# Bio-medical X-ray Imaging with Spectroscopic Pixel Detectors


Anthony Butler

MARS Project, New Zealand


Canterbury District Health Board
Te Poari Hauora o Waitaha

# Goal

To review the potential benefits of spectral information for bio-medical X-ray imaging

# Goal

To review the potential benefits of spectral information for bio-medical X-ray imaging

*Imminent clinical reality*

Detector Technology

Clinical Application

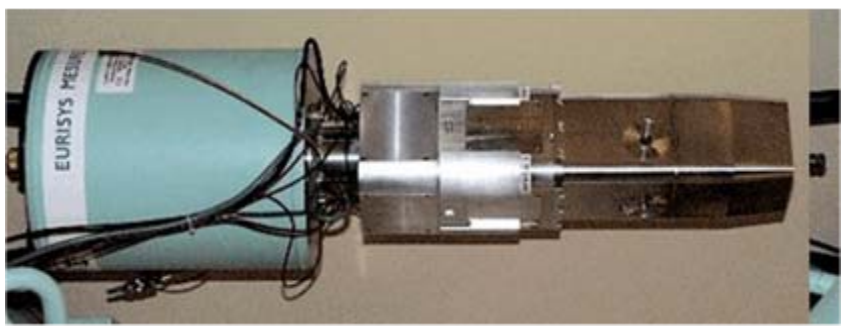
# Disclosure

The University of Canterbury is commercialising this technology.

# Spectroscopic imaging is now possible

Traditional spectrographs

(eg. Germanium crystals)

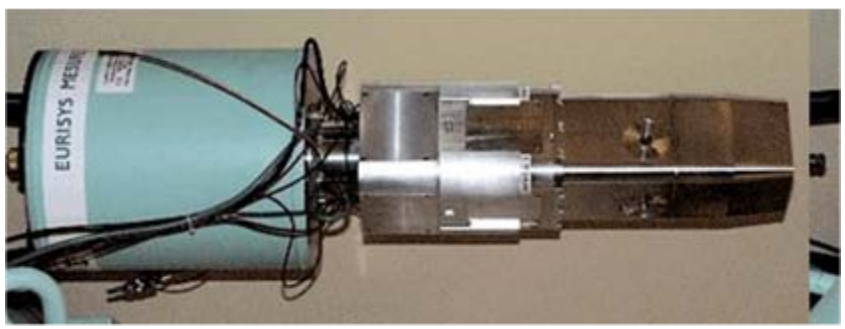


- 1 pixel
- 3 cm pitch
- 256 channels

# Spectroscopic imaging is now possible

## Traditional spectrographs

(eg. Germanium crystals)



- 1 pixel
- 3 cm pitch
- 256 channels

## Pixel technology

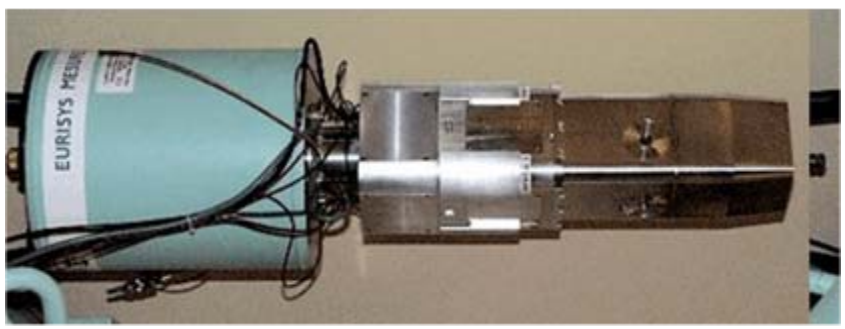
(eg. **Medipix**)

- 16,384 pixels
- 110 micron pitch
- 8 channels

# Spectroscopic imaging is now possible

Traditional spectrographs

(eg. Germanium crystals)



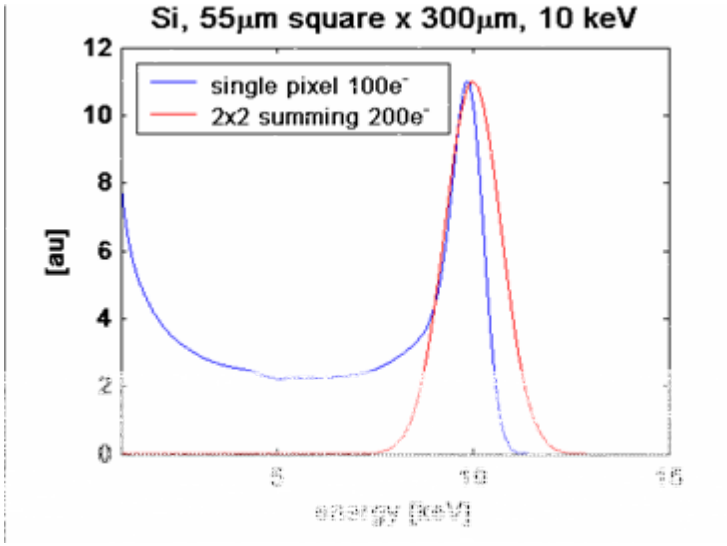
Pixel technology

(eg. **Medipix**)

**NMR ?**

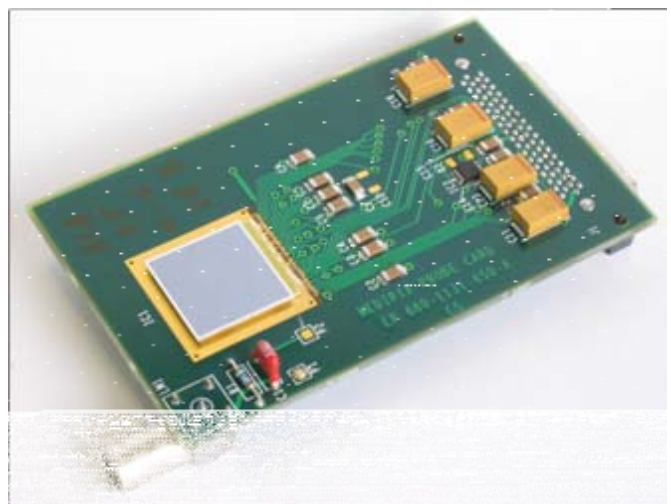
**MRI ?**

# Spectroscopic imaging is now possible




Pixel technology

(eg. **Medipix**)



**M**edipix **A**ll **R**esolution **S**ystem

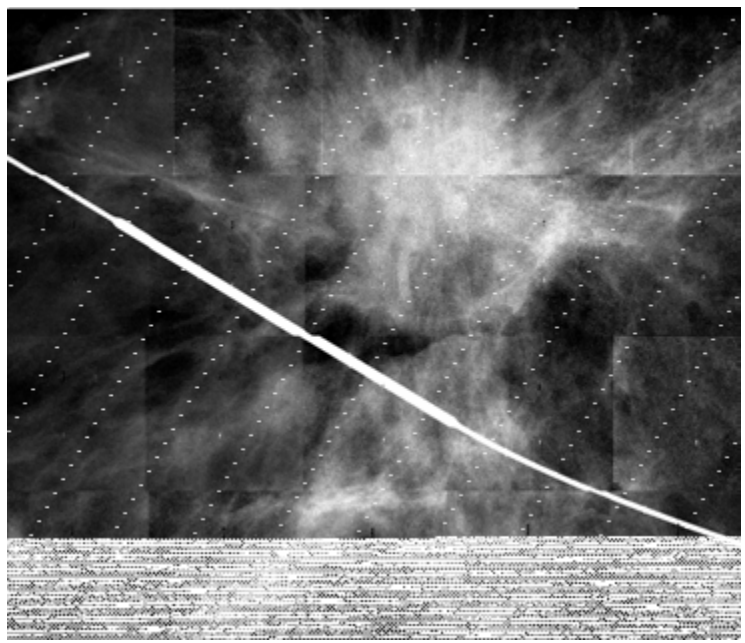
- Energy resolution
- Spatial resolution
- Temporal resolution

mars
Medipix All Resolution System

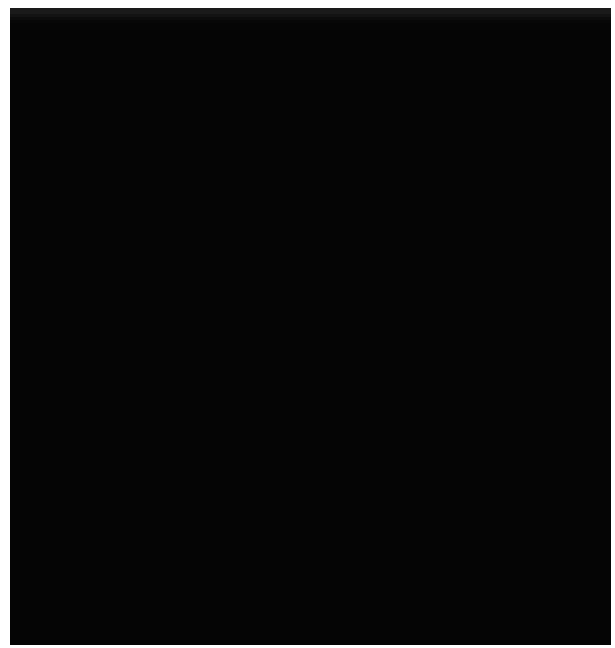
# Imaging

# Imaging

# Imaging



# Imaging



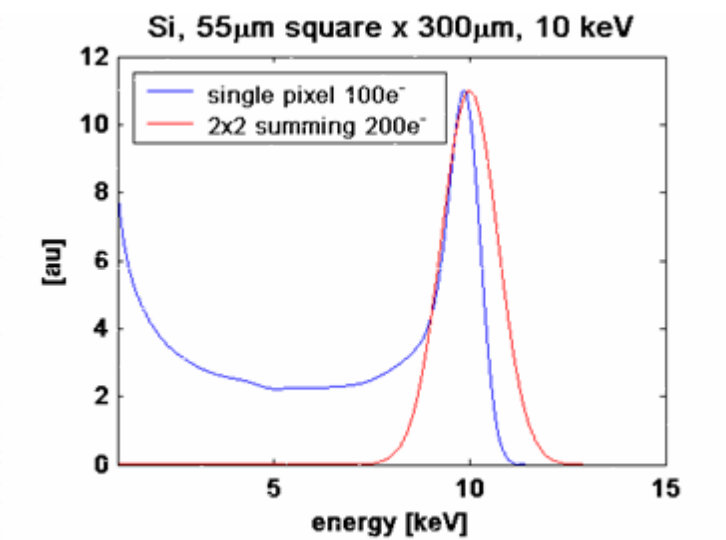
# Spectroscopic imaging is now possible

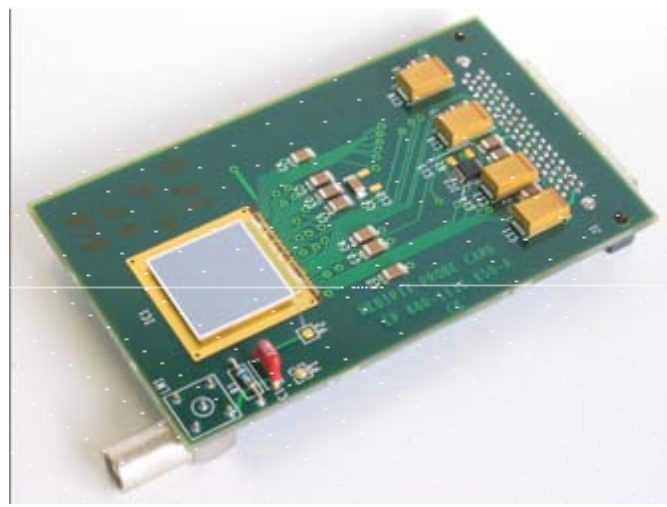
**M**edipix **A**ll **R**esolution **S**ystem

**Energy resolution**

Spatial resolution

Temporal resolution



Medipix

# Benefits of Spectral X-rays

- Better image quality
  - Less artefacts

    eg. Around coronary artery stents

- K-edge imaging
  - Better use of contrast agents

    eg. Less scanning

- Intrinsic tissue contrast
  - eg. Breast cancer from normal tissue

# Improving Image Quality

Aim:

To use the spectral nature of the detector to reduce beam hardening artefact in CT

# No Beam Hardening Artefact

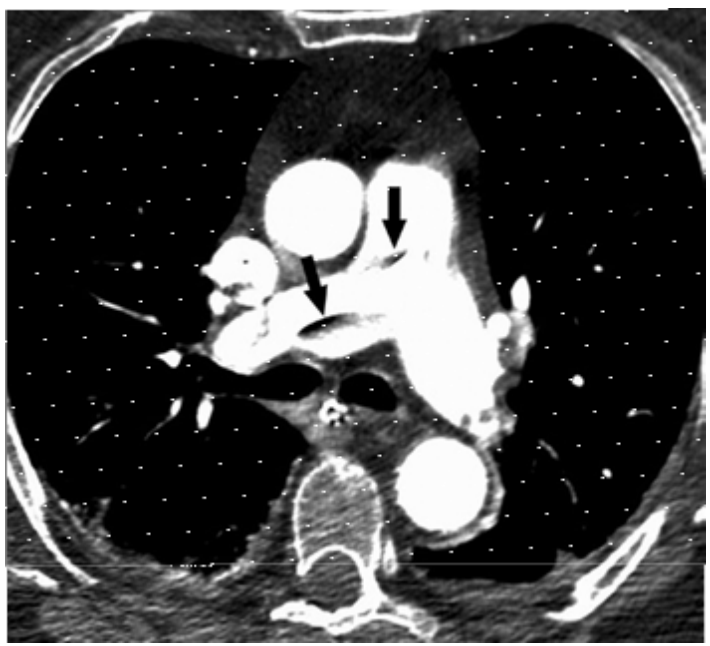
BH is failure of the approximation that:

The spectrum of transmitted X-rays is constant regardless of the object being scanned.

# No Beam Hardening Artefact

BH is failure of the approximation that:

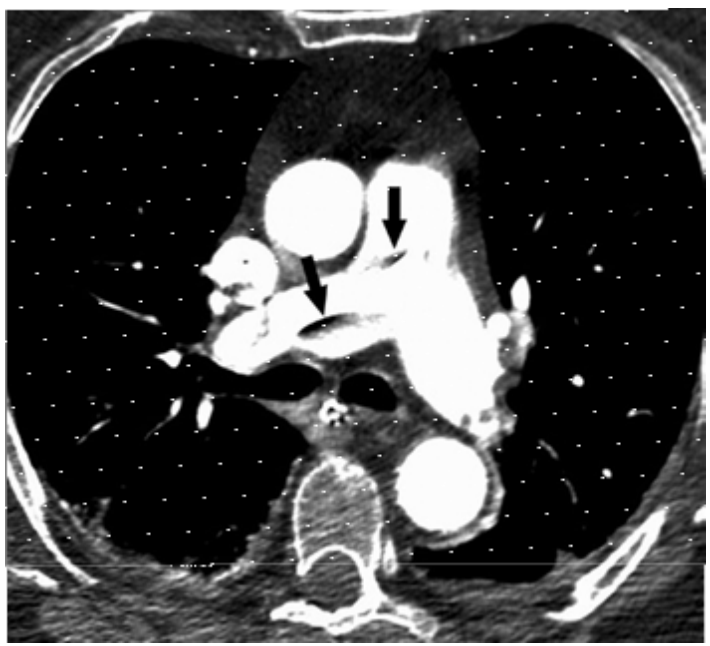
The spectrum of transmitted X-rays is constant regardless of the object being scanned.

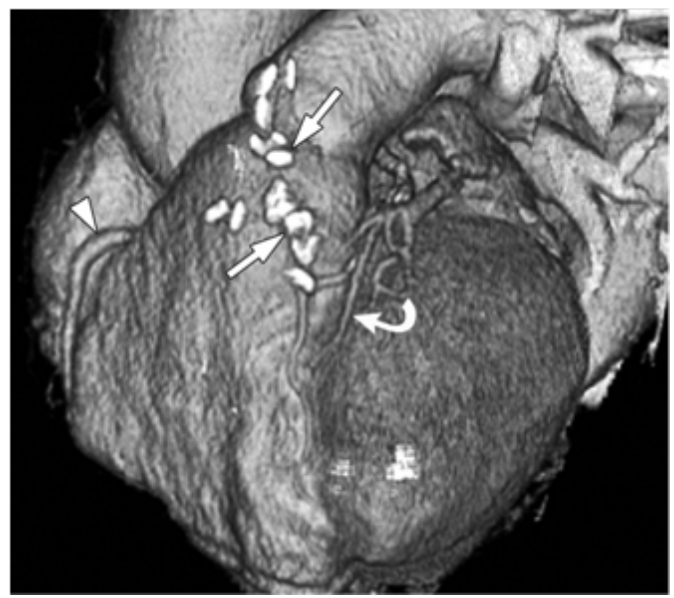


# No Beam Hardening Artefact

BH is failure of the approximation that:

The spectrum of transmitted X-rays is constant regardless of the object being scanned.





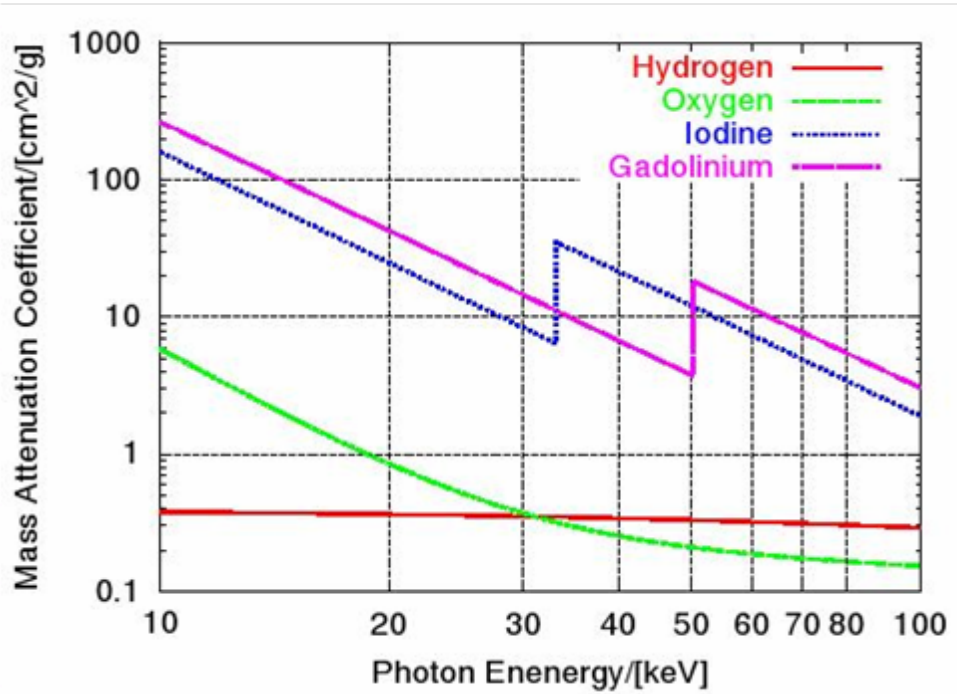
# K-edge Imaging

Aim:

To identify certain elements based on their k-edge.

Often these elements are used as contrast agents introduced to aid diagnosis.

# K-edge Imaging

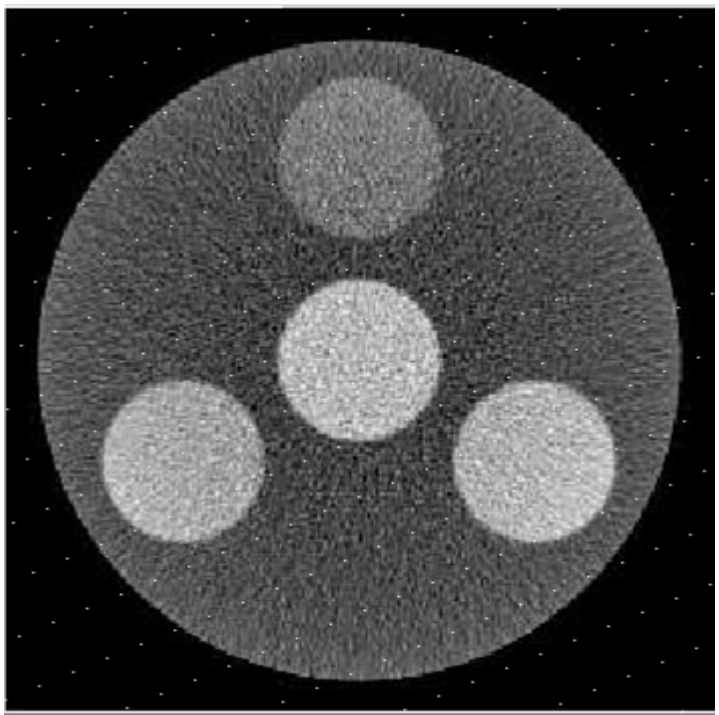



Vascular contrast agents:

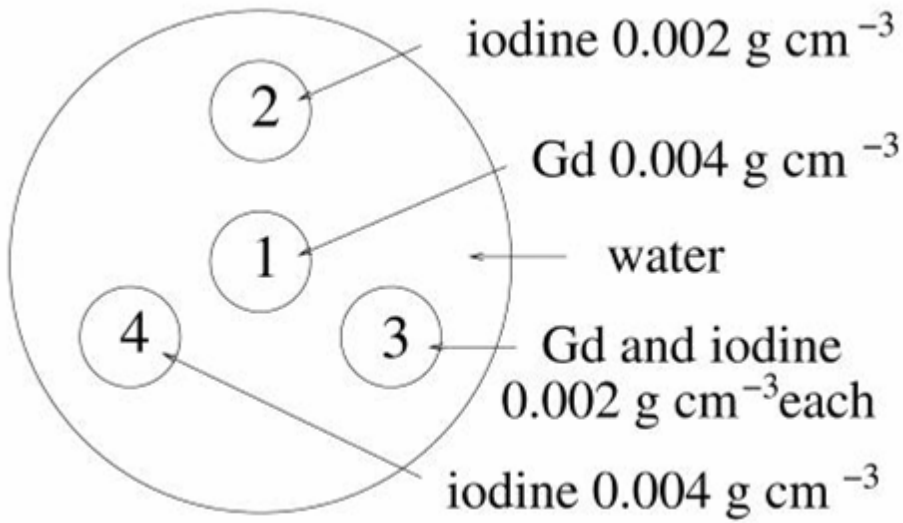
- Iodine
- Gadolinium

- “follows blood”

# K-edge Imaging

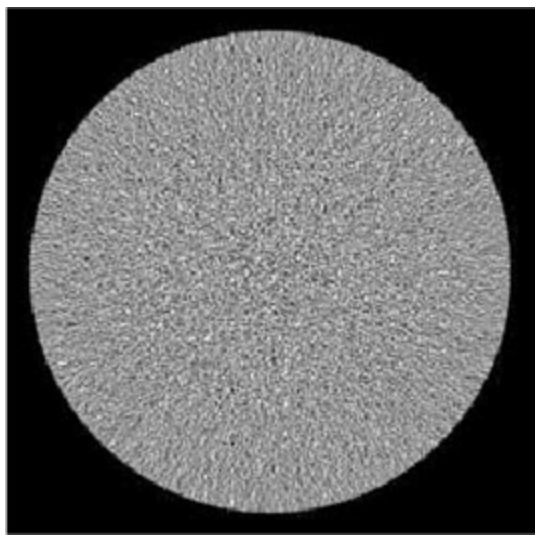


CT
/cm$^3$

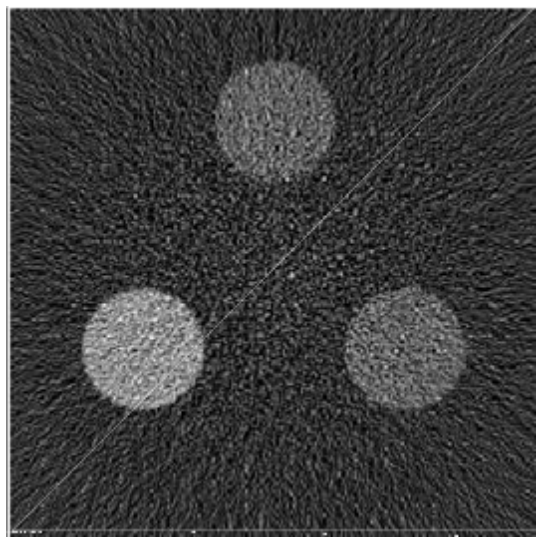



*M Firsching et al. Nuclear Science Symposium Conference Record, 2006*

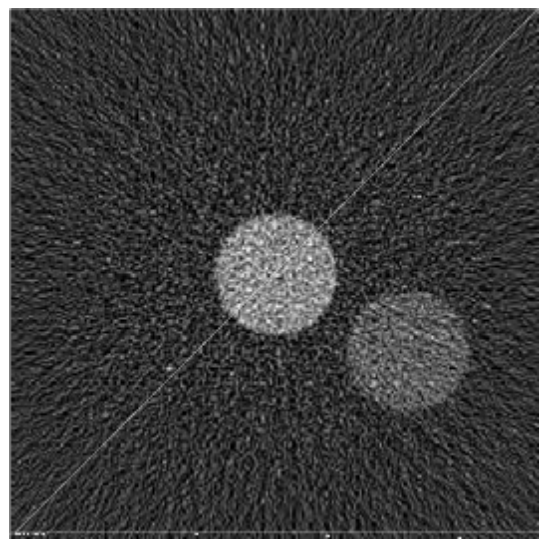
# K-edge Imaging



Water
g/cm$^3$



Iodine
g/cm$^3$



Gadolinium
g/cm$^3$

*M Firsching et al. Nuclear Science Symposium Conference Record, 2006*

# Multi-phase Protocols

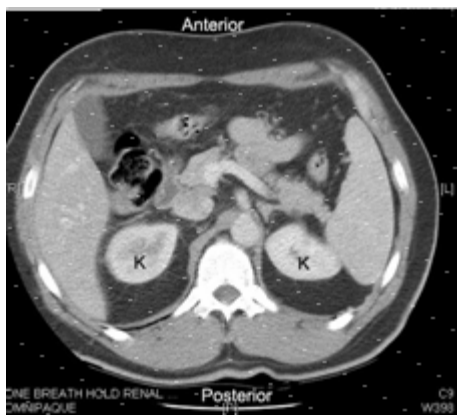
## Clinical uses

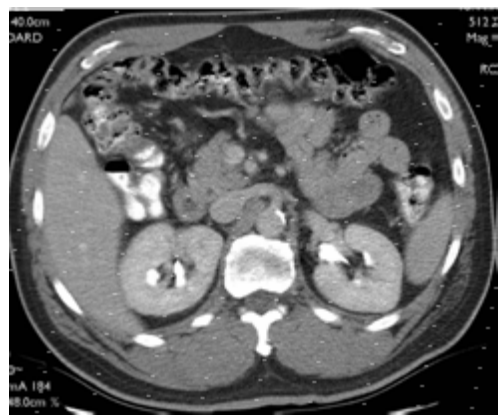
- Vascular
  - Heart
  - Brain
- Cancer
  - Almost all forms
- Other
  - Kidney stones

# Triple Phase Protocol

## Renal

- Non-contrast
- PV contrast (30 second)
- Delayed (15 minutes)



- 3 scans
- Twice on table

# Triple Phase Protocol

## CT

1) Scan (C-)
2) Give iodine
3) Scan (C+ PV)
4) Wait 15 minutes
5) Scan (C+ delayed)

- 3 scans
- Twice on table

## MARS

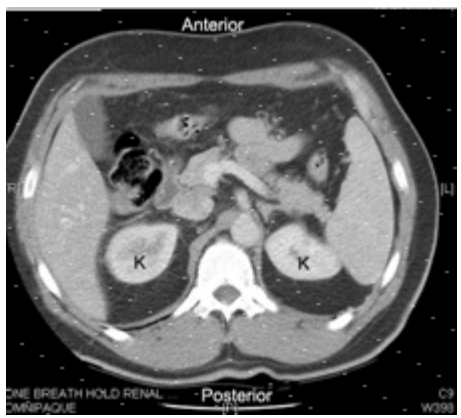
1) Give iodine
2) Wait 15 minutes
3) Give gadolinium
4) Scan

- 1 scan
- Once on table

# Triple Phase Protocol

## CT

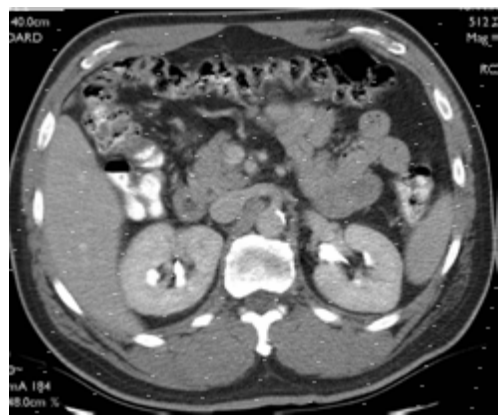
- C-
- C+
- Delayed




- 3 scans
- Twice on table

## MARS

- C-
- C+
- Delayed



- 1 scan
- Once on table

# Intrinsic Tissue Contrast

Aim:

To measure the energy dependence of tissue's X-ray absorption in order to better define subtle differences in tissues.

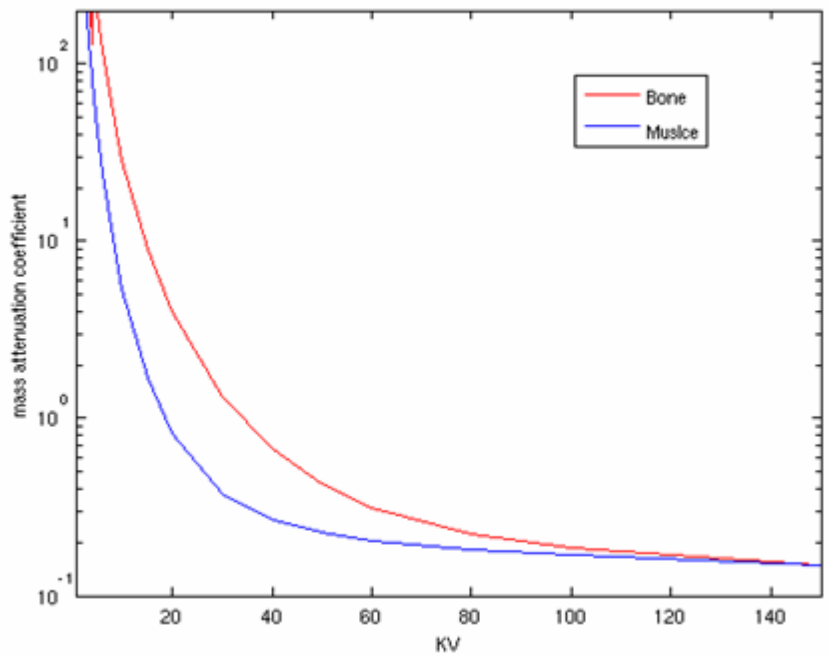
ie. Provide more information than just tissue morphology (shape).

# Intrinsic Tissue Contrast

Closest current technology is

DEXA

(Dual Energy X-ray Absorption)




*National Institute of Standards and Technology*

# Intrinsic Tissue Contrast

Closest current technology is

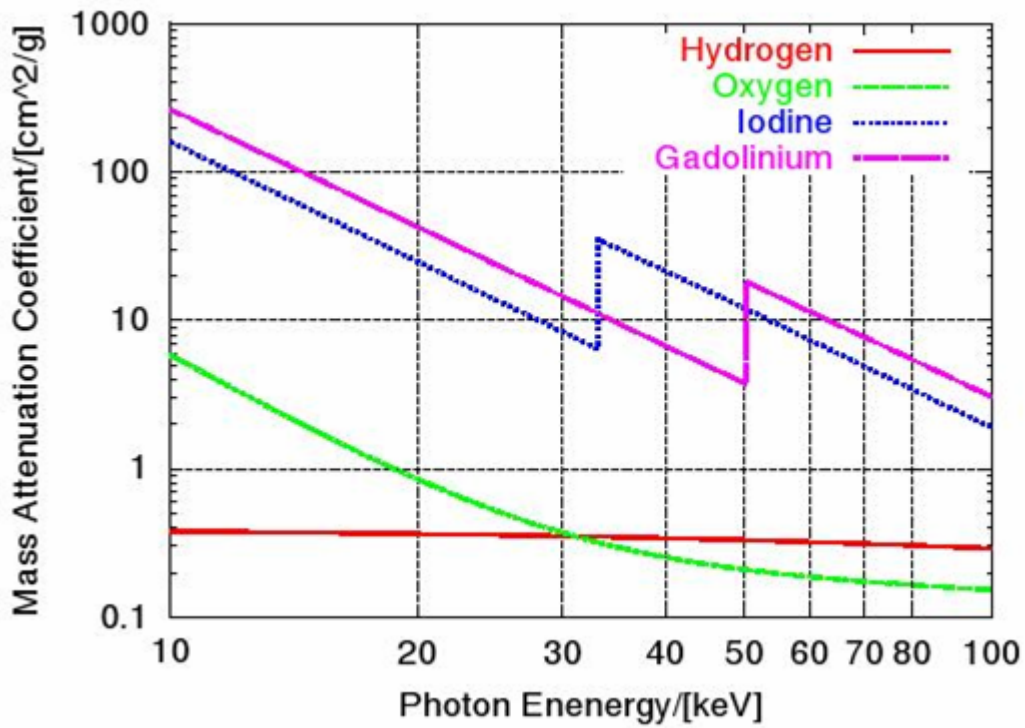
DEXA

(Dual Energy X-ray Absorption)

MARS imaging is:

- Multi-energy
- Single exposure
  - lower dose
  - no movement
  - no “overlapping spectra”

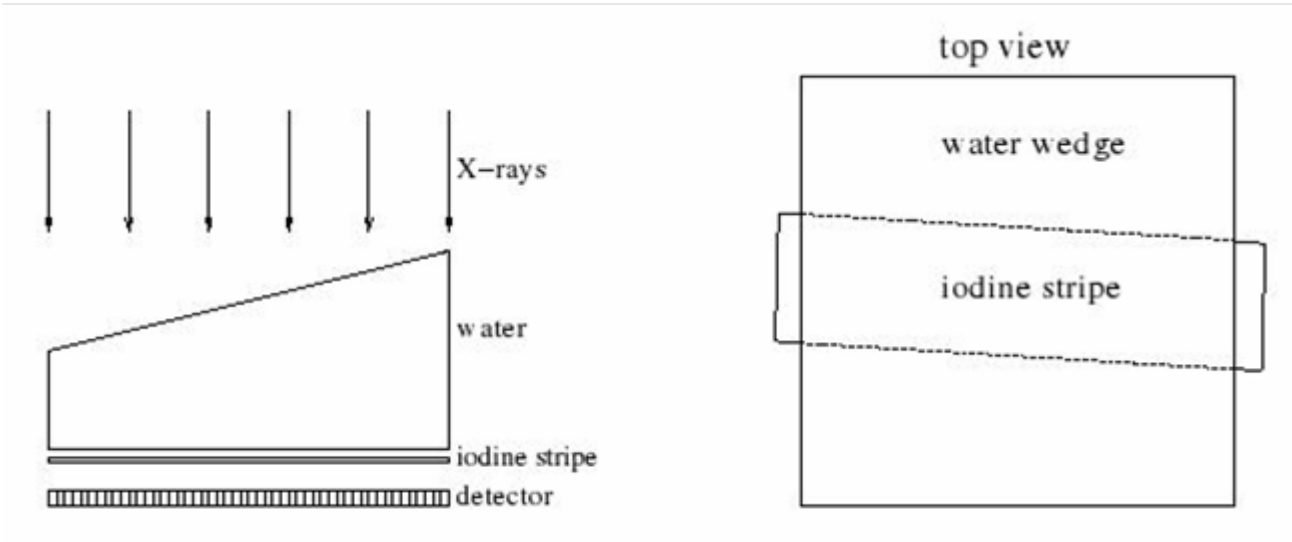
# Intrinsic Tissue Contrast

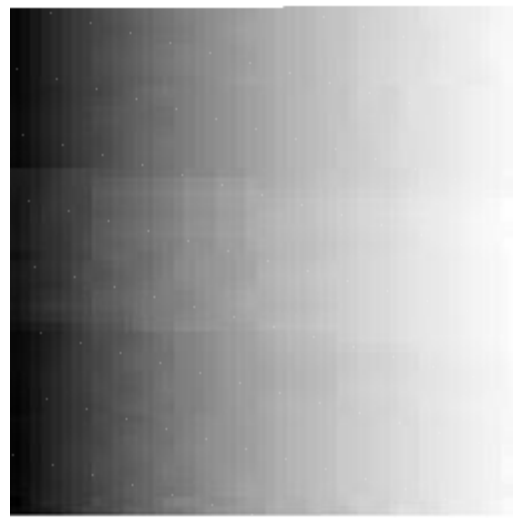



All atoms are different

- less pronounced effect than k-edge
- harder to distinguish each atom

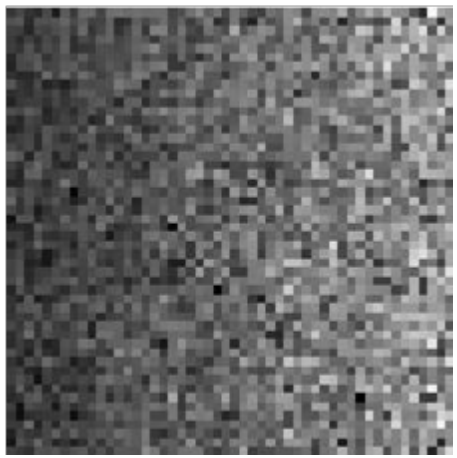
# Intrinsic Tissue Contrast



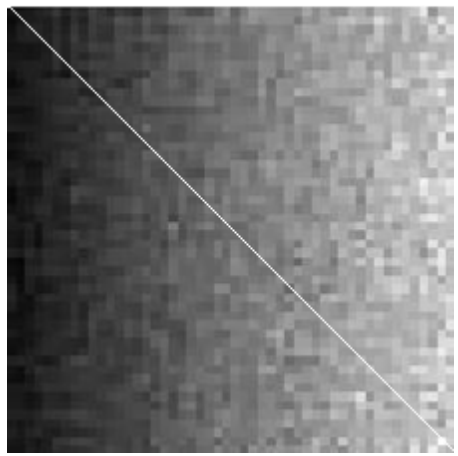



*M Firsching et al. Nuclear Science Symposium Conference Record, 2004*

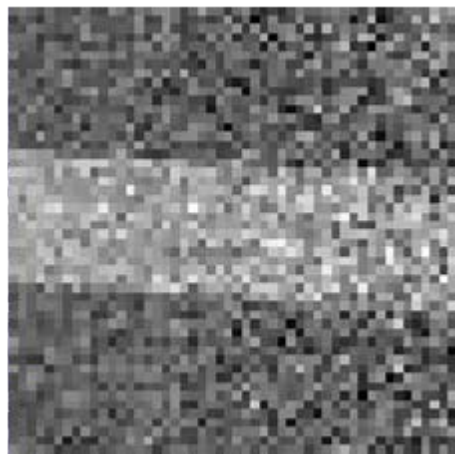
# Intrinsic Tissue Contrast



Hydrogen



Oxygen

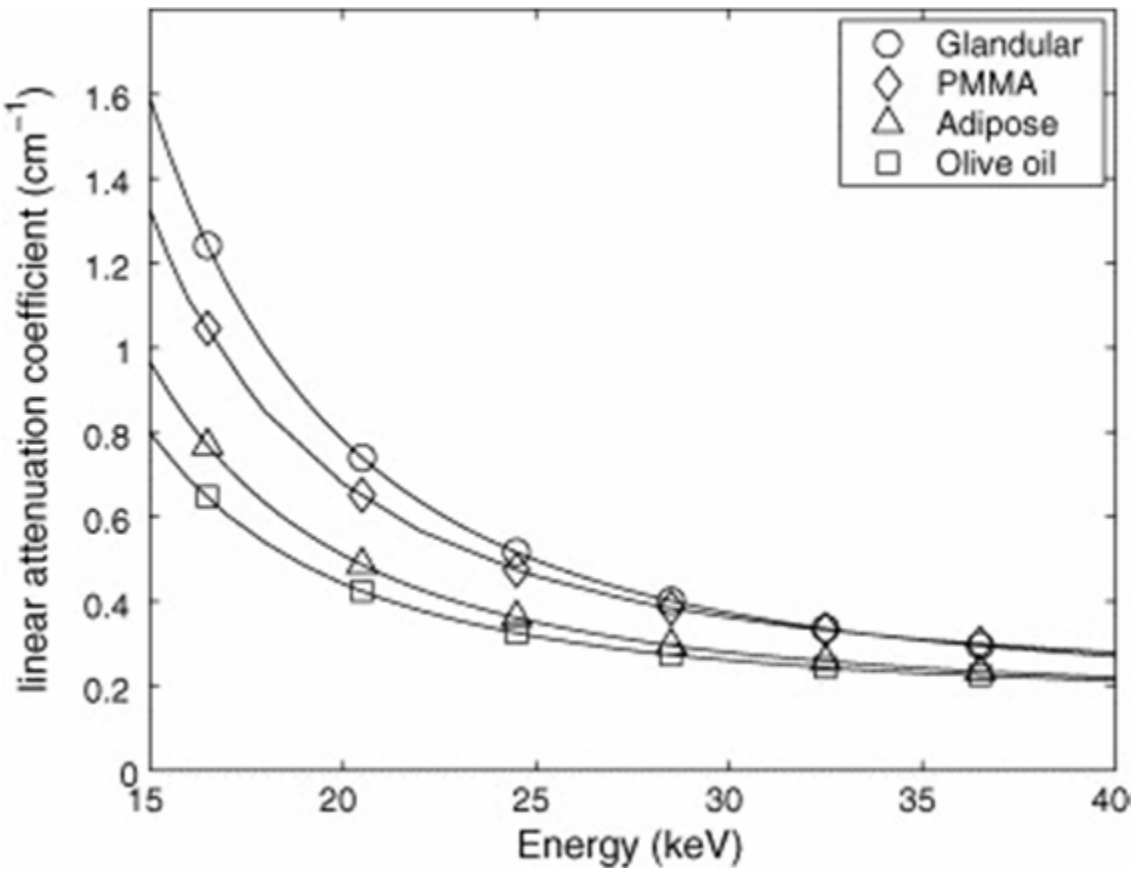


Iodine

*M Firsching et al. Nuclear Science Symposium Conference Record, 2004*

# Intrinsic Tissue Contrast

Example: Breast imaging



# Intrinsic Tissue Contrast

Example: Breast imaging

- Lower energy photons provide more contrast

  *Radiology 2003*

- Micro-calcifications can be detected

  *Med.Phys. 1985 and 2002*

- Fibrous tissue and tumour have different attenuation characteristics

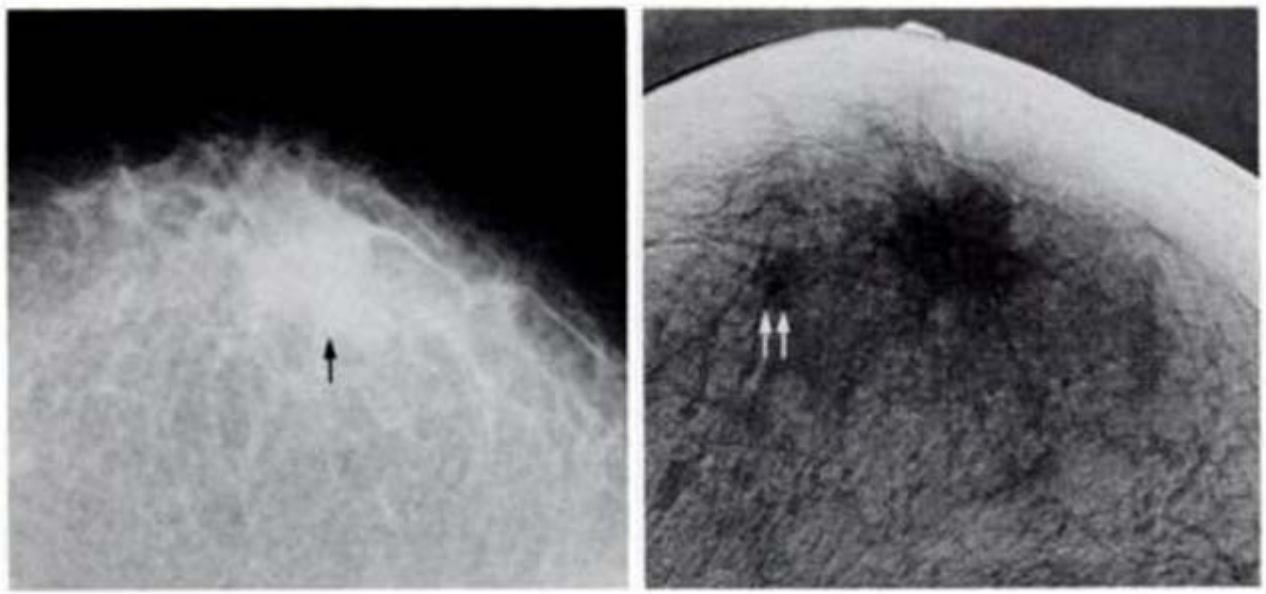
  *Phys.Med.Biol. 1987, JDI 1995, Radiology 2003*

- Tumours retain iodine contrast

  *Dahnet 2003. Basis of MRI tumour enhancement*

# Intrinsic Tissue Contrast

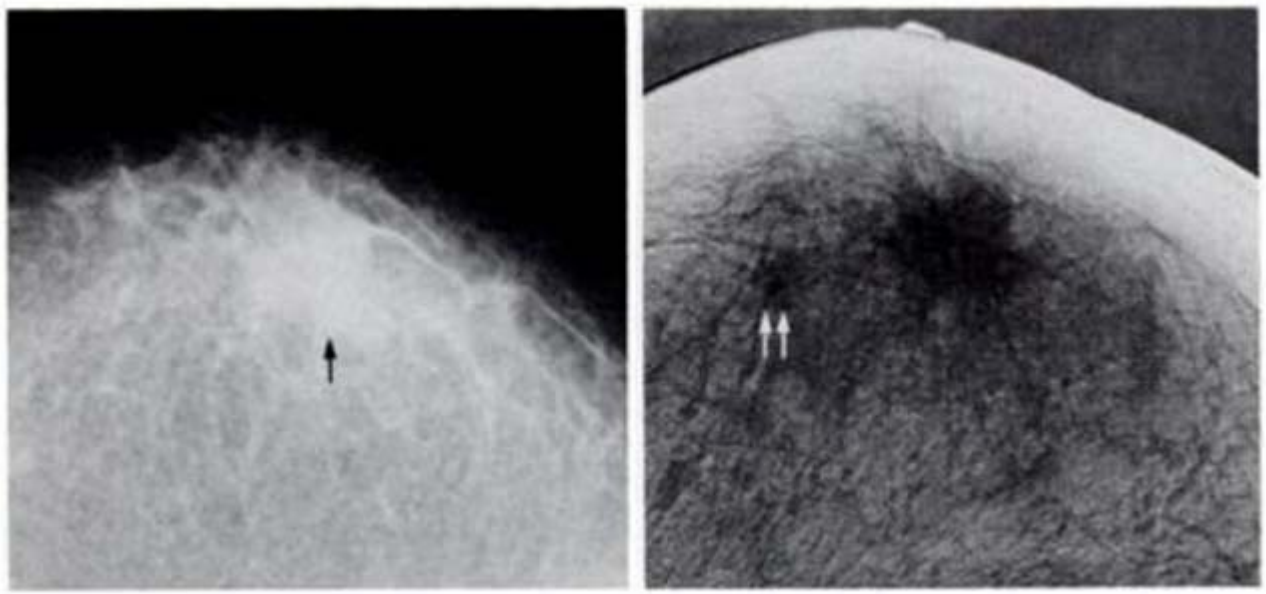
Example: Breast imaging



*Radiology, 1987*

# Intrinsic Tissue Contrast

## Example: Breast imaging



- 18/29 cases of cancer there was improved recognition or definition of tumour
- 9/11 cases of benign disease the margins were more clearly depicted

*Radiology, 1987*

# Benefits of Spectral X-rays

- Better image quality
  - Less artefacts

    eg. Around coronary artery stents

- K-edge imaging
  - Better use of contrast agents

    eg. Less scanning

- Intrinsic tissue contrast
  - eg. Breast cancer from normal tissue

# Summary

- Spectroscopic imaging is an

  *Imminent clinical reality*

- **MARS** imaging
  - Energy resolution
  - Spatial resolution
  - Temporal resolution

- Wide range of clinical benefits

# Questions

Anthony Butler

Nick Cook

Nigel Anderson

Rita Tipples

Phil Butler

Tracey Melzer