What is Brilliant & BRIGHT at the Australian Synchrotron

Professor Michael James

Director, Australian Synchrotron

AfLS-2024

ANSTO

ANSTO

Australian Nuclear Science & Technology Organisation

A leader in nuclear science and technology

Operating safely for over 70 years

Over 1450 skilled employees

Managing over $1.5 billion in scientific infrastructure

ANSTO's Lucas Heights campus

TWO LOCATIONS

Lucas Heights (Sydney)

Clayton (Melbourne)

1000 km between offices

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The Australian Synchrotron at a Glance

Operational since **2007**

220 Staff on the Clayton Site

5000 Hours of Stored Beam P.A.

14 Operational Beamlines;

4 Beamlines Under Construction

1000 Experiments P.A

10,000 Registered Users

600 Journal Publications P.A.

300 Protein Data Bank Structures P.A.

150 Graduate Theses; **20** Patents P.A.

~$40M Facility Refurbishment Projects

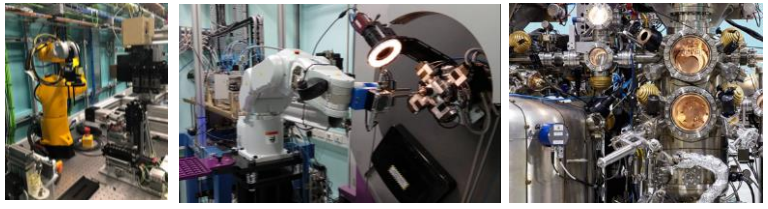
$105M BRIGHT Beamline Program

International User Facility

New Solar Plant

Nanoprobe Satellite Building

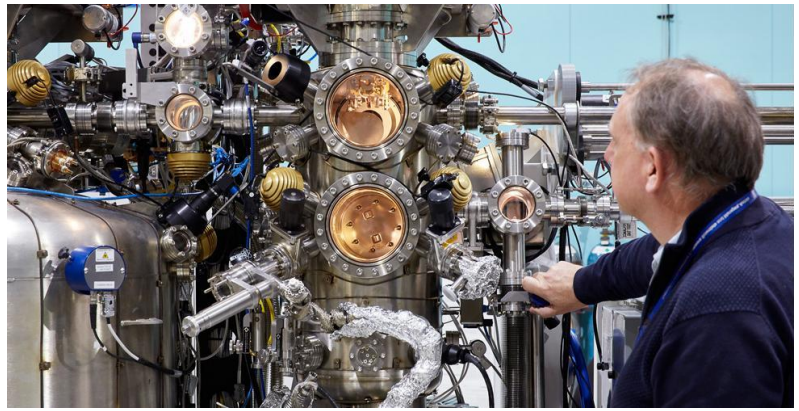
3 GeV Electron Accelerator



14 Operational Beamlines + 4 to come

Operate 50 Room Guesthouse

The Australian Synchrotron is a *User* Facility



- Beam available 24 hours, 5-6 days per week
- Experiments run from a few hours to up to 6 days
- Some beamlines can run 1000's of samples per day
- Some experiments generate 100,000's datasets & up to 10 Tb
- Onsite training & support from beamline staff
- 24 hr support from Controls Operators
- Interactive data capture & storage, analysis & processing
- On-site 50 room Guest House
- *Free Coffee !!!*

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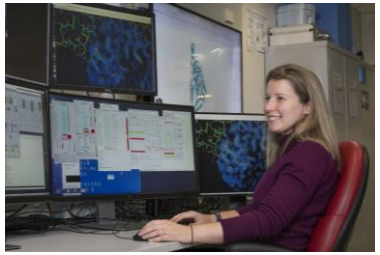
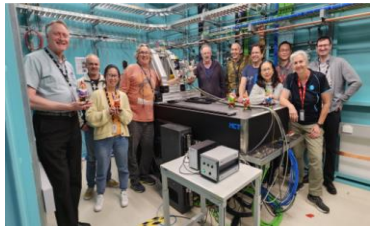
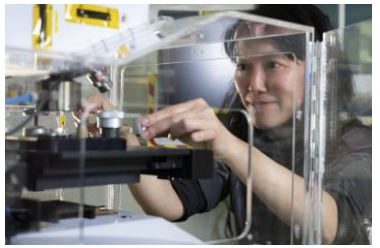
Our Team @ The Australian Synchrotron





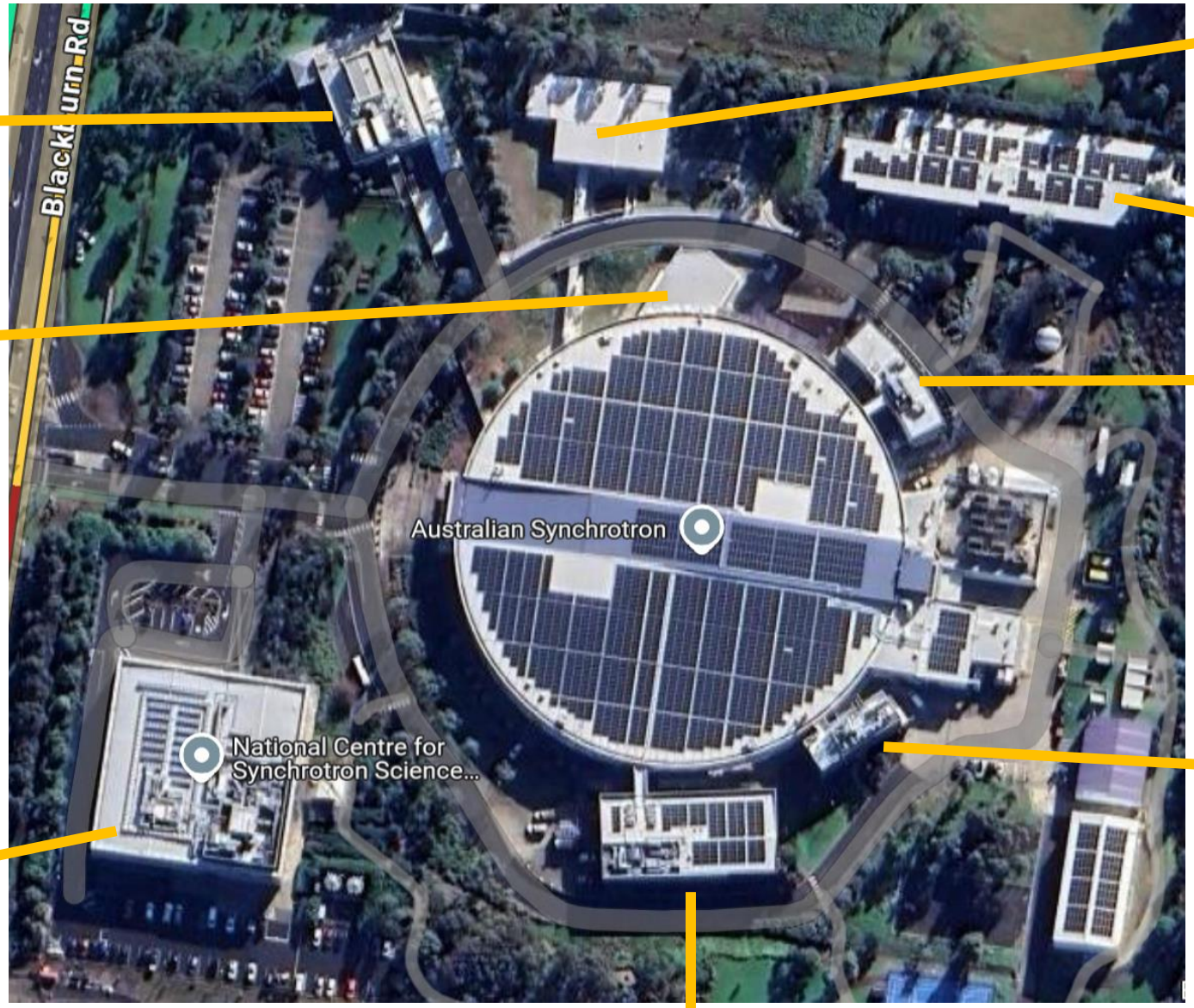


220 Staff

60 Scientists
55 Engineers
55 Controls & Computing
20 Accelerators Ops
30 HR, WHS, Finance,
User Office, PMO, Quality, IT

Australian Government | ANSTO

The Australian Synchrotron



Imaging & Medical Beamline

X-ray Fluorescence Nanoprobe

Guesthouse

Advanced Diffraction & Scattering

Chemistry Lab & Controls

Medicines Manufacturing Innovation Centre

National Centre for Synchrotron Science

Engineering

ANSTO

The Australian Synchrotron – Now Solar Powered…

New Solar Plant – January 2024

3,200 new solar panels

Generate over two million kWh / year

and reduce our carbon footprint by over

1,680 tonnes of CO_2 / year.

Light from the sun generates electricity,
that is used to generate *synchrotron light,*
that is used to develop new solar cell technologies,
that can be used to generate electricity…

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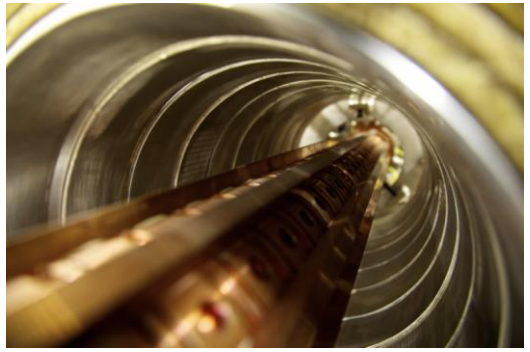
The Australian Synchrotron – Accelerator Systems



3rd Generation Storage Ring

Energy: **3 GeV**; Current: **200 mA**

Storage Ring Circumference: **216 m**

No. of Sectors: **14**

Electron Beam Size: **σx – 90 µm, σy – 60µm**

(Horizontal) Emittance: **10,350 pm.rad**

Vacuum Pressure: **10^{-11} mbar**

Magnetic fields: **up to 4.5 T**

IDs: Wigglers: 3; Undulators: 7

Australian Synchrotron Beamlines

10 Original Beamlines

Imaging and Medical Beamline

Macromolecular Crystallography

Micro-focused Crystallography

Infrared Microscopy

Powder Diffraction

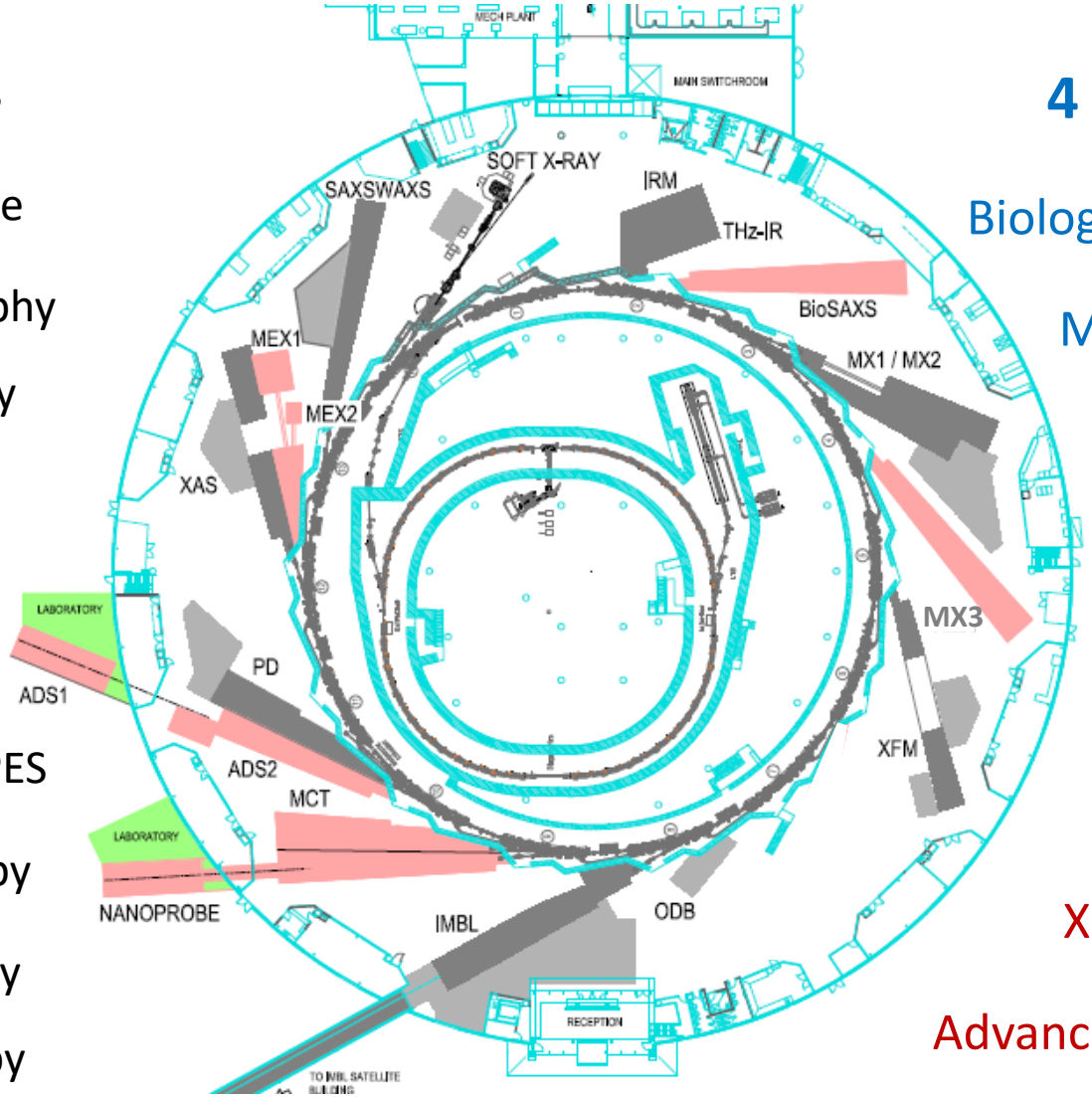
SAXS / WAXS

Soft X-ray Spectroscopy / ARPES

Terahertz / Far-IR Spectroscopy

X-ray Absorption Spectroscopy

X-ray Fluorescence Microscopy



4 New BRIGHT Beamlines

Biological Small Angle X-ray Scattering

Micro-Computed Tomography

Medium Energy XAS 1 & 2

4 BRIGHT Beamlines
(Under Construction)

High Performance MX

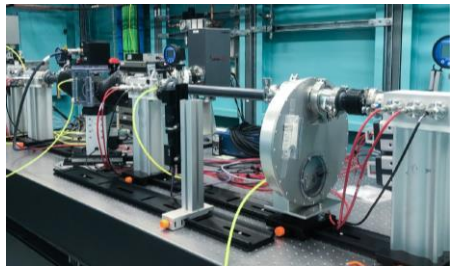
X-ray Fluoresence Nanoprobe

Advanced Diffraction and Scattering 1 & 2

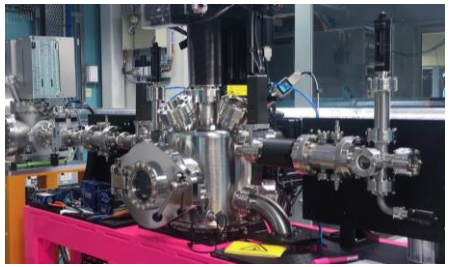
The BRIGHT Beamline Program

Operational Beamlines

Micro-CT
Bending Magnet (8-40 keV)
Phase-contrast & Hi-Speed CT
Operational: Sept. 2022



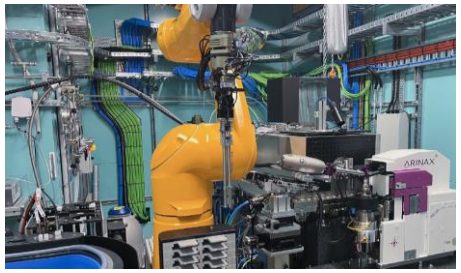
MEX1
Bending Magnet (3.5-13.6 keV)
XANES, EXAFS, Microprobe
Operational: Nov. 2022



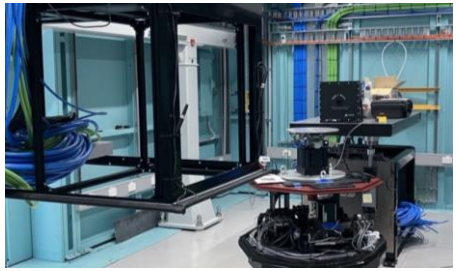
MEX2
Bending Magnet (1.7-3.5 keV)
XANES, EXAFS
Operational: April 2023

BioSAXS
Supercon. Undulator (8-15 keV)
CoFlow/SEC-SAXS; RheoSAXS
Operational: Oct. 2023

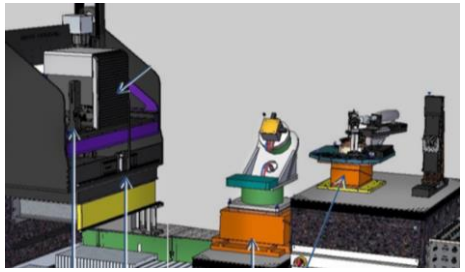
Beamlines Under Construction



MX3 (Hot Commissioning)
In vacuum Undulator (10-15 keV)
Goniometer, Tray screening; Serial
Commissioning: Sept. 2024



ADS1
Supercon. Wiggler (50-150 keV)
Diffraction, Imaging
Commissioning: Early 2025



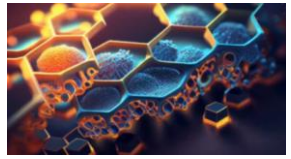
ADS2
Supercon. Wiggler (45, 74, 87 keV)
Diffraction, PDF, CX
Commissioning: Early 2026

NANO (100m; 60 nm)
Cryo-Undulator (5-18 keV)
XRF, Ptycho, μ-SAXS, μ-XRD
Commissioning: Early 2026

Collaboration Via National Research Partnerships

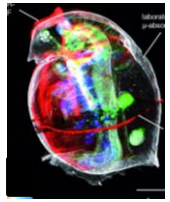
Grain Research Development Corporation
Synchrotron Program

Reducing Impacts of CO_2 Emissions

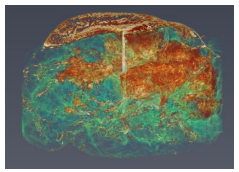


Fragment Screening for Drug Discovery

Developing New Tomography Methods



X-ray Phase-Contrast Tomography to
Transform Cancer Diagnosis



Development of Pharmaceutical Formulations

International Partnerships & Networks

The Australian Synchrotron currently has two key international partners:

NEW ZEALAND SYNCHROTRON GROUP

NZSG has been a partner since the foundation of the Australian Synchrotron and is a major funder of the BRIGHT Program.

Singapore National Synchrotron Programme

In May 2023 Singapore commenced a 5-year Preferred Access Program on our original suite of 10 beamlines.

AOF

Asia Oceania Forum for Synchrotron Radiation Research

Australia | China | India | Japan | Singapore | South Korea | Taiwan
Thailand | New Zealand | Malaysia | Vietnam | Indonesia | Philippines

ANSTO coordinates Australia's engagement in this regional forum of synchrotron research active countries.

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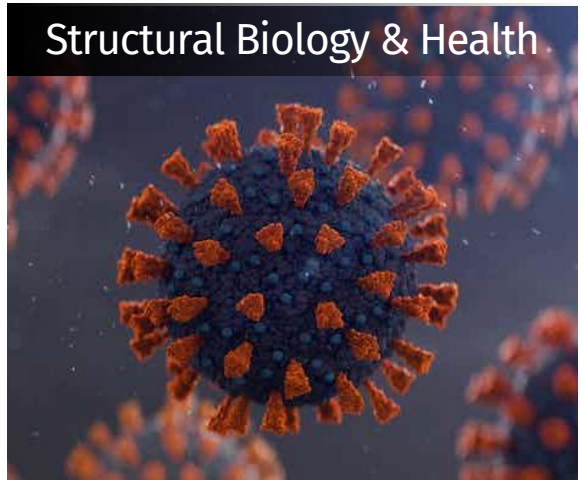
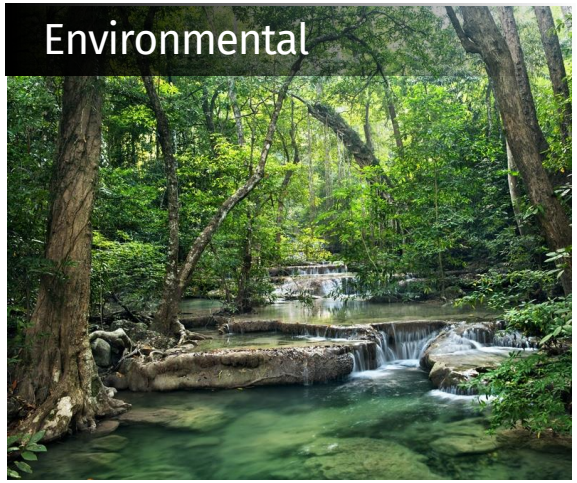
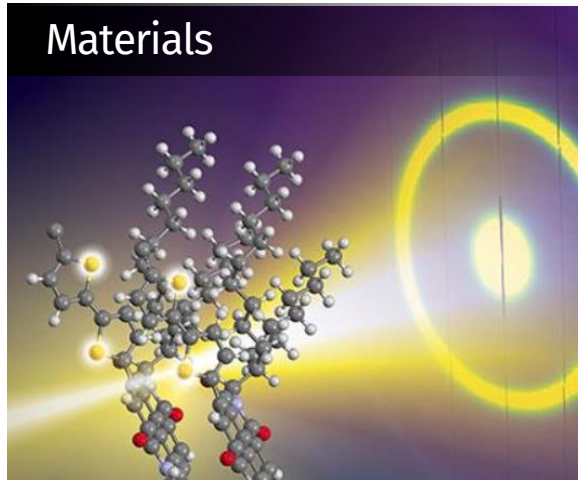
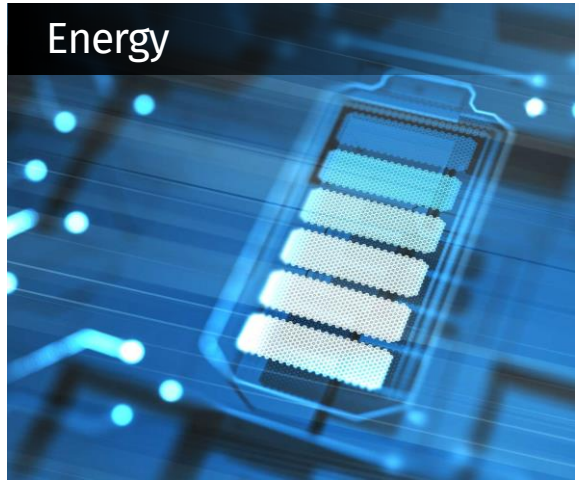
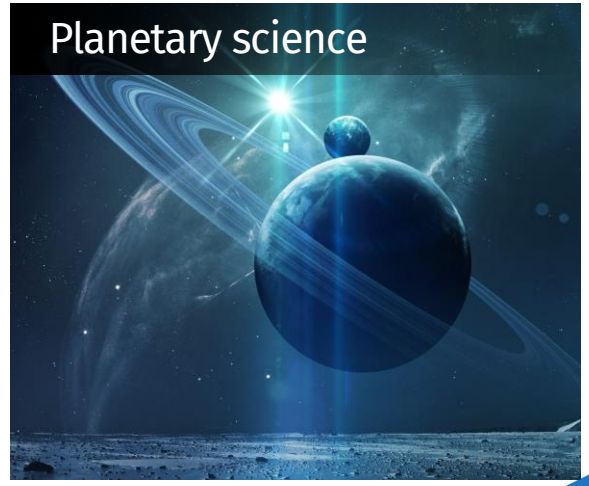
Synchrotron Research











590 peer-Reviewed Publications in 2023

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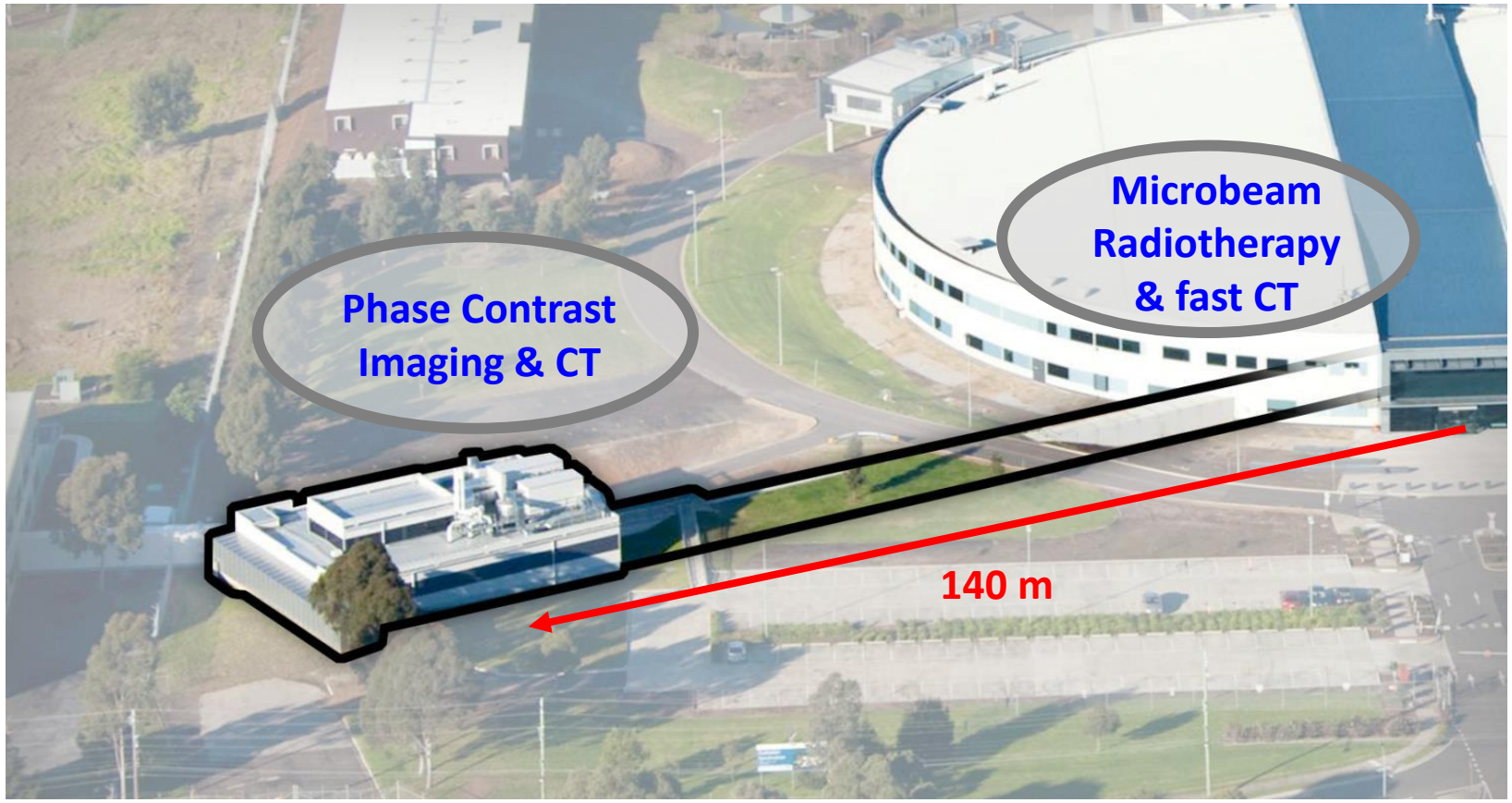
The Imaging and Medical Beamline (IMBL)



4T Superconducting Wiggler

Photon Energy: **Up to 300 keV**

Pink and Mono beams

Double Laue Monochromator

Beam Dimensions: **300 mm x 20 mm**

Beam Expander: **80 mm x 80 mm**

Heavy **(100 kg)** & Large **(> 1m)** objects

Resolution: **10-20 μm**

Phase Contrast Imaging & CT and Microbeam Radiotherapy

- Biomedical & In vivo studies
- Industrial, Engineering & Agriculture studies
- Earth Sciences & Palaeontology

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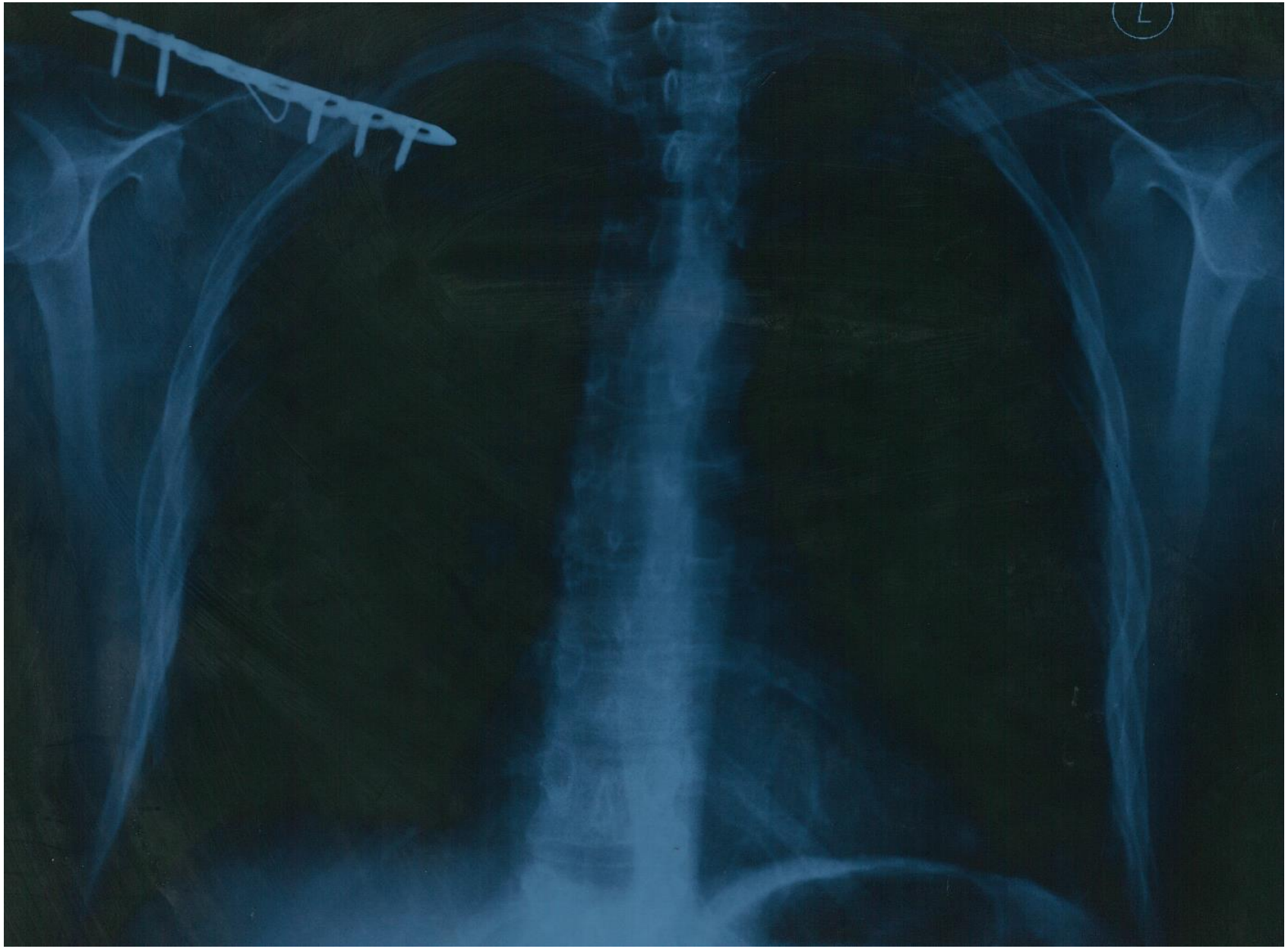
Conventional (Adsorption) X-ray Imaging



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Helping Pre-Term Infants Breathe Easier

Finding better ways to deliver air to pre-term infants in the first vital minutes of life.

- 23% of babies in Australia (~71,000 P.A.) need assistance at birth.
- Many experience neurodevelopmental, respiratory and cardiovascular complications due to a failure to adequately transition to natural breathing.
- Research on understanding the critical processes regulating the cardiorespiratory transition at birth and how best to assist in delivering improved outcomes.

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Fighting Cardiorespiratory Diseases in Pre-Term Infants

Testing specific inflammatory signalling molecules is critical to understanding and treatment of diseases such as *Paediatric Bronchopulmonary Dysplasia* and *Pulmonary Hypertension*.

Mouse lung in model of PBD.
Feature resolution in the blood-gas exchange interface below 50µm.

A/Prof Marcel Nold and Dr Claudia Nold,
(Hudson Institute of Medical Research)

Christine B. Bui, et al.,
Frontiers in Immunology, **10**, 1480 (2019).

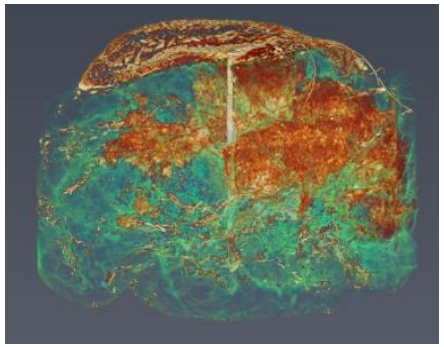
Jason C. Lao, et al.,
Science Translational Medicine, **14**, 639 (2022).

Science Highlights – Imaging and Computed Tomography

Breast Cancer Research on IMBL

Standard breast mammography imaging does not serve high risk women with high density tissue

High level of false positives lead to unnecessary surgical interventions



Phase-contrast CT reveals tumours at lower dose than conventional radiography

British Journal of Radiography, **96**, 20221189 (2023)

MonashHealth

ANSTO

Science Highlights – Imaging and Computed Tomography

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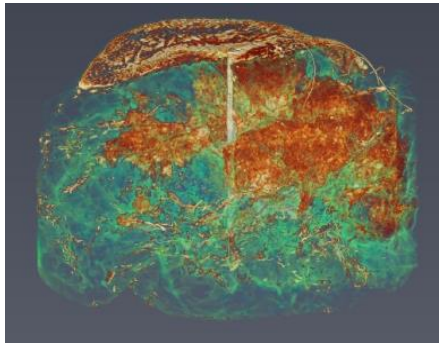


Phase-contrast CT reveals tumours at lower dose than conventional radiography

British Journal of Radiography, **96**, 20221189 (2023)

MonashHealth

Human Imaging in 2025

Participants in the

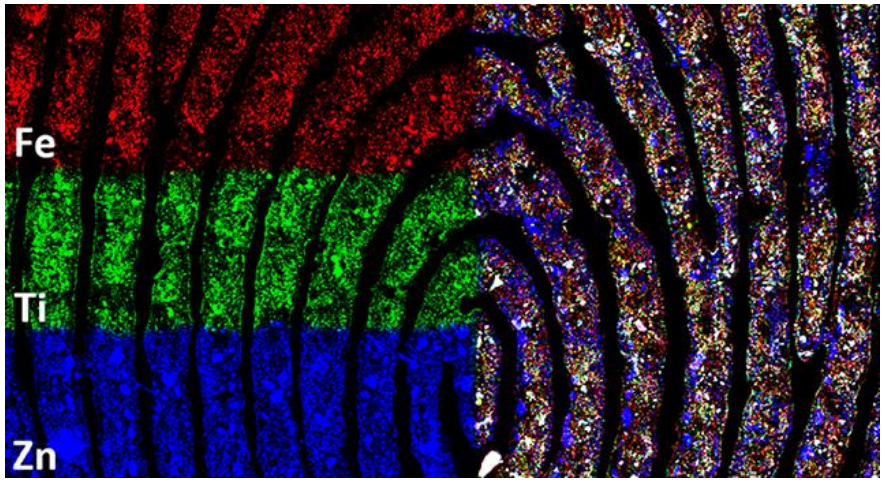
Breast-CT Research Program

Major upgrades to:

Safety Systems, Controls Systems,
Data Acquisition & Storage
Analysis & Reconstruction

Forensic Analysis of Fingermarks

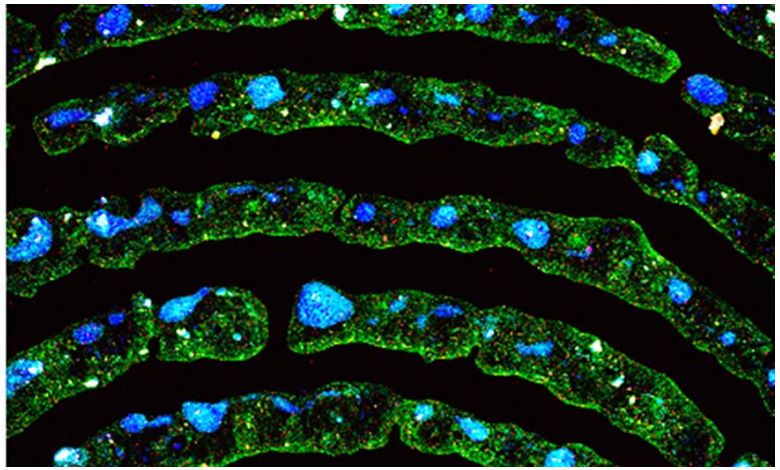
(IRM and XFM)



Fingermarks contain important trace information for forensic analysis.

Understanding the chemical contributions from organic and inorganic components provide new detection capabilities.

A multimodal study using X-ray Fluorescence Microscopy and Infrared Microspectroscopy gives colocalization of endogenous metals within the hydrophilic organic components.



Rhiannon E. Boseley, *et al.*,
Analytical Chemistry, **81**, 10622 (2019).
Analyst, **147**, 387 (2022).

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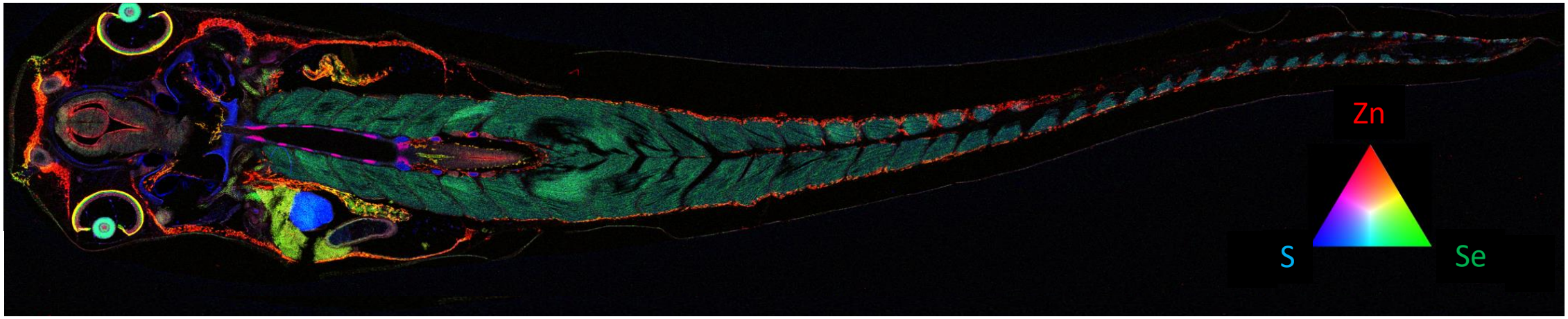
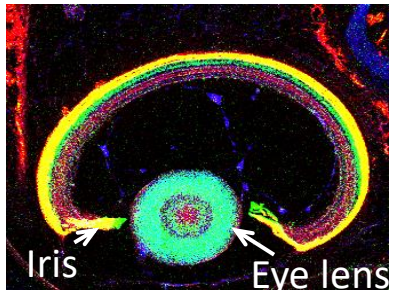
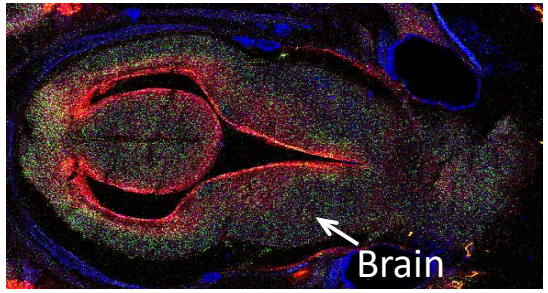
Selenium Bioaccumulation on the Micron Scale

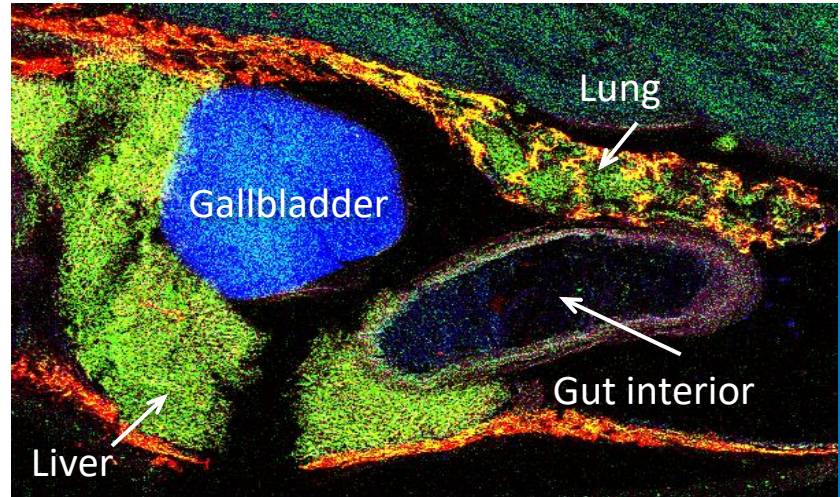


(XFM)





Tadpole exposed to Se(IV) (30 µg/L)



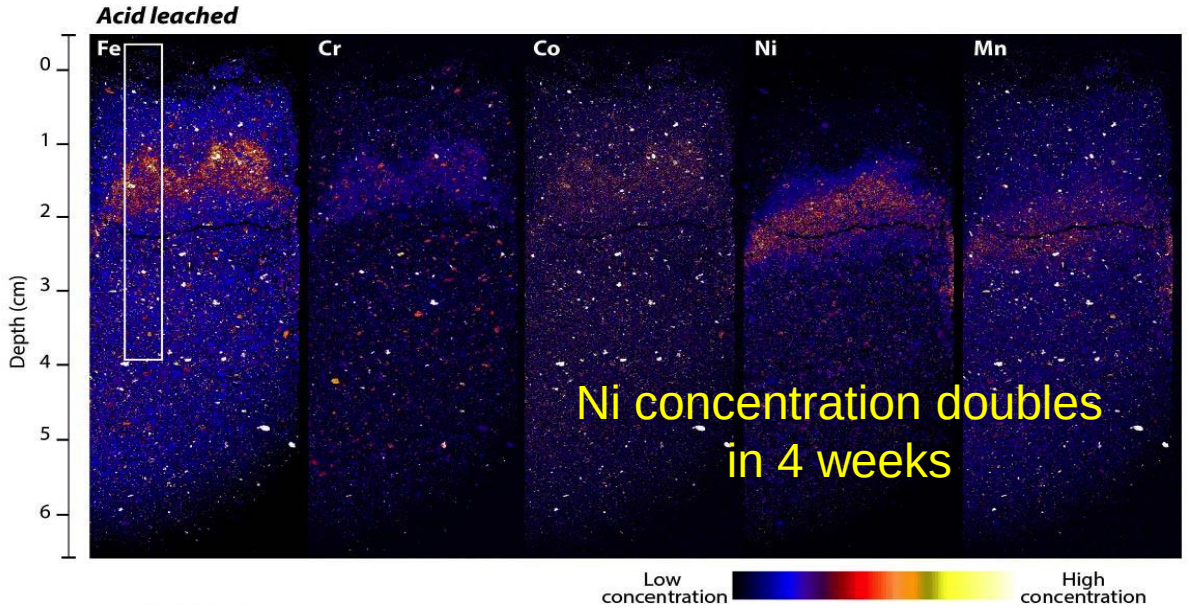
- Exposed tadpoles to Se for 7 days followed by 3 days depuration
- Observed bioaccumulation in the liver, iris, eye lens, brain, retained through metamorphosis

Lanctôt, *et al.*, *Environ. Sci. Technol.* **55**, 11848 (2021)

Mine Tailings: From Waste to Resource

Researchers have demonstrated the ability to recover critical metals (Ni, Co) from mine waste in a CO_2 sequestering process

The XFM and XAS beamlines were used to investigate how critical metal chemistry changes during acid leaching, to optimise opportunities for metal recovery



(XFM)

Valuable trace metals were previously inaccessible

After leaching, they could be recovered by conventional methods

Frontiers in Climate, 913632 (2022)
Chemical Geology, **617**, 121270 (2023)
Geochemical Trans., **24**, 1 (2023)

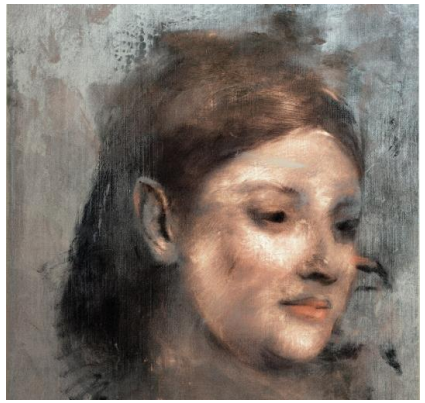
Grantham Foundation for the Protection of the Environment

Revealing That Which Has Been Hidden…

Portrait of a Woman
Edgar Degas, ~1876

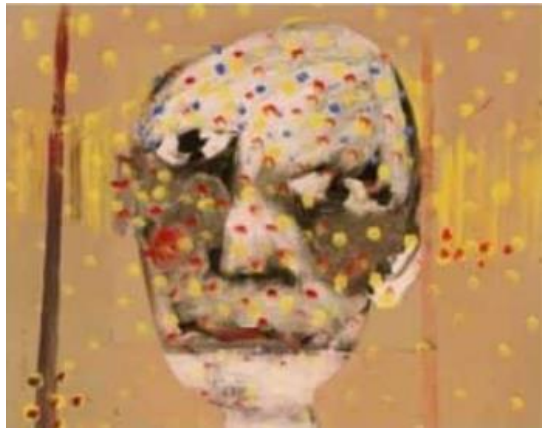
The North Wind
Frederick McCubbin, 1888 (?)

Ned Kelly: : 'Nobody knows anything about my case but myself'
Sidney Nolan, 1945



Ms Emma Dobigny

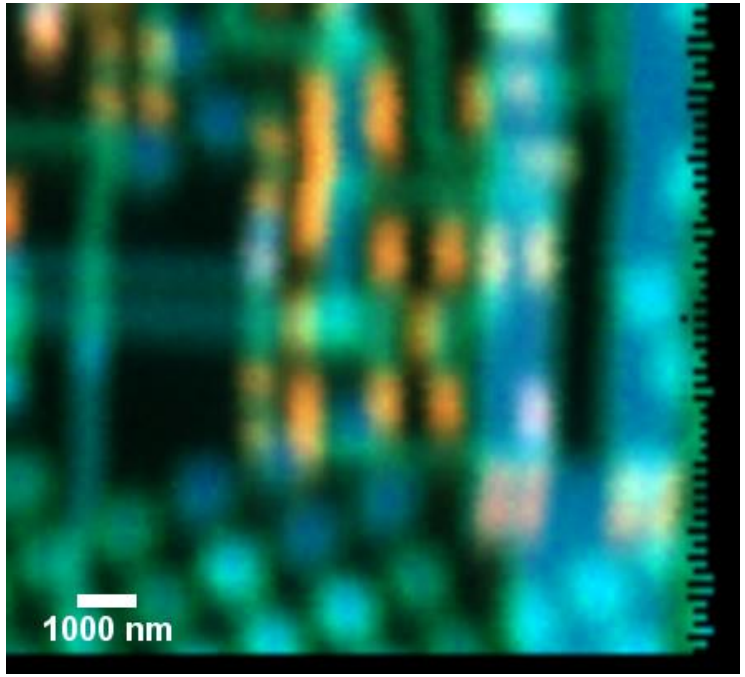
The Two-Headed Horse…



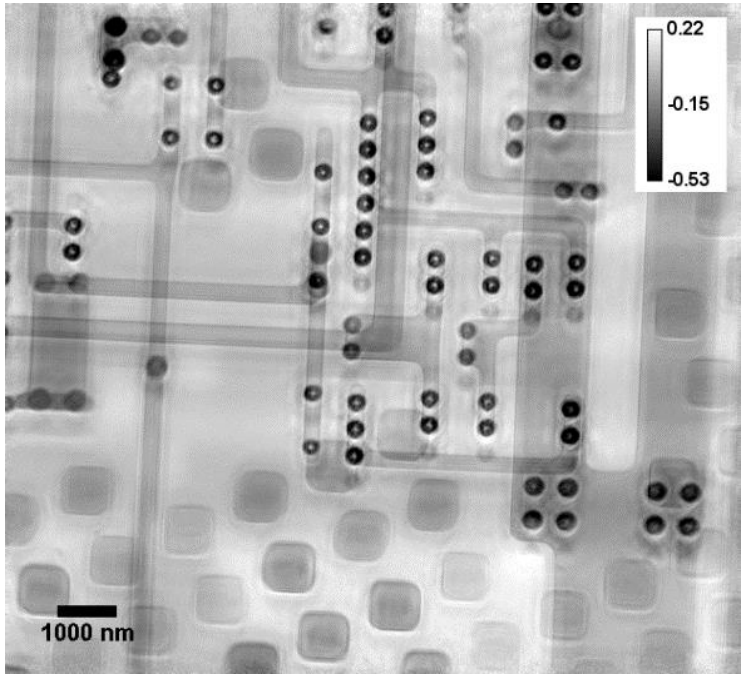
Sidney Nolan - Self Portrait

XFM – Ptychography Imaging on the Nanoscale

- *Scanning X-ray Diffraction Microscopy* → providing high spatial resolution and high sensitivity
- Automated algorithms to reconstruct image



X-ray fluorescence map:
orange - tungsten, green - tantalum,
blue – copper.
Features resolved significantly better
than the **probe size of ~1 µm**.



Ptychographic phase reconstruction of an
integrated circuit at
~50 nm resolution.

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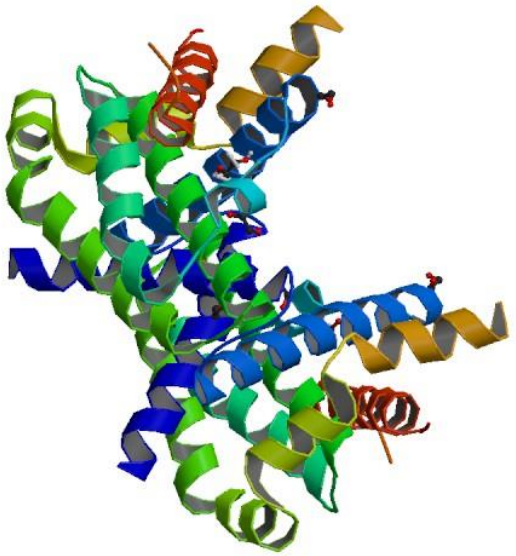
Life Saving Pharmaceutical Break Throughs

Venetoclax (Venclexta™) is now being used to treat *Chronic Lymphocytic Leukaemia* in the USA, Europe and Australia

There have been very few effective treatment for this Leukaemia for the past 50 years.



Venetoclax blocks the B-cell lymphoma-2 (Bcl-2) protein, leading to programmed cell death of CLL cells.

Global sales in 2023: US$2.3 billion

> 500 Clinical Trials for Venetoclax worldwide

Cell Death & Differentiation **31**, 711 (2024)

abbvie | Genentech
A Member of the Roche Group

FIAT LUX
Walter+ Eliza Hall
Institute of Medical Research

ANSTO

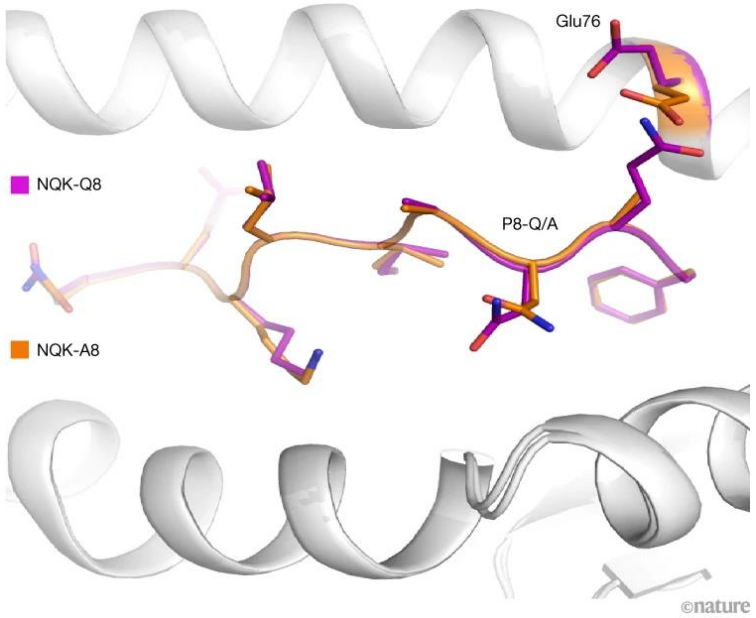
Why Some People Don't Get Sick From SARS-CoV-2

At least 20% of people who become infected with SARS-CoV-2 never feel sick.

Researchers have identified a genetic mutation that is linked to a higher likelihood of avoiding symptoms during infection.

This mutation may give an advantage to the immune cells of people who have previously been exposed to 'seasonal' coronaviruses, that cause the common cold.

That extra boost means the immune system can quickly track down and destroy SARS-CoV-2 infections.



Human leukocyte antigen B (HLA-B) interacts with SARS-CoV-2 and with cold viruses in a similar manner.

MX2

Danillo G. Augusto, et al., *Nature* **620**, 128 (2023)

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Plastic Recycling Technologies

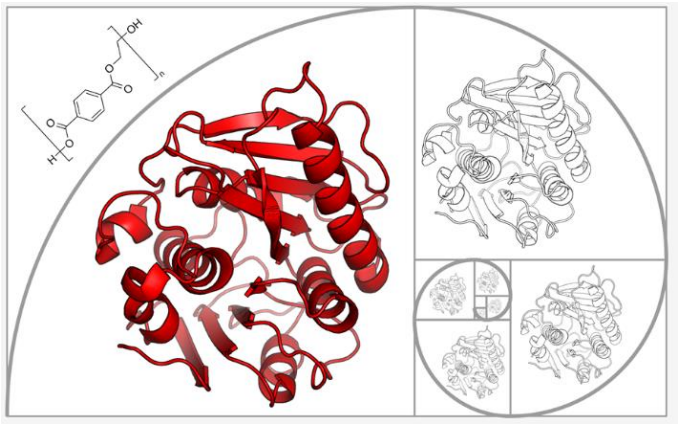
Australian National University

samsara eco

Delivering climate repair through infinite recycling

Samsara Eco uses enzymes that attack complex polymers, (PET & Polyesters) reverting them back to their original monomer building blocks.

By reverting complex polymers back into simple monomers, they can make new, virgin-grade plastics without needing fossil fuels again.



Samsara Eco makes use of the MX1 and MX2 beamlines to characterize & engineer PETase polymer-breaking enzymes

Yvonne Joho, et al. *Biochemistry*, **62**, 437 (2022)
Yvonne Joho, et al. *ChemBioChem* 25, e202400084 (2024)

ANSTO

How Treat Malaria with Milk

Instead of putting an antimalarial drug in milk…
Put it in a simplified formulation made from milk derivatives

- Cheap & readily available
- Known to be human compatible
- Already have FDA approval

Prof. Ben Boyd (Monash) and colleagues from ANSTO have developed an effective *single-dose* anti-malarial treatment

BILL & MELINDA GATES *foundation*

MMV Medicines for Malaria Venture

Eureka Prize 2020

Ben J. Boyd, et al., *Journal of Controlled Release*, **292**, 13 (2018)
Syaza Y. Binte Abu Bakar, et al., *International Journal of Pharmaceutics*, **554**, 179 (2019)
Malinda Salim, et al., *Molecular Pham.* **17**, 885 (2020); **20**, 2256 (2023)

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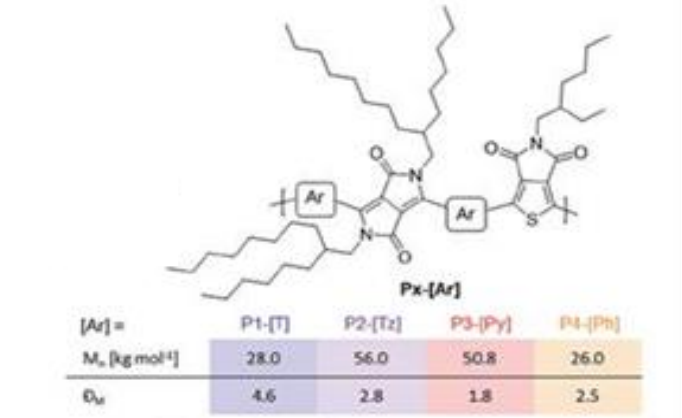
Polymer-Based Organic Photovoltaics & Electronics

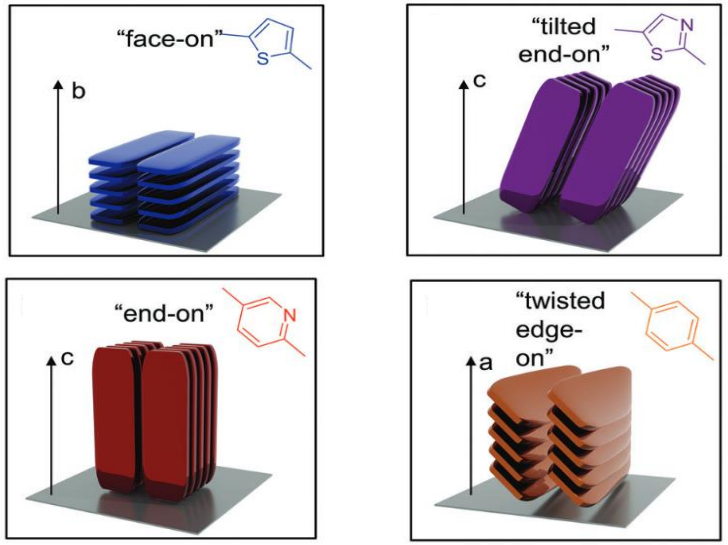
Soft X-ray Spectroscopy & Medium Energy XAS 2 beamlines (NEXAFS) to determine **molecular orientation**, and the **SAXS/WAXS beamline (GIWAXS)** to study **polymer crystallinity** in semiconducting polymer devices.

~ 40 journal articles P.A.
on photovoltaics &
conducting polymers

Nature Communications,
Applied Materials Interfaces,
Advanced Materials,
Advanced Energy Materials,
Energy & Environmental Science,
Nano Energy,
Chemistry of Materials,…



[Ar] =	P1-[T]	P2-[Tz]	P3-[Py]	P4-[Ph]
M_n [kg mol^{-1}]	28.0	56.0	50.8	26.0
$Đ_M$	4.6	2.8	1.8	2.5



Design Principles of Diketopyrrolopyrrole-Thienopyrrolodione Acceptor1–Acceptor2 Copolymers

(SAXS/WAXS, MEX2, SXR)

Andreas Erhardt, *et al.*,
Advanced Functional Materials,
34, 2314696 (2024)

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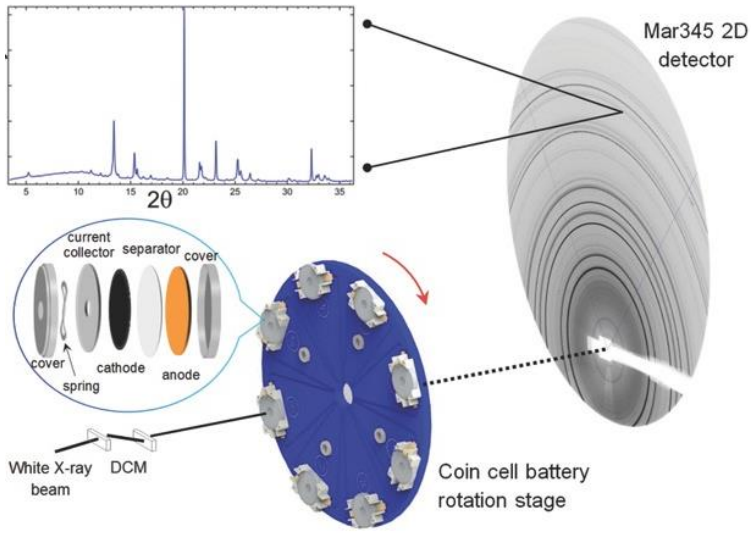
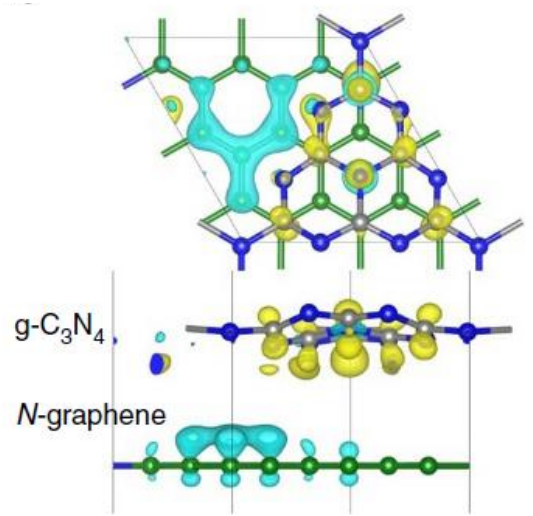
Energy Materials Research at the Australian Synchrotron

Clean energy and renewables studies account for ~25%
of research outcomes from the facility.



~ 40 journal articles P.A. on battery research
PD, MEX1, SXR, XAS, IRM



~ 60 journal articles P.A. on catalysis research
PD, MEX1, SAXS, SXR, THz, XAS

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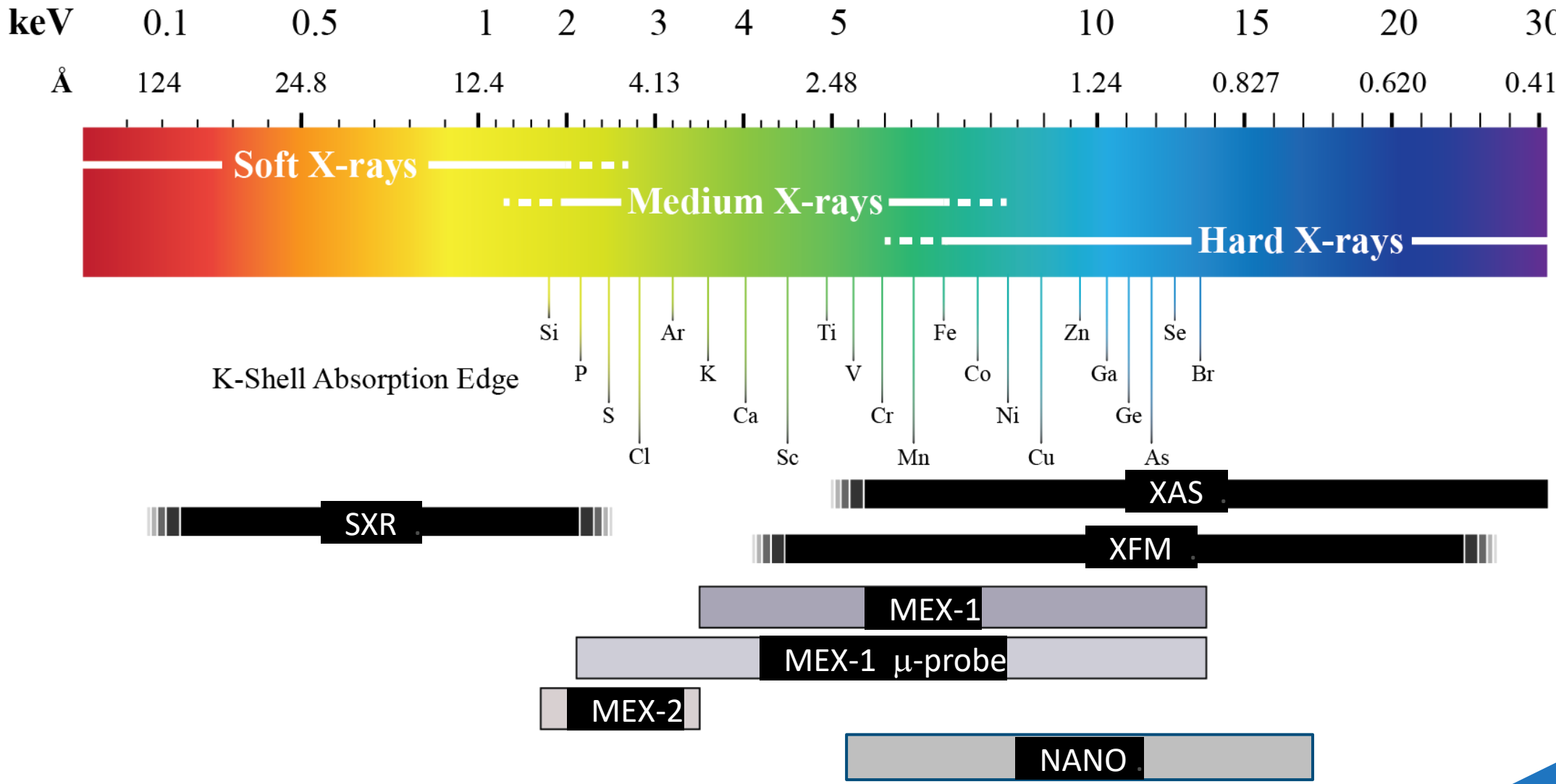
Australian Synchrotron Spectroscopy Beamlines



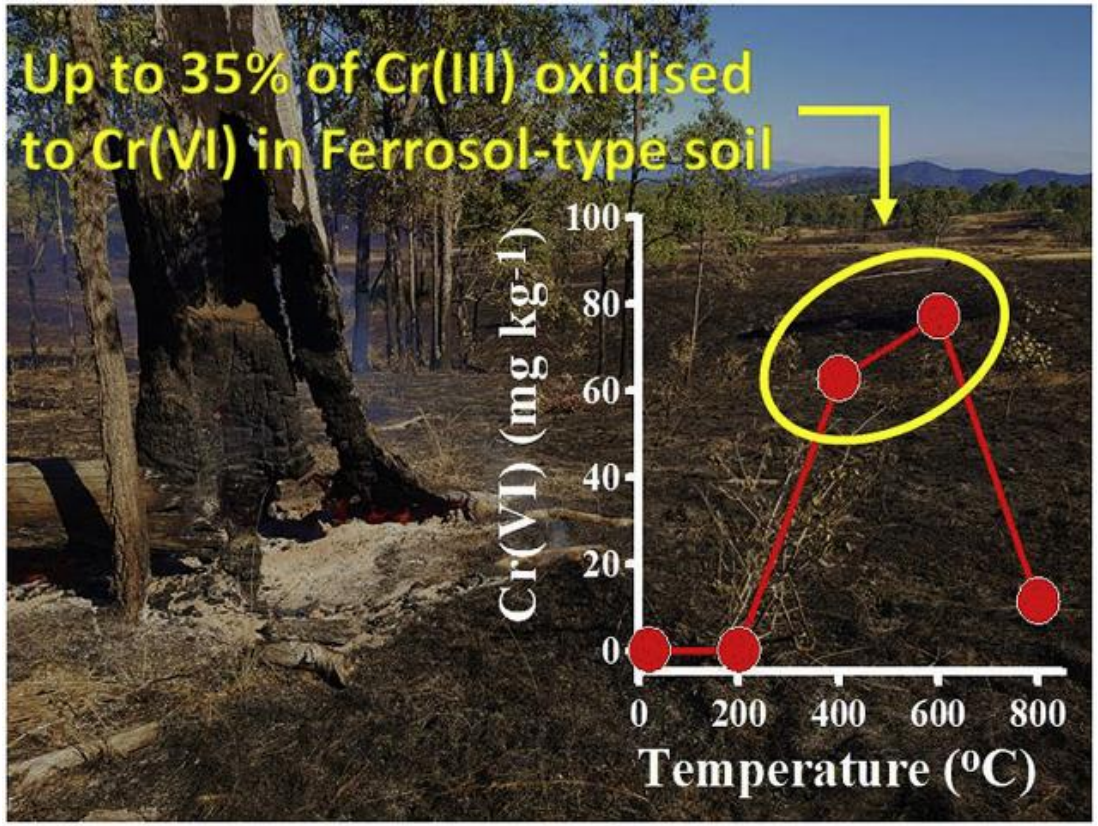
Do Bushfires Generate Hazardous Chromium In Soil?

Chromium is commonly hosted in iron oxy/hydroxide minerals in soil.

These minerals transform at high temperatures but the fate of trace metals such as chromium has not been well explored.

- At bushfire temperatures (200-700 °C), Cr^{3+} is oxidised to Cr^{6+} in soil
- Cr^{3+} is benign; Cr^{6+} Is highly toxic and carcinogenic
- 30-40% of this Cr^{6+} is extractable/mobile, meaning it could be flushed into waterways with rainfall

This is a previously unrecognised environmental risk associated with bushfires.



Ed Burton, *et al.*
Environ. Pollut. **247**, 618 (2019).

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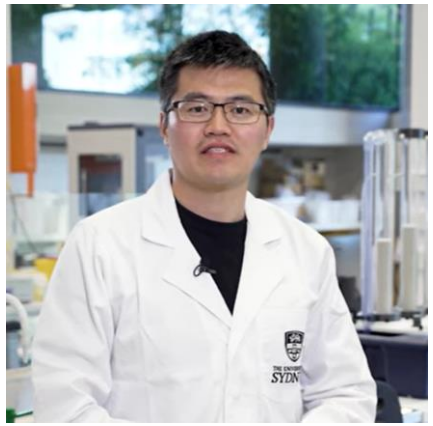
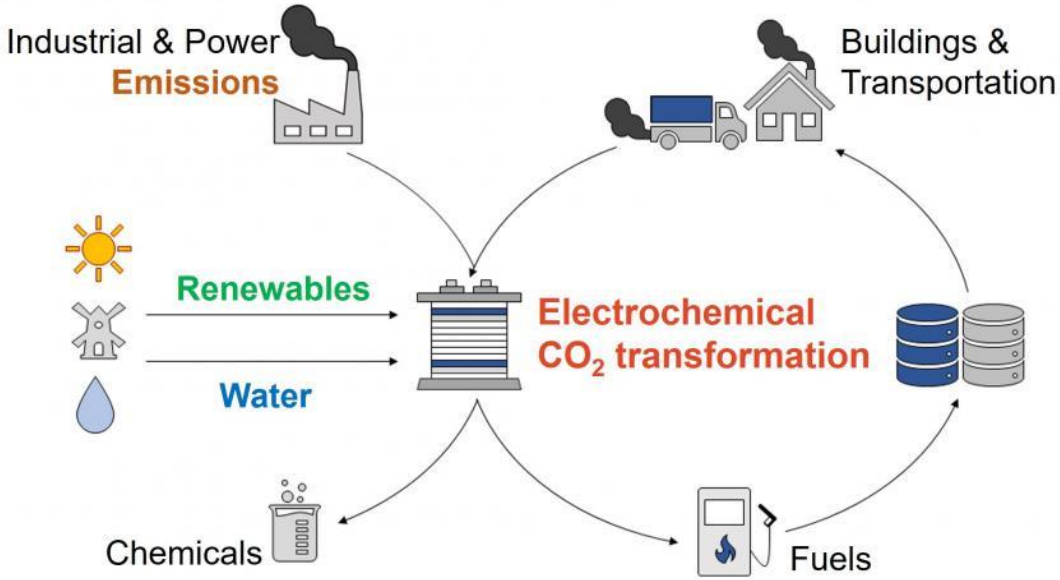
Catalytic Reactions That Eat CO_2



Dr Fengwang Li was recently awarded the *2023 Eureka Prize* for research to create an affordable and efficient process to electrochemically convert captured CO_2 emissions into ethylene, a basic manufacturing component of organic and polymeric materials.



Dr Li made use of the *X-ray Absorption Spectroscopy*, *Infrared Microspectroscopy* and *Terahertz Spectroscopy*, beamlines to study the reduction of CO_2 to ethylene using *in situ* electrochemical methods that he developed.

Advanced Materials, **35**, 2209567 (2023)
Nature Communications, **14**, 474 (2023)
Nanoscale, **15**, 1092 (2023)

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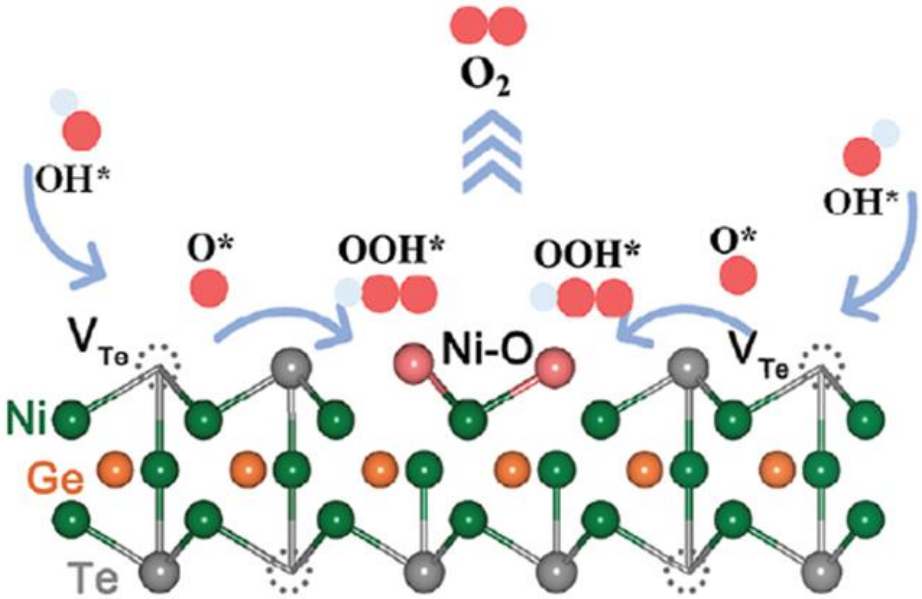
Catalysts for Hydrogen Generation

2D Ferromagnetic M_3GeTe_2 (M = Ni/Fe) for Faster Water Oxidation

This study made use of 3 synchrotron beamlines to investigate the complex chemistry of a 2D engineered electrocatalyst Ni_3GeTe_2 used in an anion-exchange membrane for water electrolysis.

SXR – Oxygen chemistry
MEX-1 – Ni & Ge Chemistry
XAS – Te Chemistry



Guyue Bo, *et al.*, *Advanced Science* **11**, 2310115 (2024).

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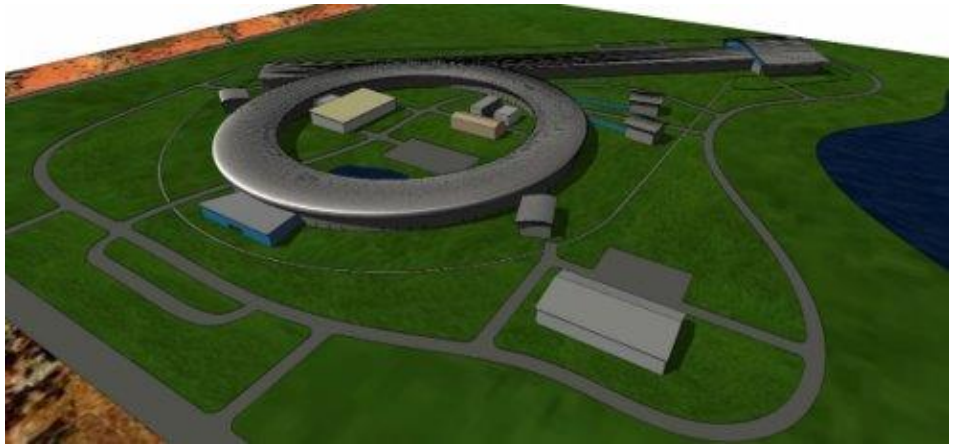
A Future Synchrotron Light Source for Australia (AS2)

- The Australian Synchrotron has an operational life to 2037.
- International synchrotron facilities all over the world are currently upgrading or building new 4th Generation Synchrotron facilities.
- Synchrotron light in new facilities is ~100 – 1000x brighter than existing facilities.



- Preliminary design and development of the business case for a new facility has commenced.
- A 450 m circumference, 4th Gen facility is envisaged.
- 3 GeV; 400 mA; 6 MBA Lattice; 100 pm.rad
- Important to ensure operational overlap between the two facilities.

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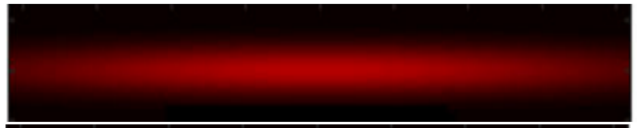
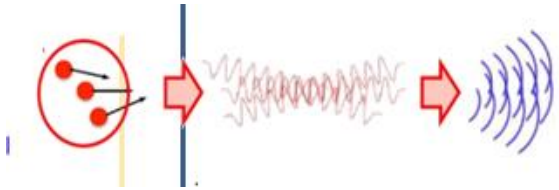
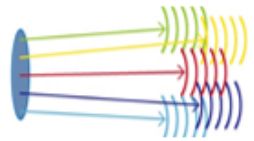
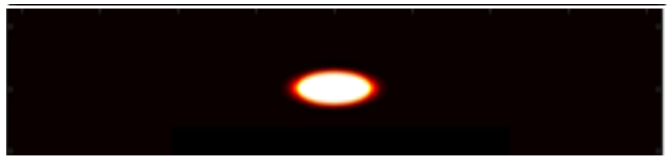
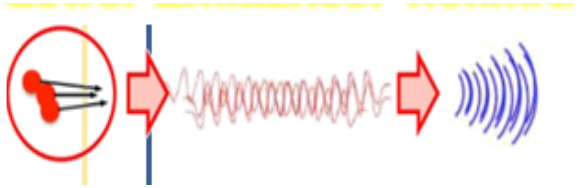
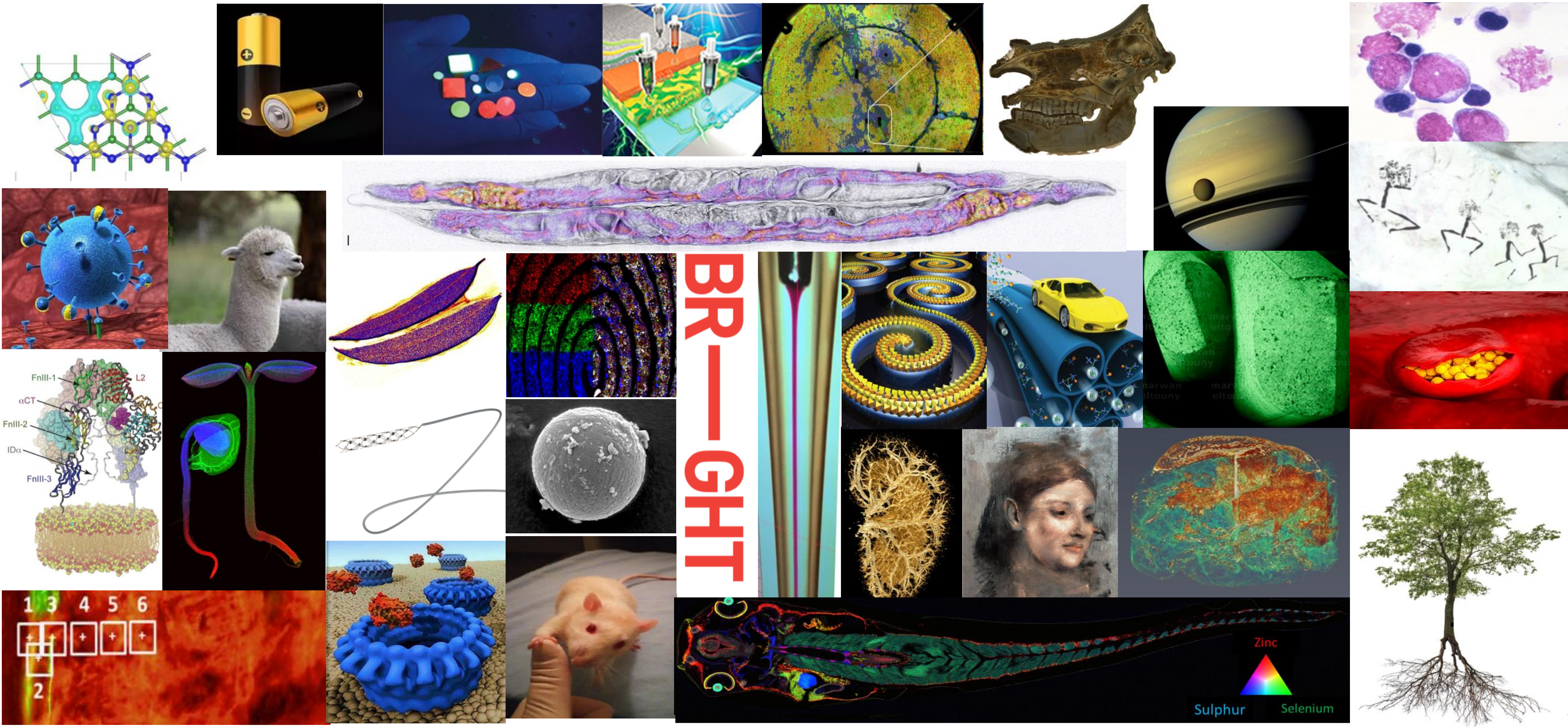
The Australian Synchrotron vs AS2

	Electron Beam (Emittance)	Undulator	X-ray Beam
AS	 (10349 pm.rad)		
		3rd Generation	
AS2	 (100 pm.rad)		
		4th Generation	

17 Years of Brilliance at the Australian Synchrotron



17 Years of Brilliance at the Australian Synchrotron

Especially at Night !!!

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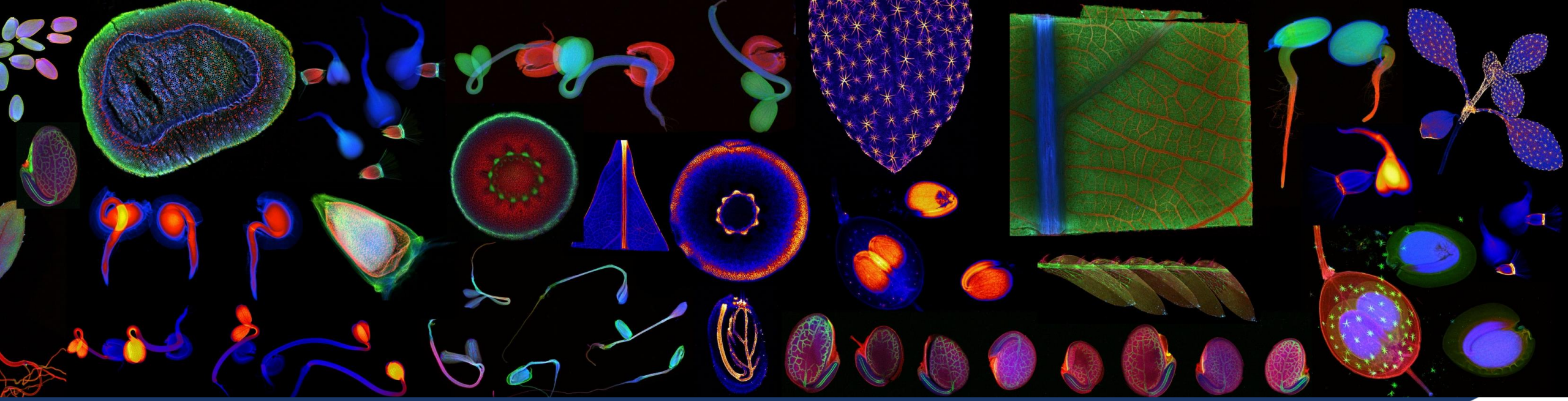

Thank you

mja@ansto.gov.au

Australian Government

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