Australian Synchrotron
Turning bright ideas into brilliant outcomes

X-ray Fluorescence Microscopy:

- What's in your sample?
- How much?
- Where is it?

Dr. Daryl Howard

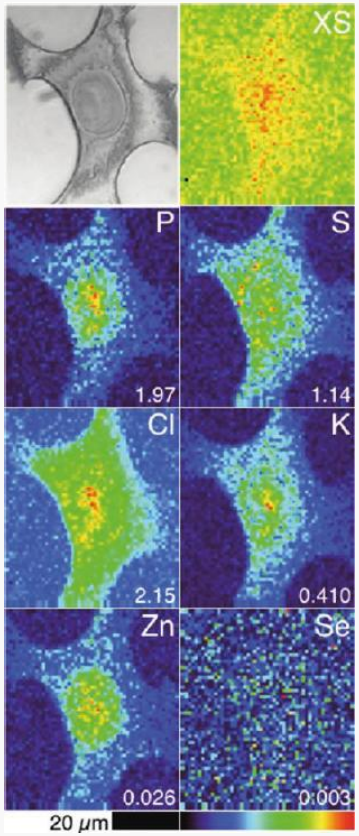
New User Symposium 2016
Australian Synchrotron, 6 September, 2016

X-ray Fluorescence Microscopy (XFM)

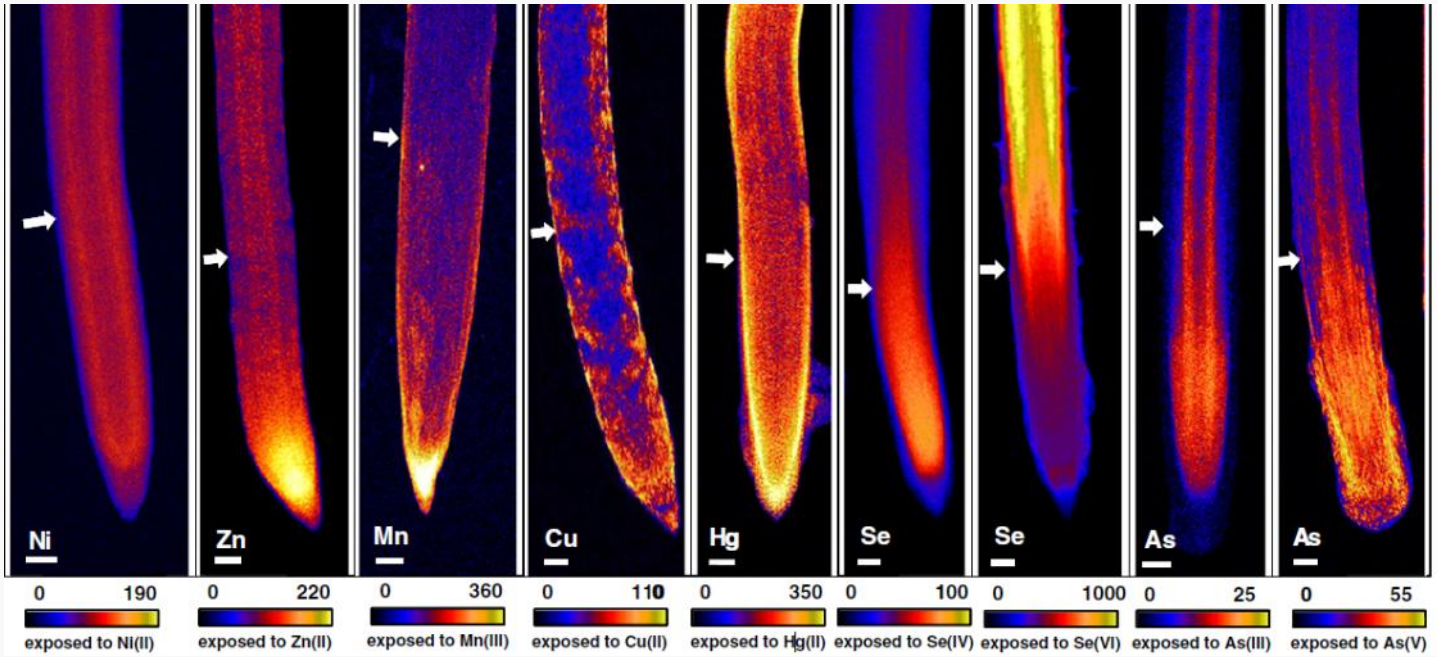
What does XFM offer?

TAKE HOME MESSAGE

Quantitative elemental mapping



C Weekley et al., Biochem 2011

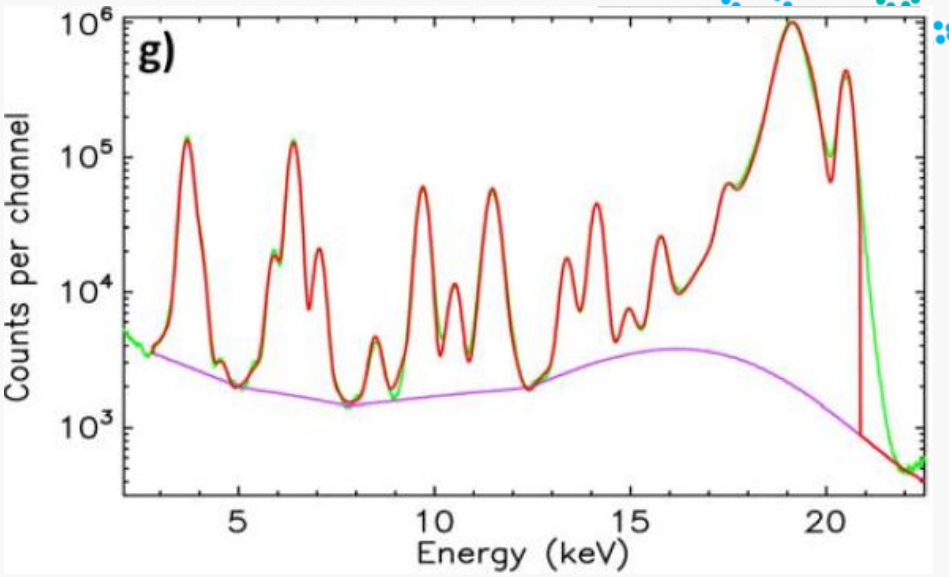


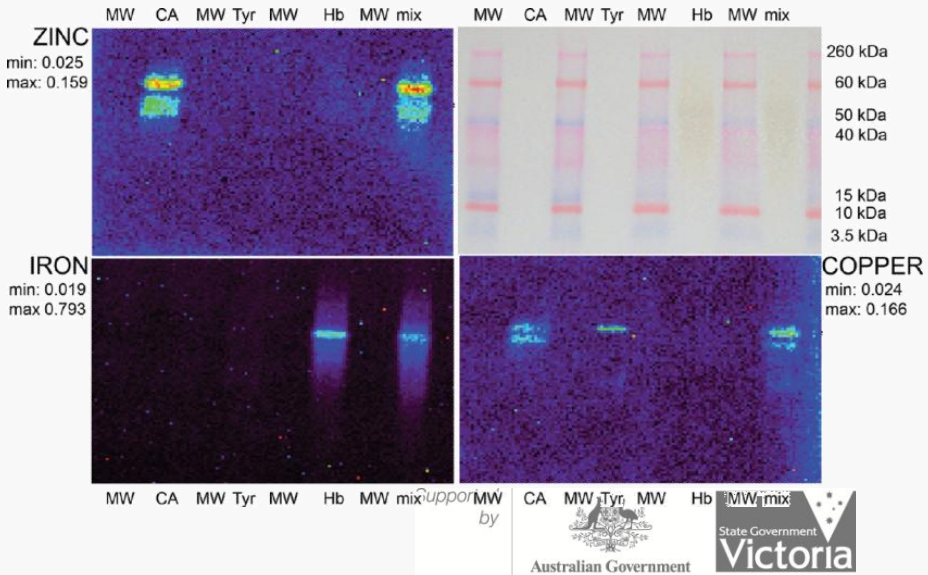
XFM of cowpea roots

Wang et al., Sci. Tot. Env. 2013

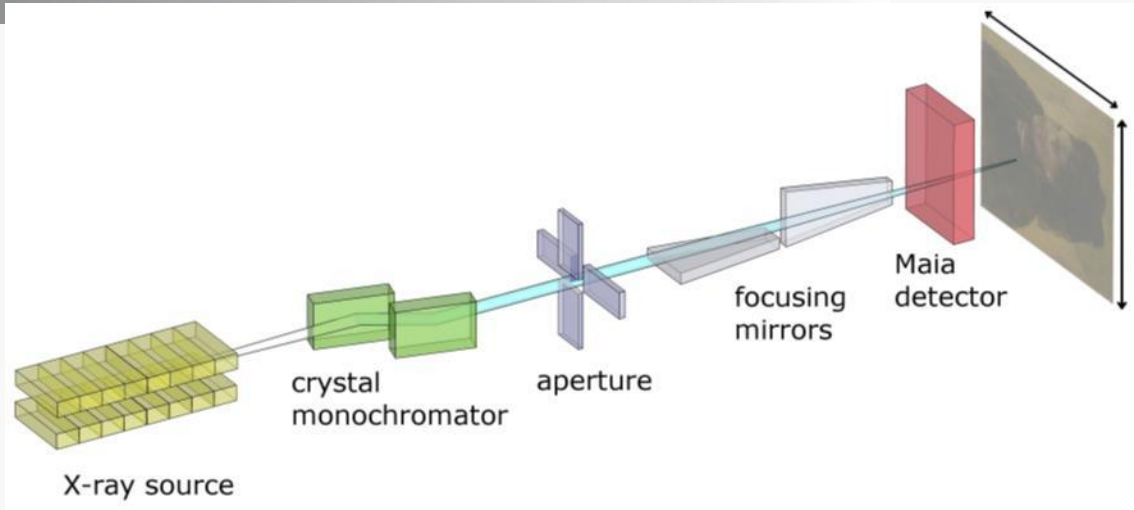
X-ray Fluorescence Microscopy (XFM)

- Simultaneous access to 10+ elements
- No contrast agents required
  - but possible!
- Quantitative
- High signal-to-noise ratio
  - ppb sensitivity, improving with Z
- Little sample damage
- Extended Penetration depth
  - Study “intact” specimens
- Sensitive to chemical bonding
  - XANES mapping





X-ray Fluorescence Microscopy (XFM)



- **The XFM beamline at the Australian Synchrotron has a number of world-leading capabilities...**

  1. Elemental mapping over large areas

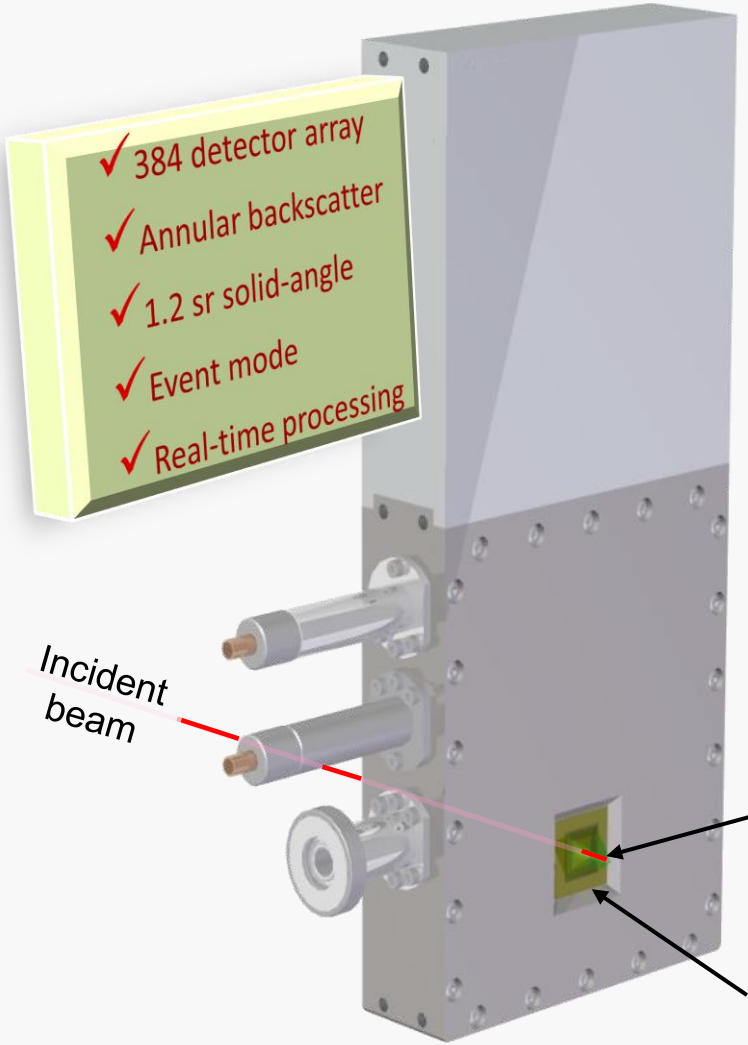
  2. Very (very) fast elemental mapping

  3. Elemental mapping in 3-dimensions

  4. Mapping of chemical species

L. Finney et al., ACS Chem Biol 2010

XFM – Maia (better, faster, stronger)

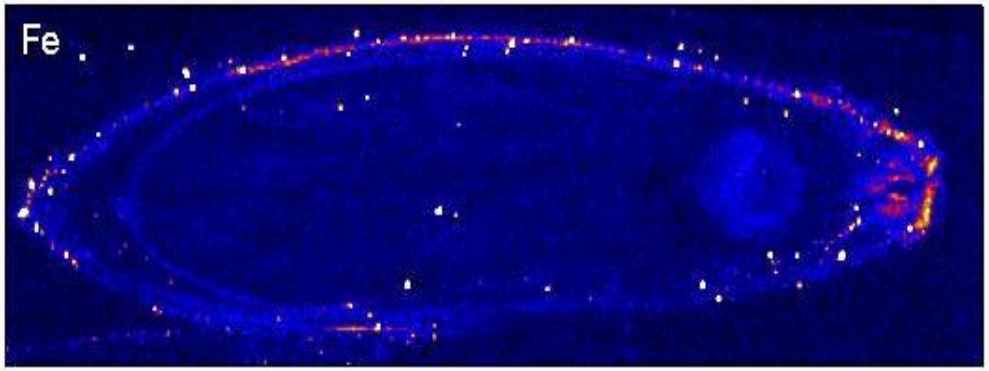


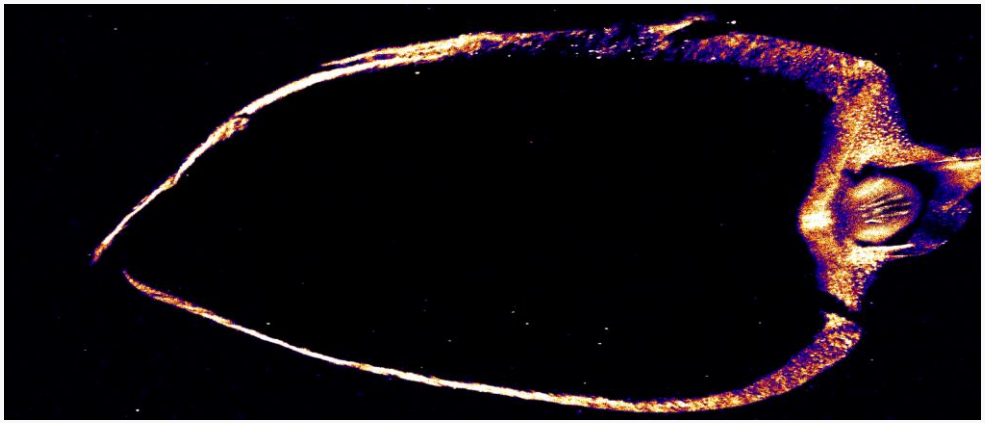
- **Capture spatial detail in complex natural samples** from **~2 µm to >50 mm scales**
  → images **~100 M pixels** or more
- **Pixel transit times down to 50 µs**
  → count rates to **10 M/s** typical (40 M/s peak)
- **Real-time spectral deconvolution**
  → real-time display of element images

Kirkham *et al.*, AIP Conf. Series 1234 (2010) 240.

X-ray Fluorescence Microscopy (XFM)

The need for speed...





20ID – APS

6.0 x 2.0 mm (scanned area) — 15 µm (stepsize)

~53 kpix — **500 ms/step**

≈7.5 h

XFM - AS

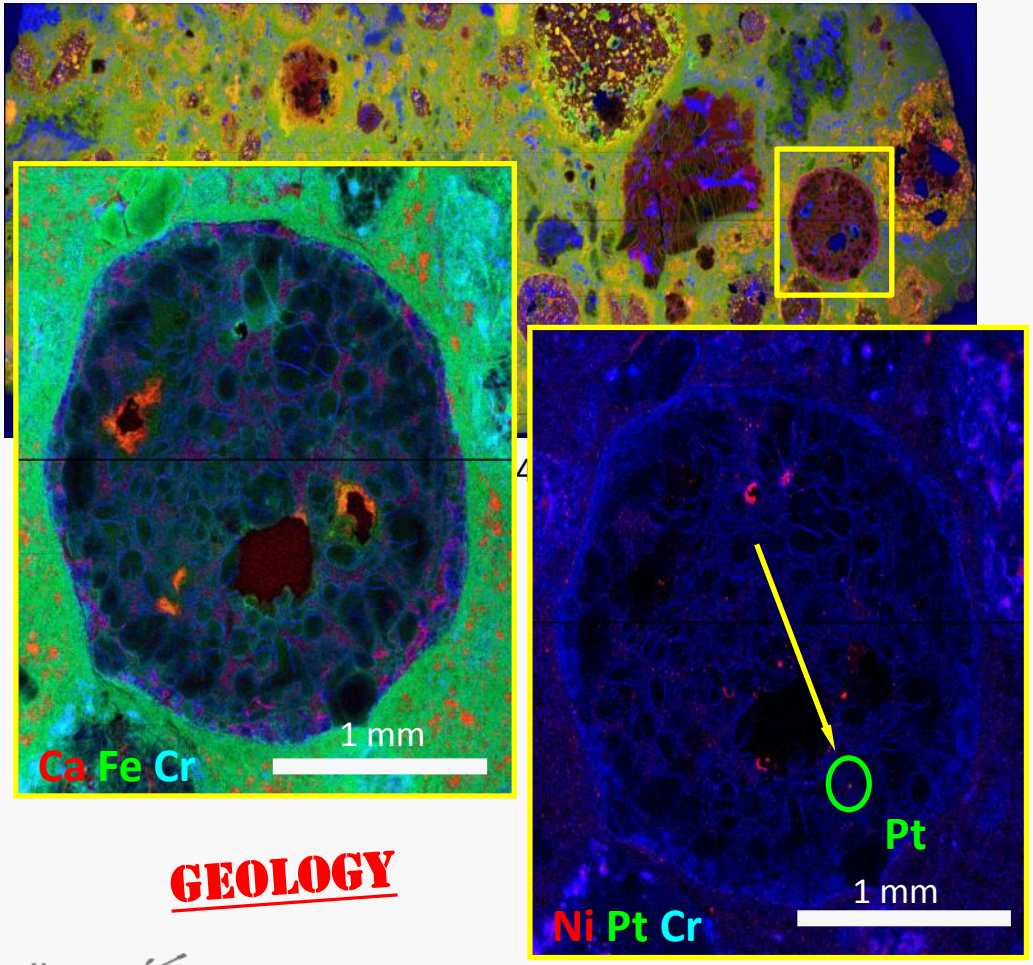
5.7 x 2.6 mm (scanned area) — 1.25 µm (stepsize)

~9.5 Mpix — **0.5ms/step**

≈1.2 h

XFM at the Australian Synchrotron

1. Elemental mapping over large areas = HIGH DEFINITION



GEOLOGY

- **Maia image of Allende meteorite**

  Image area: 18.5 x 6.5 mm, **30M pixels**

  Acquisition time: 3.5 hours, **0.49 ms/pixel**

  Detector: Maia 384 annular array, **3 M counts/s**

  Beam: 18.5 keV, ϕ = 2 µm

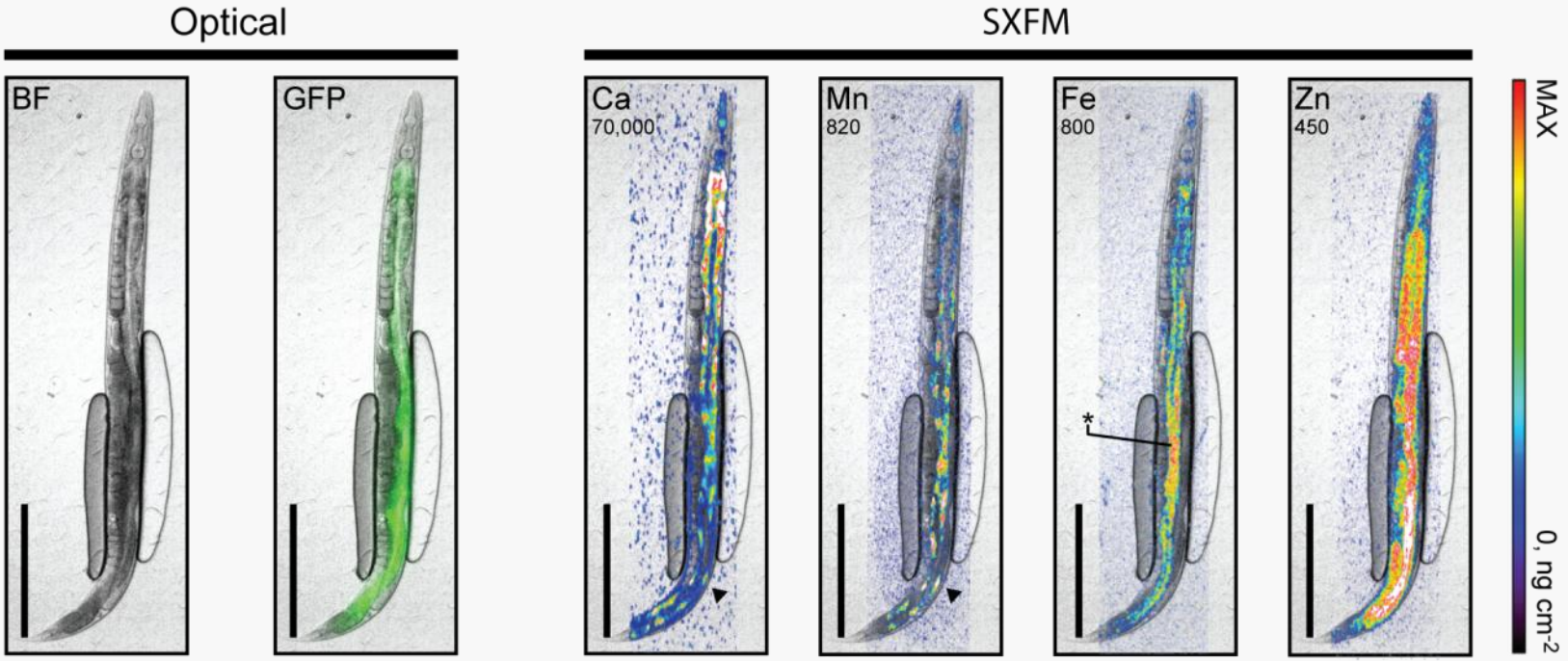
Rob Hough, James Cleverley, Chris Ryan, *CSIRO*; Philip Bland, *Curtin University*

David Paterson, Martin de Jonge, Daryl Howard, *Australian Synchrotron*

Supported by
Australian Government
State Government Victoria

X-ray Fluorescence Microscopy (XFM)

2. Very (very) fast elemental mapping = LESS DAMAGE



James *et al.*, Metallomics 2013

BIOLOGY

- **Maia of anesthetised C.elegans**

  Image area: 1.1 x 0.3 mm, **0.1 M pixels**

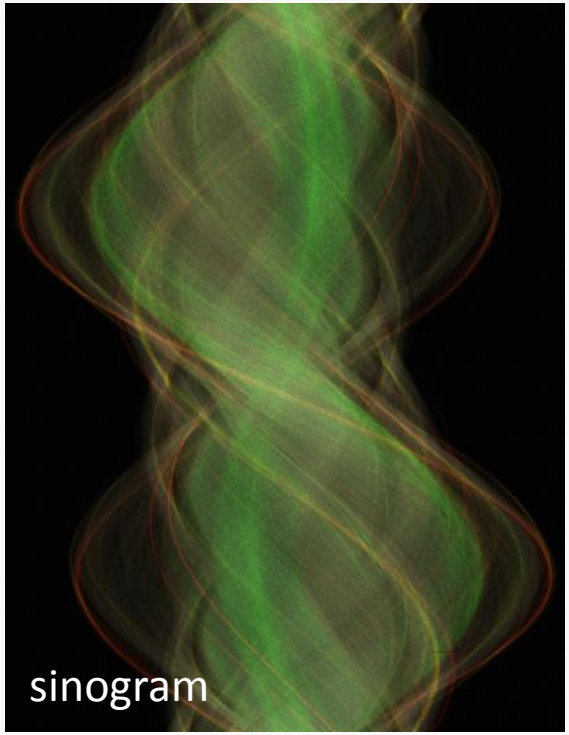
  Acquisition time: 20 mins, **15 ms/pixel**

  Detector: Maia 384 annular array, **2 M counts/s**

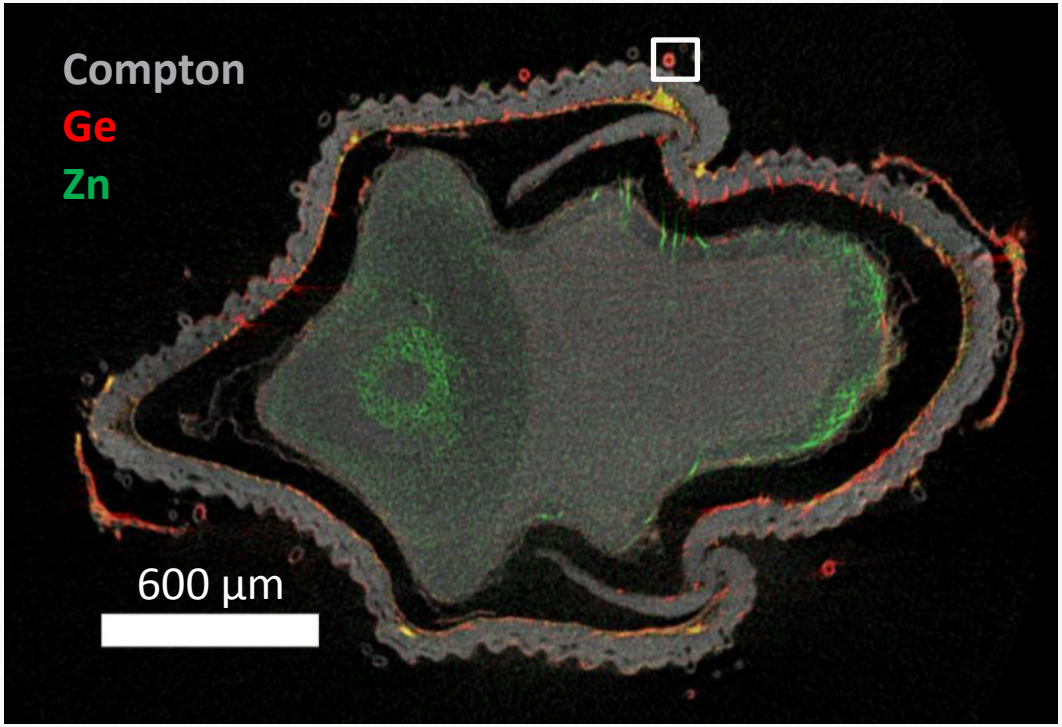
  Beam: 12.7 keV, ϕ = 2 µm

X-ray Fluorescence Microscopy (XFM)

3. Elemental mapping in 3-dimensions = CONCENTRATION in 3D



Rice grain with husk,
measured at AS XFM Aug 2011
Carey *et al*, Anal Bioanal Chem 2011.

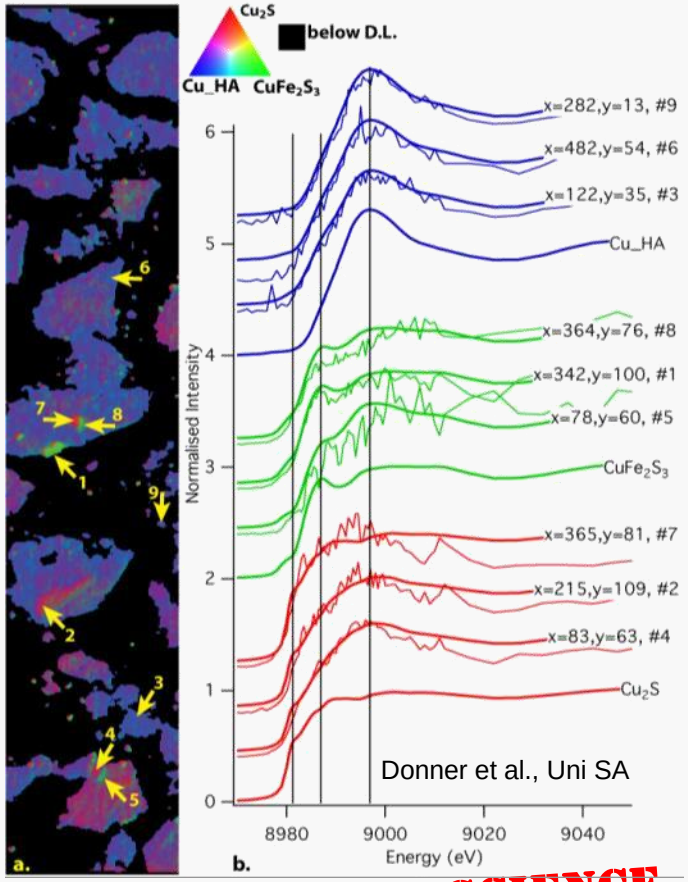


Δ = 2 µm, τ = 2 ms
2291 pixels, 2001 projections (4.6M pixels).
3 hrs measurement time

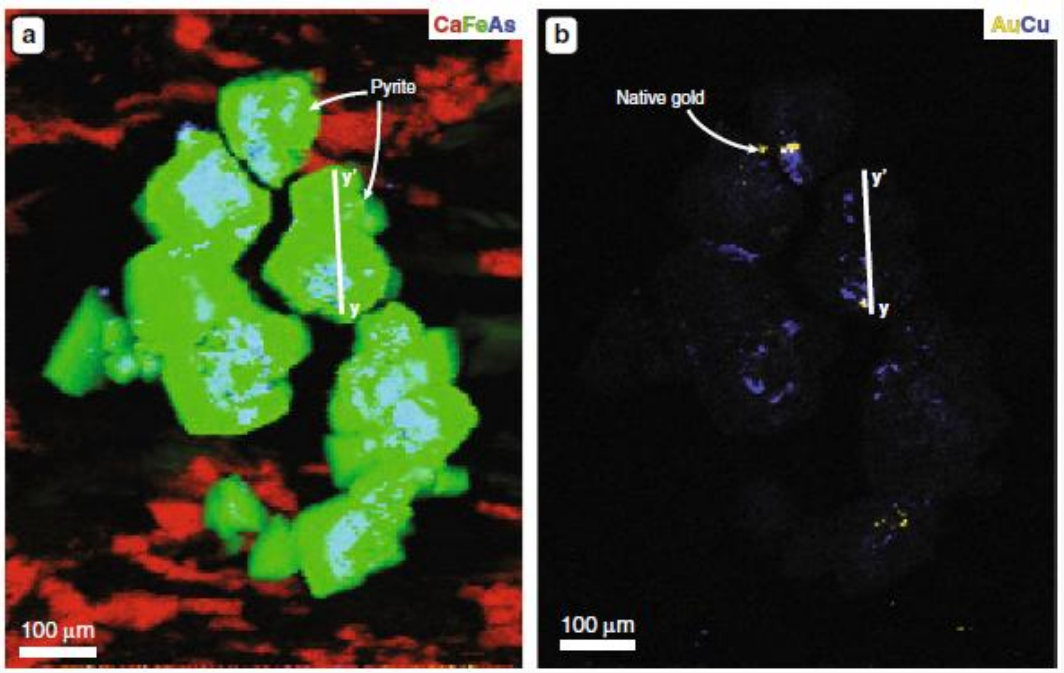
BIOLOGY/ENVIRONMENTAL SCIENCE

X-ray Fluorescence Microscopy (XFM)

4. Mapping of Chemical Species = PROCESS CHEMISTRY



Donner et al., Uni SA



Fisher el al., Min. Dep. 2014

ENVIRONMENTAL SCIENCE

GEOLOGY

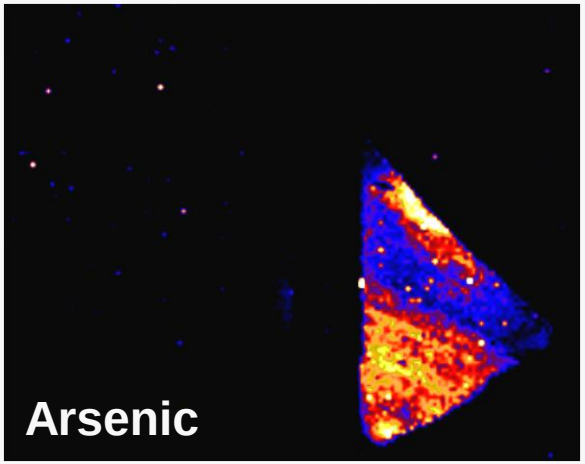
X-ray Fluorescence Microscopy (XFM)

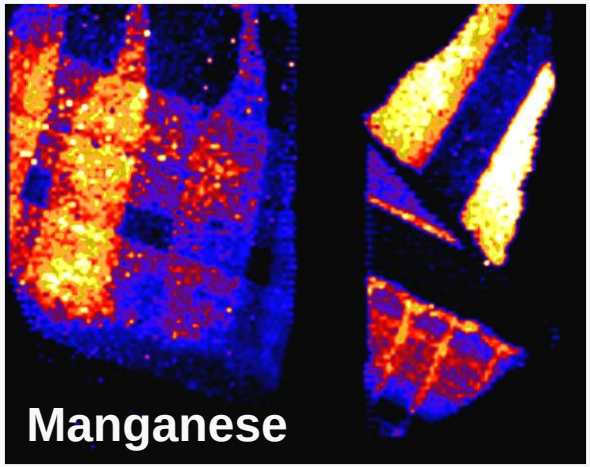
Other interesting work:

CULTURAL HERITAGE

ARCHAEOMETRY

Ancient Egyptian pottery
from 3 different sites





Min Max

W. Jay, Monash University

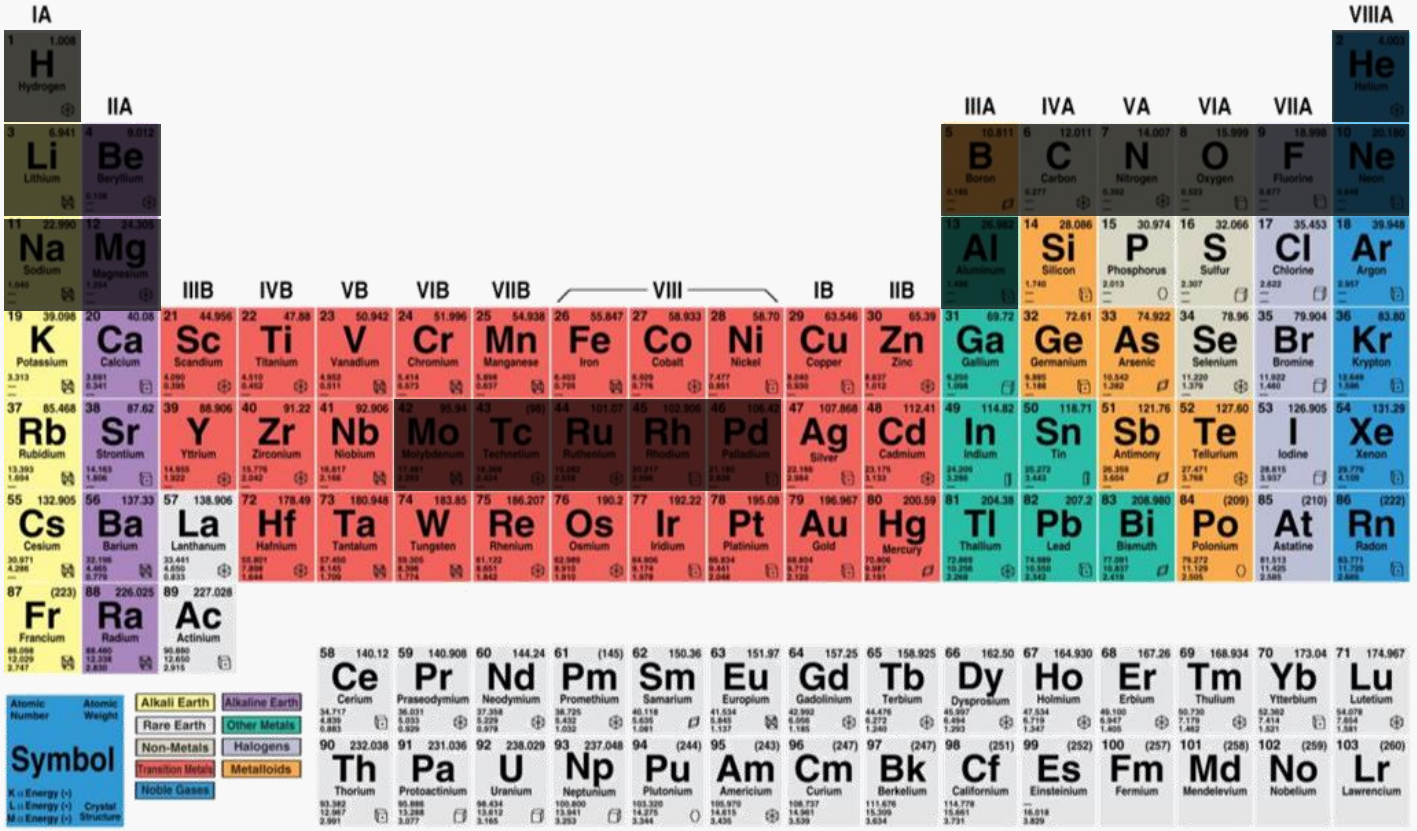
X-ray Fluorescence Microscopy (XFM)

Email: XFM@synchrotron.org.au

or

Check out:

http://www.synchrotron.org.au



The Team (XFM)

Australian Synchrotron

David Paterson
Martin de Jonge
Daryl Howard

Gary Ruben (CSIRO)

MAIA XRF Detector

CSIRO	BNL
Chris Ryan	Pete Siddons
Robin Kirkham	Tony Kuczewski
Gareth Moorhead	Angelo Dragone
Murray Jensen	Gianluigi De Geronimo

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Meteorite
R. Hough, J. Cleverley
CSIRO

P. Bland
Curtin University

C. elegans
G. McColl
Florey Institute of Neuroscience and Mental Health

Rice Grain/Bio-soilds
AH. Carey
Institute of Biological and Environmental Sciences
University of Aberdeen

E. Lombi, E. Donner
University of South Australia

Mineral
L. Fisher
CSIRO

Pottery
W. Jay
Monash University

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