral analysis of a document in the Library of Congress revealed that a draft of the Declaration of Independence originally named Americans "subjects" instead of "citizens".

Application areas

Forensics

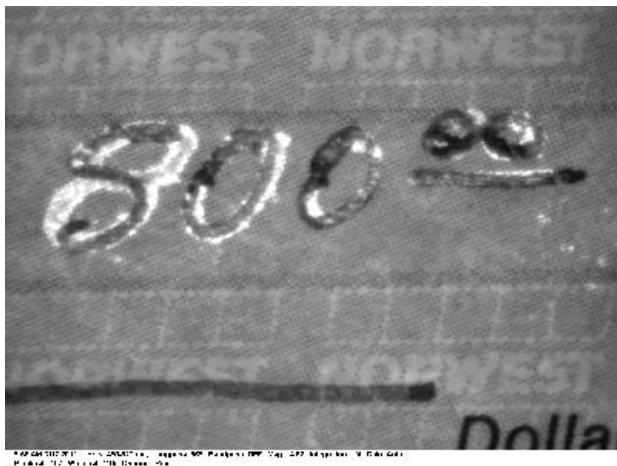
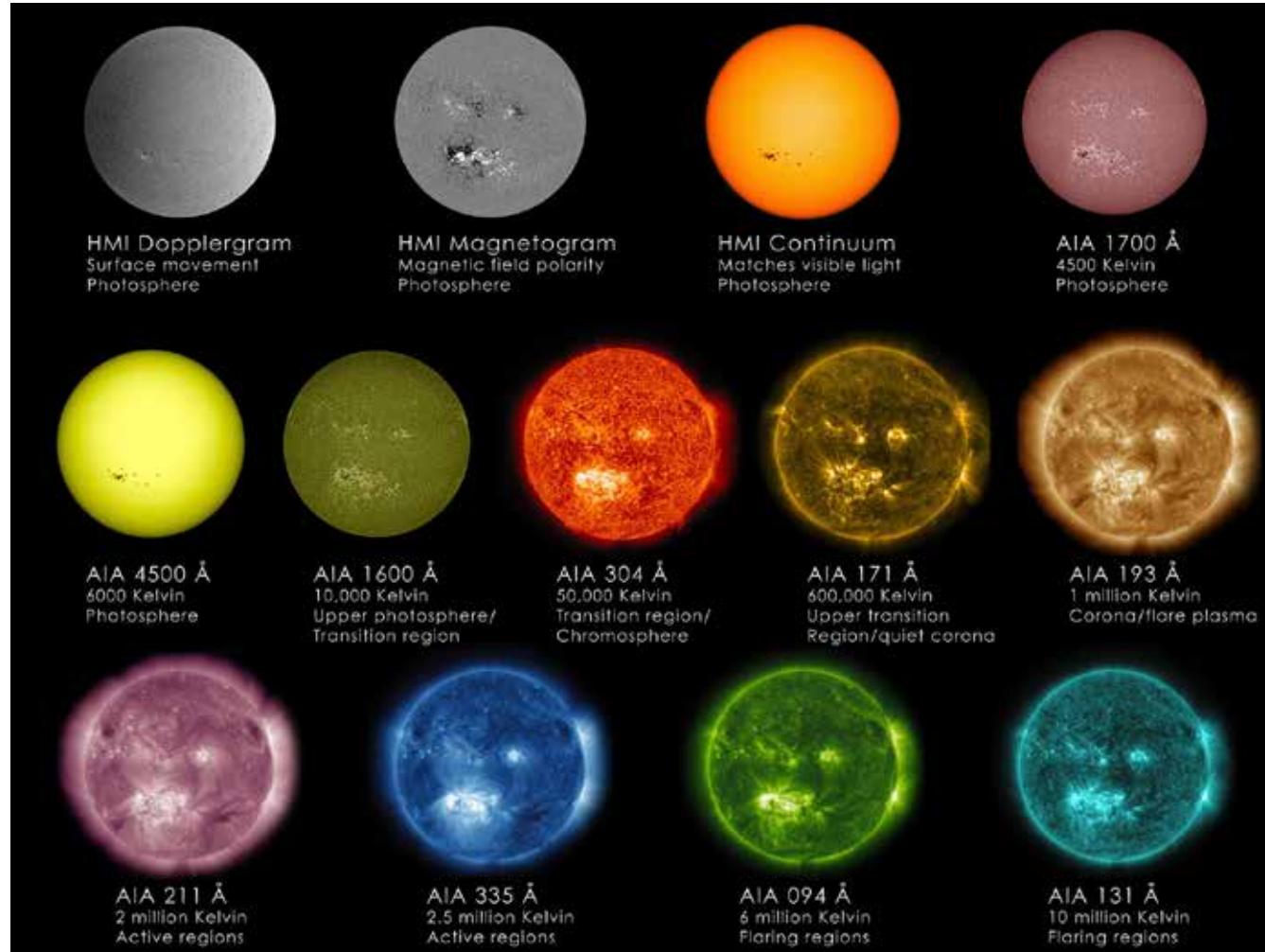


Image of a check with numbers fraudulently added to increase its value. The ink used to write the two zeros in the number "900" is different than the one used to write the remaining entries as revealed through IR luminescence and the VSC2000's integration feature.

<https://github.com/golanlevin/ExperimentalCapture/blob/master/docs/hyperspectral.md>

Application areas

Astronomy



Astronomers use multispectral imaging to understand the Sun.

Application areas

Environment



Google has recently made satellite **thermal imaging** of roofs available to the public, to prompt people's awareness about the heat inefficiency of their homes.

Application areas

Environment

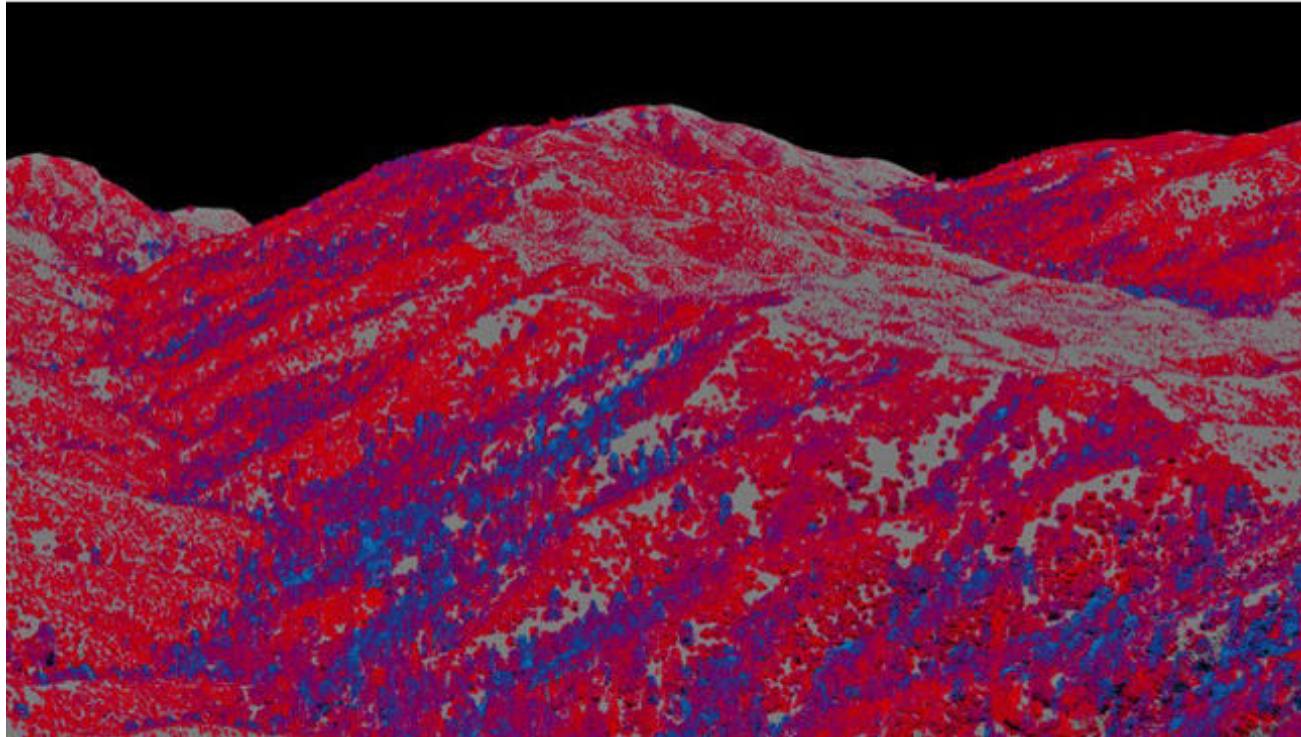


4-band multispectral imagery.

The infrared band responds to the chlorophyll found in vegetation and allows for the identification and examination of urban tree canopies.

Application areas

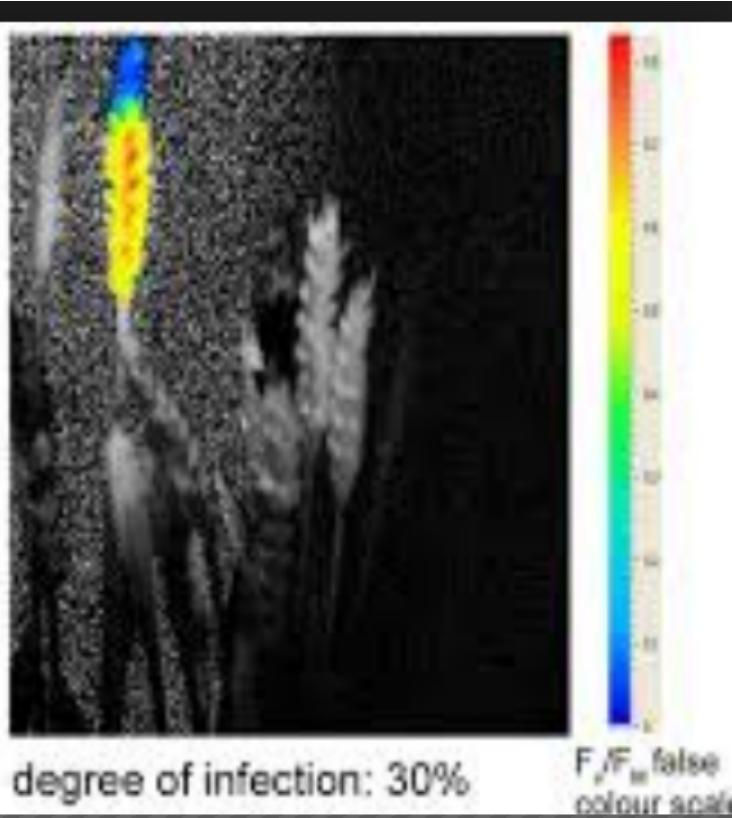
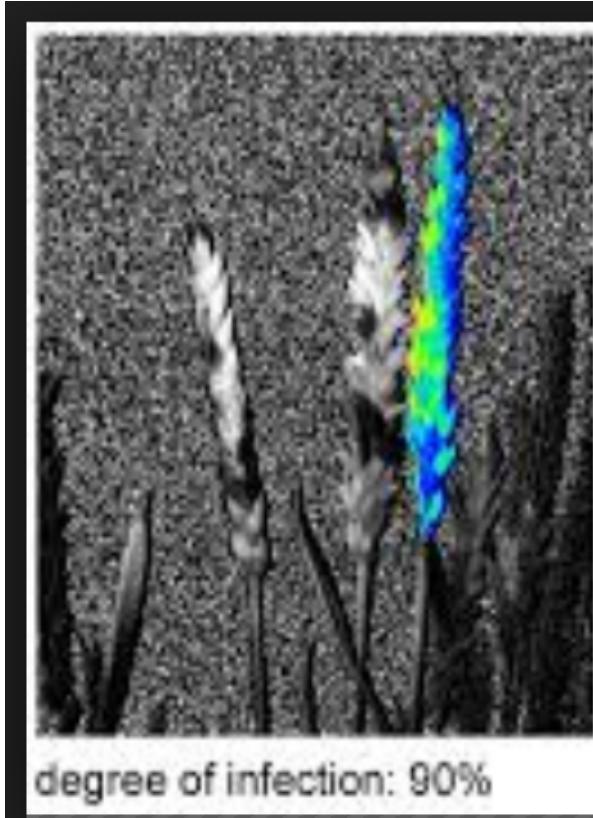
Environment



The spectrometer works in conjunction with a laser that fans out beneath the aircraft, creating a 3-D image of the forest below. By marrying the data from the spectrometer and the laser, topographic images created show the condition of the forest. Healthy trees are blue, and drought-stressed trees run from mild (yellow) to severe (red).

Application areas

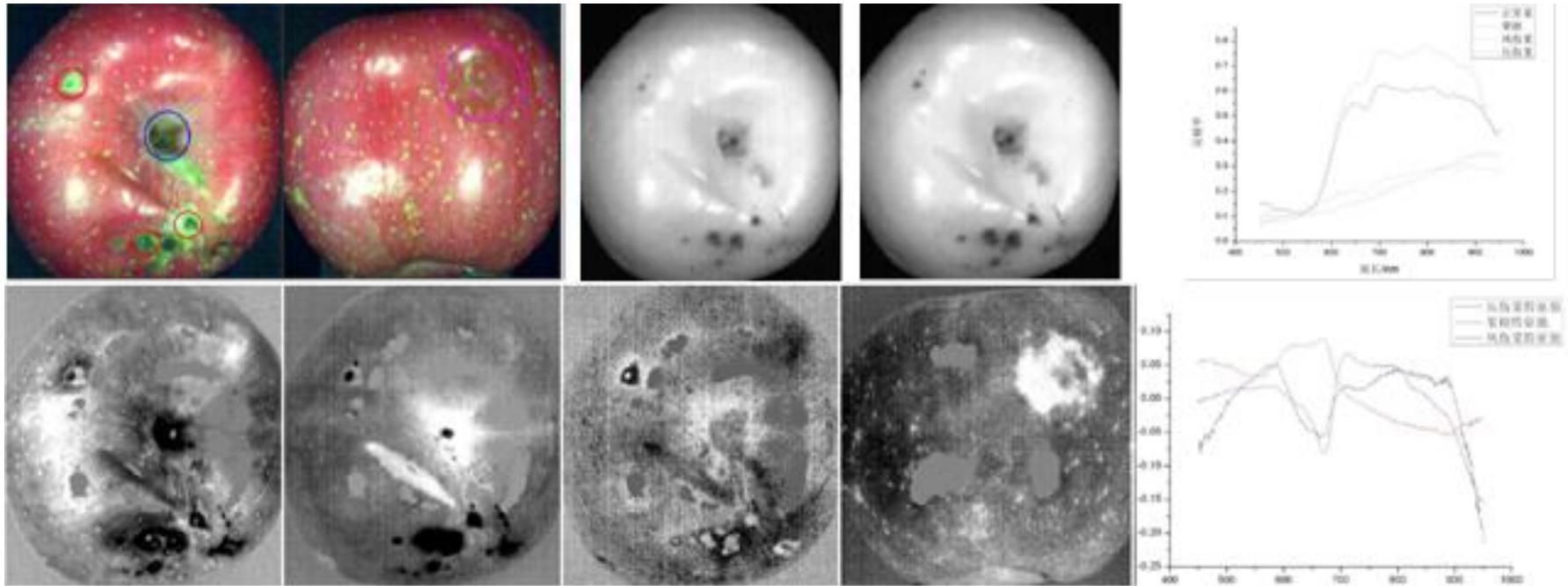
Agriculture



Hyperspectral and chlorophyll fluorescence Imaging for early detection of plant diseases, with Special Reference to Fusarium spec. Infections on Wheat

Application areas

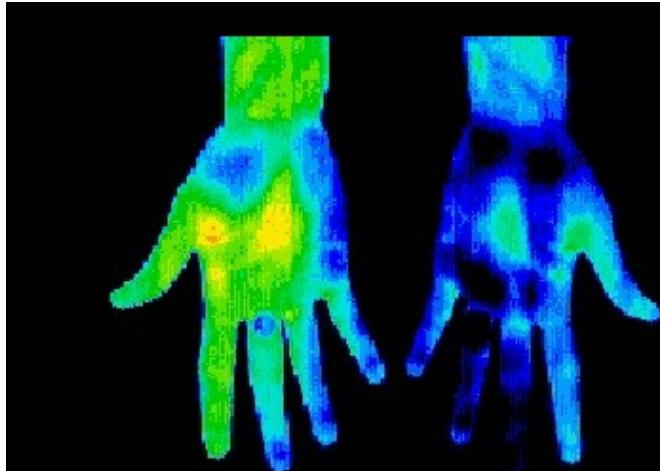
Agriculture



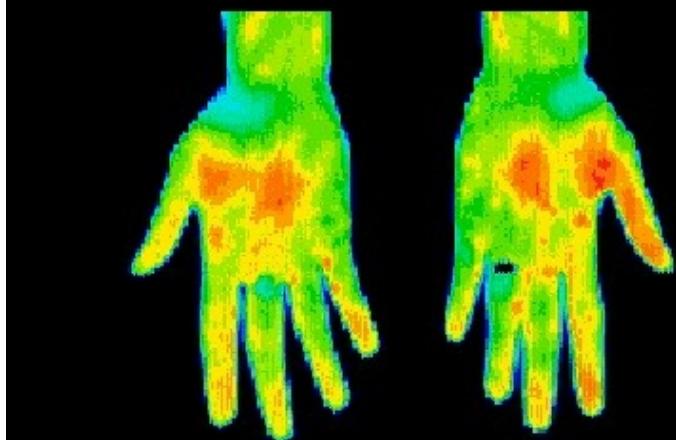
Healthy and damaged fruit areas show different reflectance spectra.

Application areas

Medicine



RSD (CRPS) of the left hand.
Glove-like hypothermia.

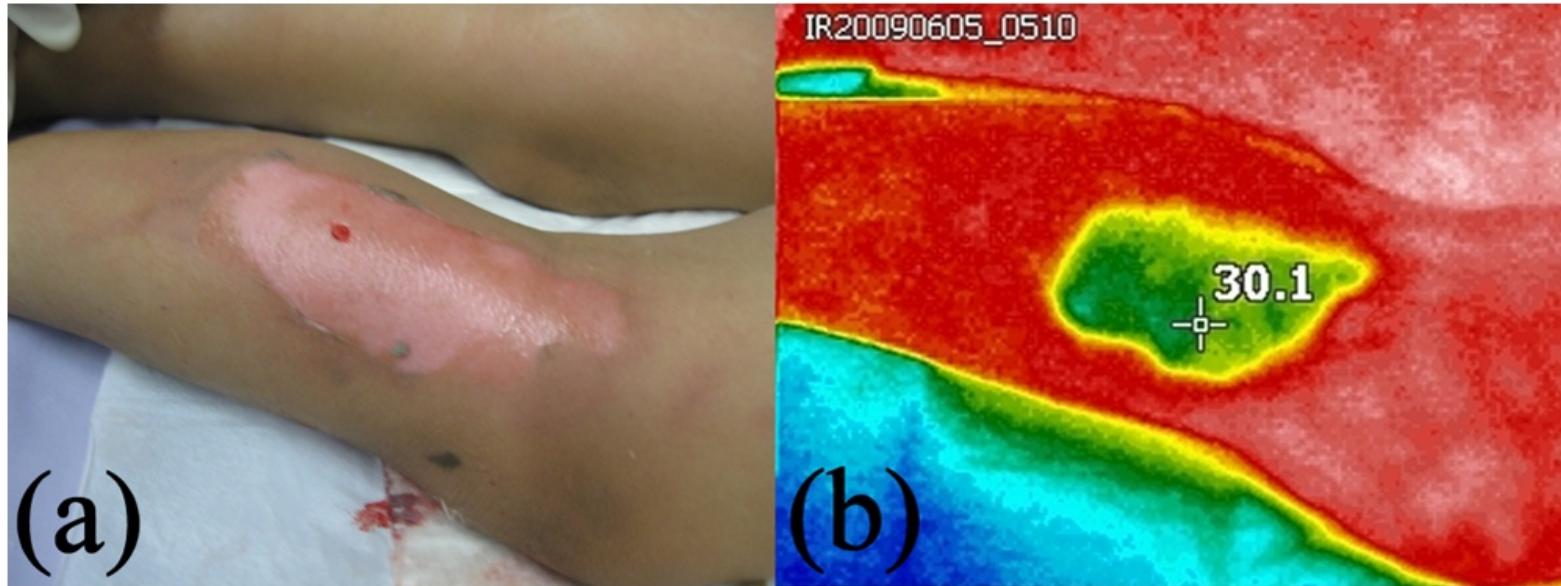


The return of normal sympathetic
function after treatment was short
term.

Thermal imaging

Application areas

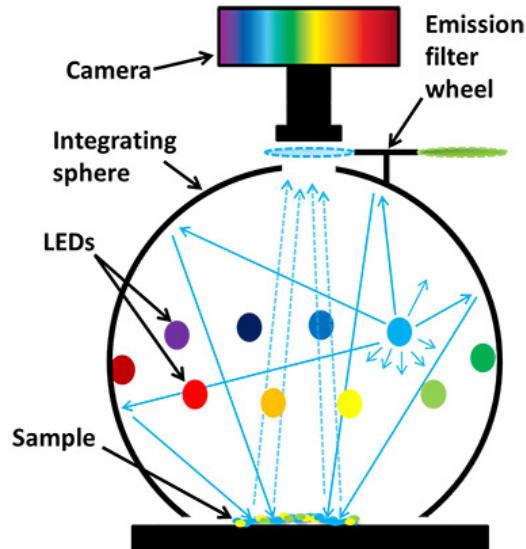
Medicine



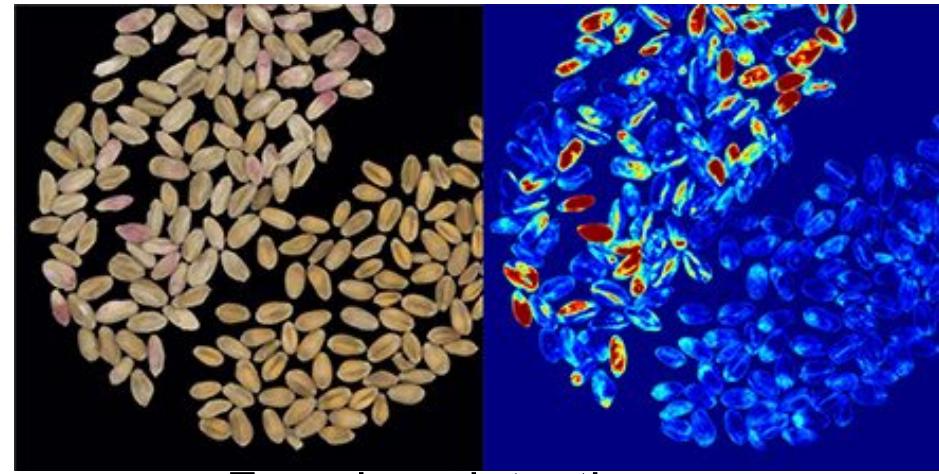
Thermal imaging of the skin burns

Application areas

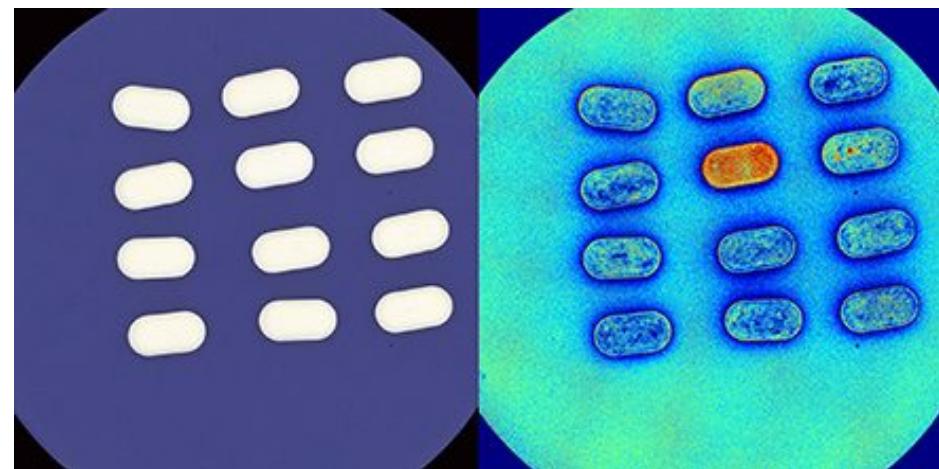
Quality control



VideometerLab Multispectral Imaging System



Fusarium detection



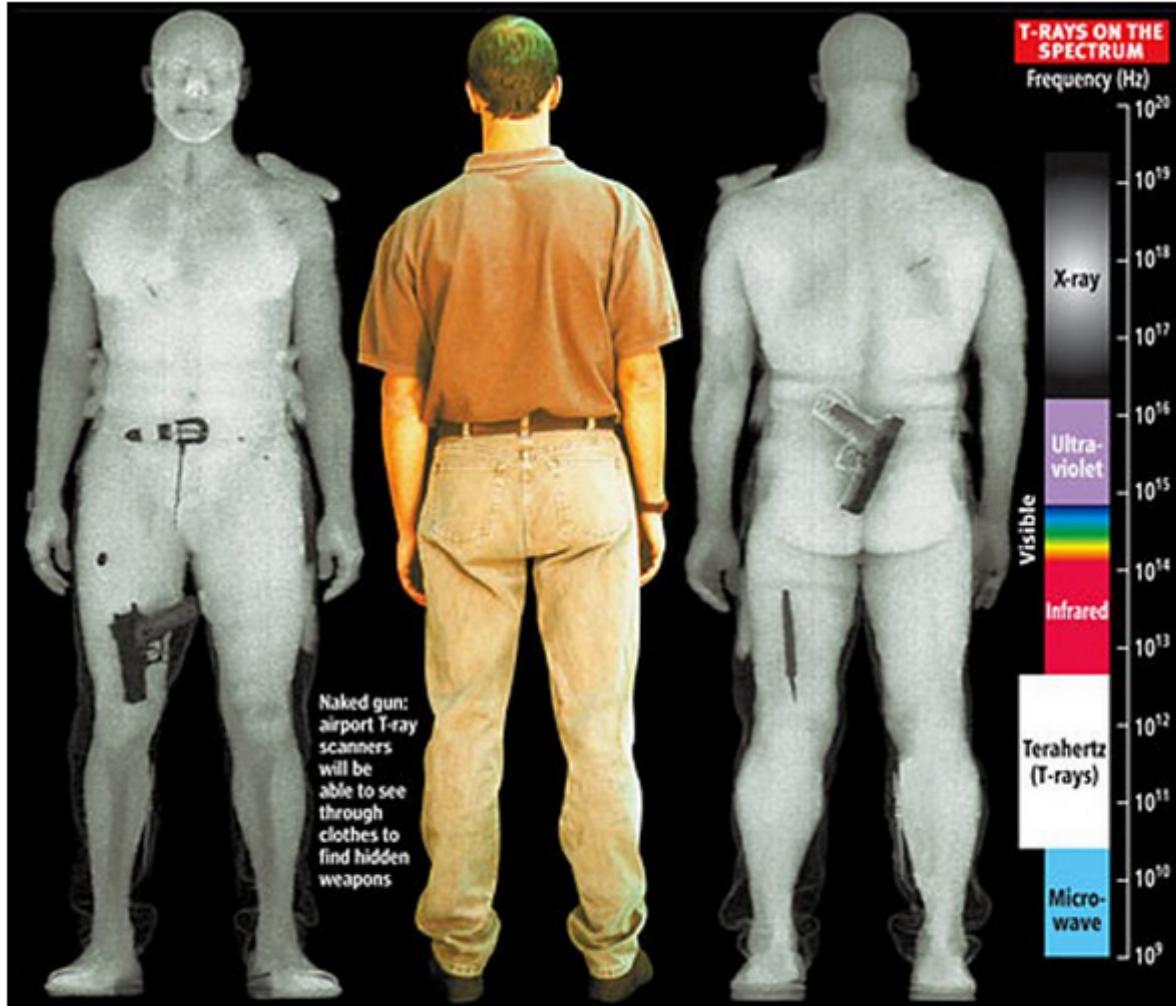
Out of range tablet identification

<http://analytik.co.uk/product/multispectral-imaging-videometerlab-analyser/>

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Application areas

Security



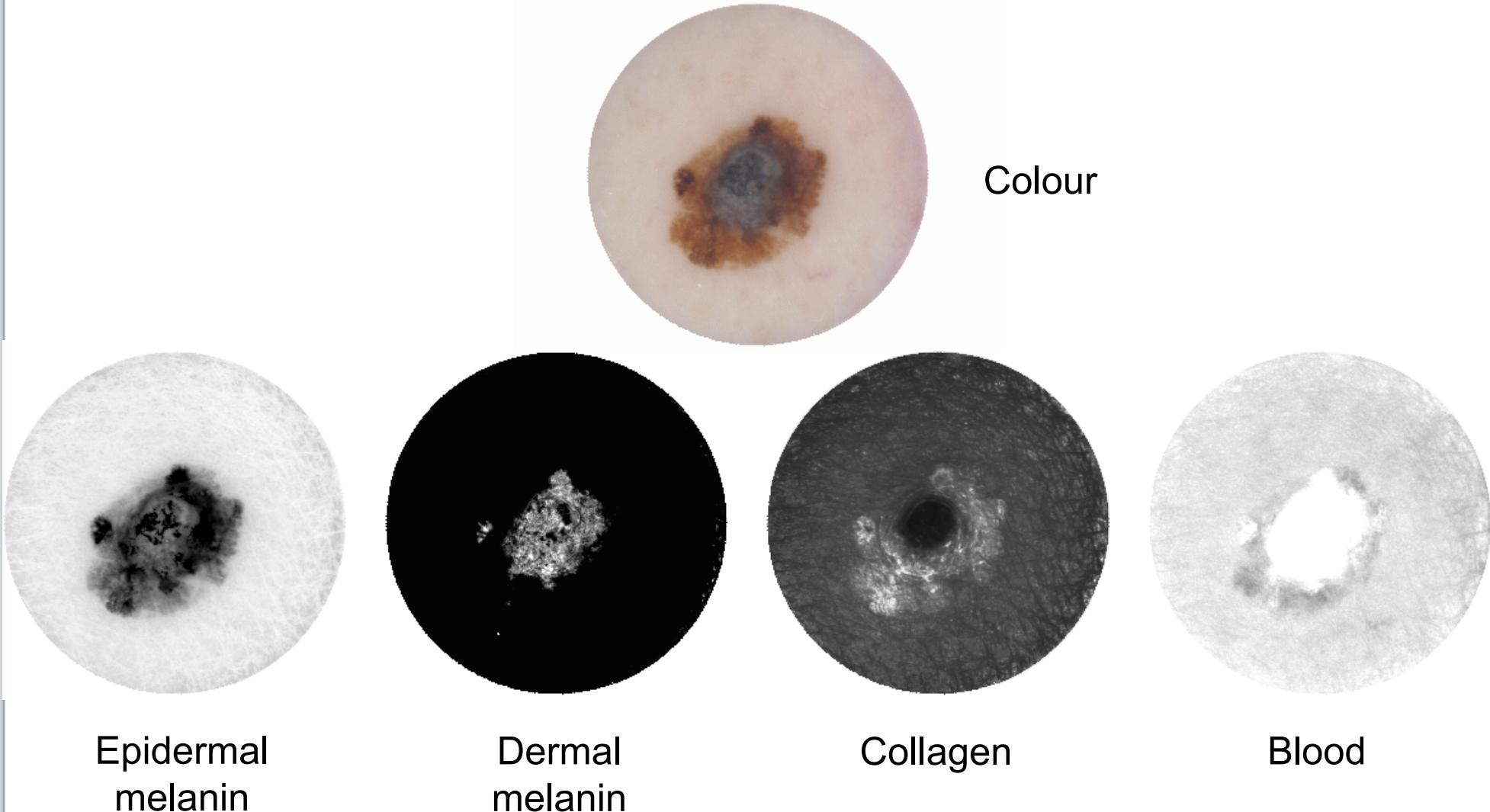
Millimeter wave and
Terahertz imaging

Research at Birmingham

Multispectral imaging for medical diagnosis

Research at Birmingham

Early diagnosis of skin cancer



Preece S and Claridge E (2004) Spectral filter optimisation for the recovery of parameters which describe human skin.
IEEE Trans. PAMI 26(7), 913-922.

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Research at Birmingham

Early diagnosis of skin cancer



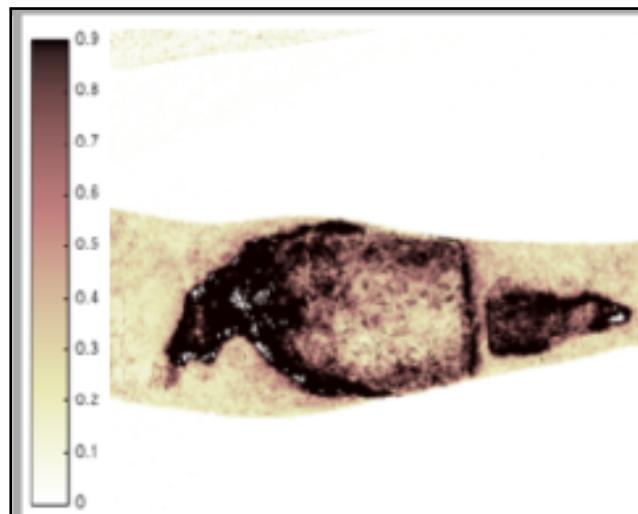
SIAscopy / MoleMate

Claridge E, Cotton S, Moncrieff M, Hall P (2006) Spectrophotometric Intracutaneous Imaging (SIAscopy): Method and clinical applications. Chapter 37 in *Handbook of Non-Invasive Methods and the Skin* (2nd ed). Serup J, Jemec GBE, Gross G (Eds), 215-225, CRC Press.

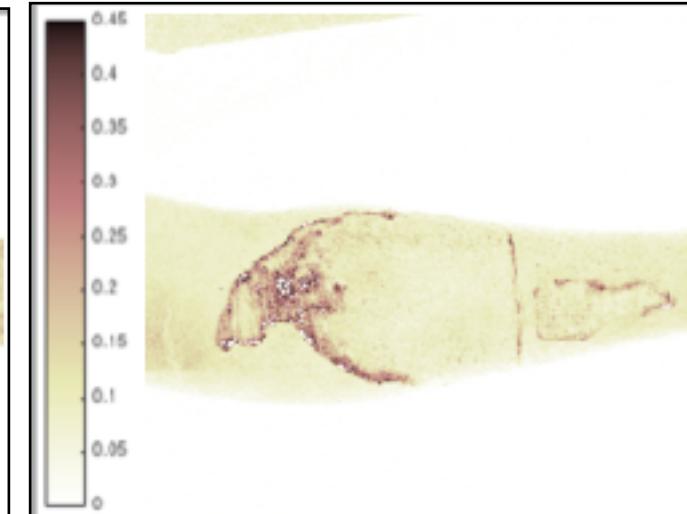
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Research at Birmingham

Burns assessment



Blood perfusion



Pigment damage

SIAscopy

Research at Birmingham

Detecting diabetic complications in the eye

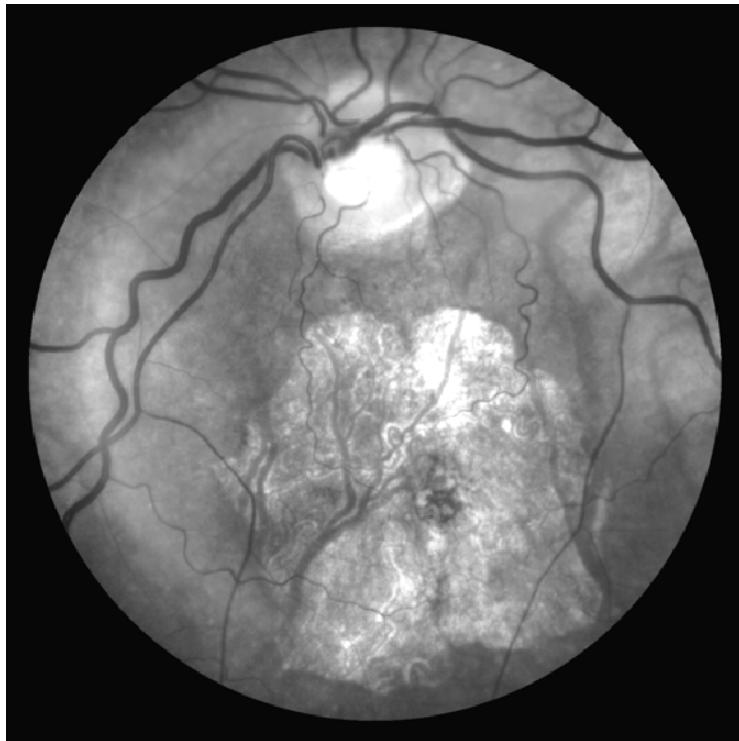
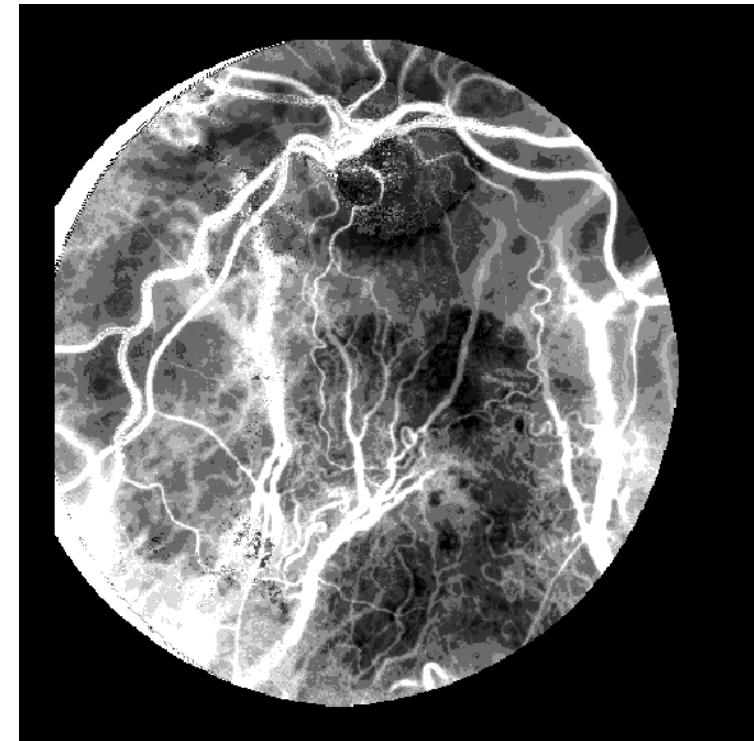


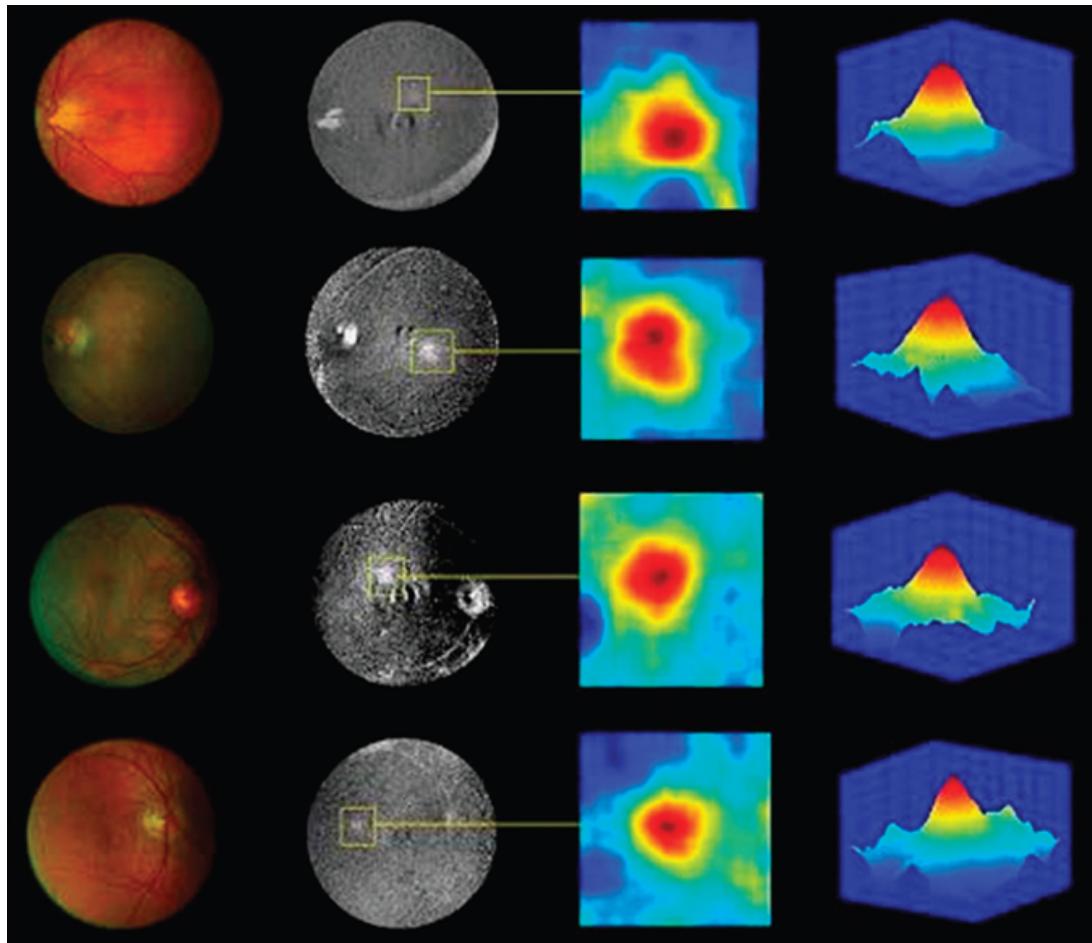
Image of retina



Haemoglobin map

Research at Birmingham

Signs of age related macular degeneration



Macular pigment
maps

Styles IB, Calcagni A, Claridge E, Orihuela Espina F, Gibson JM (2006) Quantitative analysis of multispectral fundus images. *Medical Image Analysis* 10(4), 578-597.

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Skin pigment maps



<http://www.cs.bham.ac.uk/~exc/Research/projects.php>

<http://www.cs.bham.ac.uk/~exc/Research/publications.php>

In this lecture we have covered:

- Multispectral imaging
 - Why colour that we see does not always tell the full story
 - General principles of multispectral imaging
 - How to acquire multispectral images
 - Applications

Next lecture:

- Overview and summary of the course
- Structure of the exam paper
- Revising for the exam

Further reading and experimentation

- Links to the articles and image sources are included in the individual slides, where relevant.