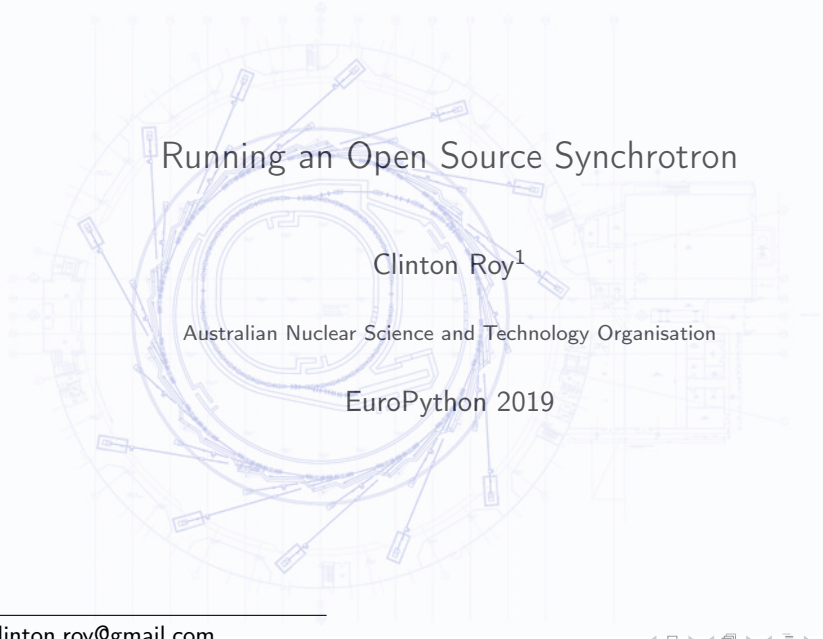


Running an Open Source Synchrotron

Clinton Roy[1]

Australian Nuclear Science and Technology Organisation

EuroPython 2019

[1] clinton.roy@gmail.com

Outline

1. Me
2. Physics
3. Synchrotron
4. BR—GHT
5. Software
6. Outcomes

WARNING

The following slides contain some diagnostic medical images.
These are in false colour and are not realistic.

Who am I?

- An Australian

Who am I?

- An Australian
- An Open Source Software Engineer

Who am I?

- An Australian
- An Open Source Software Engineer
- Mostly supporting research of various sorts

Who am I?

- An Australian
- An Open Source Software Engineer
- Mostly supporting research of various sorts
- A teacher/trainer

Who am I?

- An Australian
- An Open Source Software Engineer
- Mostly supporting research of various sorts
- A teacher/trainer
- Helps to run Open Source conferences

Who am I?

- An Australian
- An Open Source Software Engineer
- Mostly supporting research of various sorts
- A teacher/trainer
- Helps to run Open Source conferences
  - `linux.conf.au`, Gold Coast, Australia Jan 13-17

Who am I?

- An Australian
- An Open Source Software Engineer
- Mostly supporting research of various sorts
- A teacher/trainer
- Helps to run Open Source conferences
  - `linux.conf.au`, Gold Coast, Australia Jan 13-17
  - Call for presentations open, anything Open Source

Who am I **NOT**?

- A physicist
- A scientist
- A hardware engineer
- A researcher
- An academic
- An electrician

Who am I **NOT**?

- A physicist
- A scientist
- A hardware engineer
- A researcher
- An academic
- An electrician
- But that's OK, as there are plenty of those at the synchrotron

The Whole Spectrum

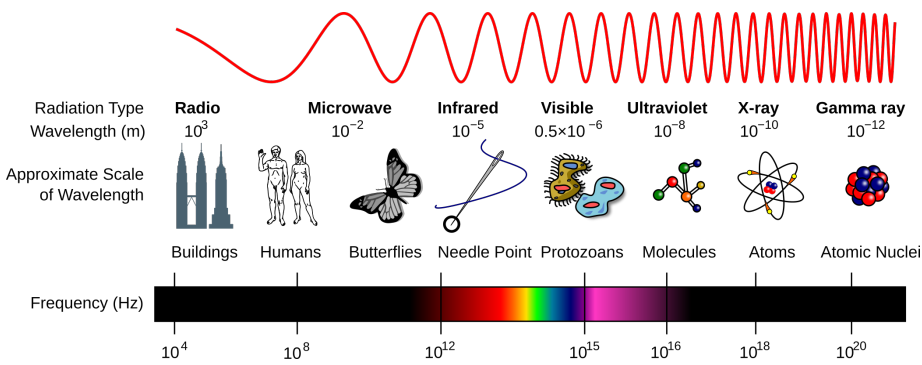


Figure: Wikipedia

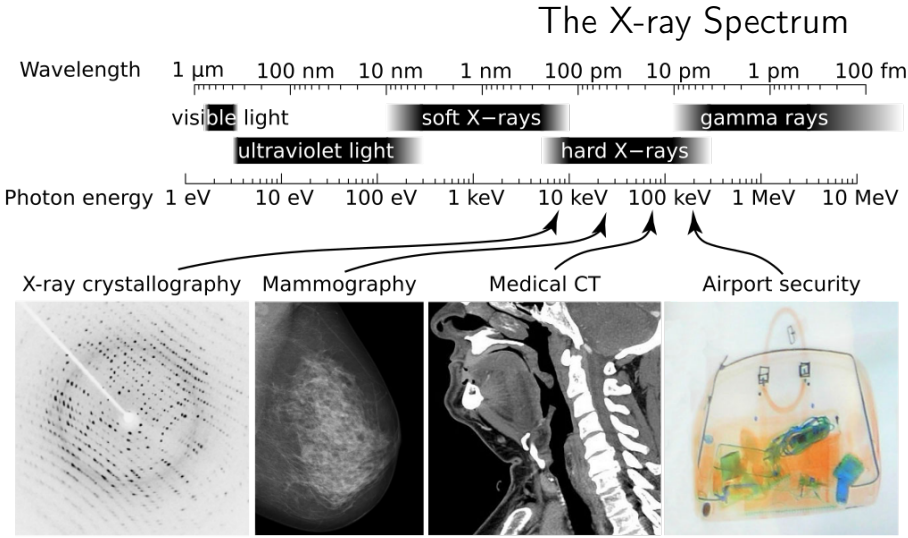


Figure: Wikipedia

What **is** a Synchrotron?

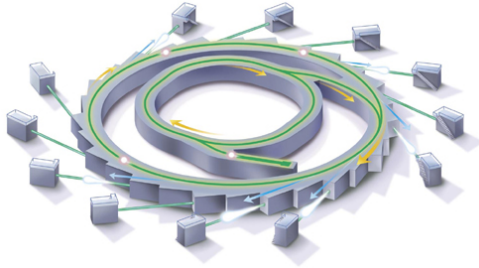


Figure: Aus Synchrotron

- A big research tool to look at really small things
- A microscope that uses X-rays instead of visible light
- A really fancy X-ray machine

What **is** a Synchrotron?

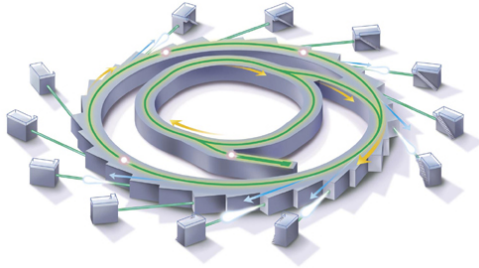
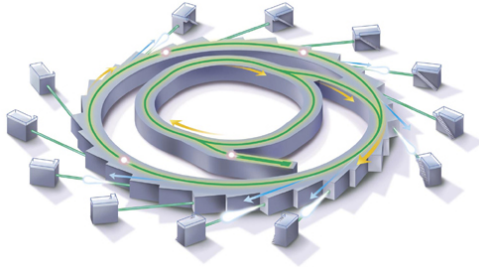


Figure: Aus Synchrotron

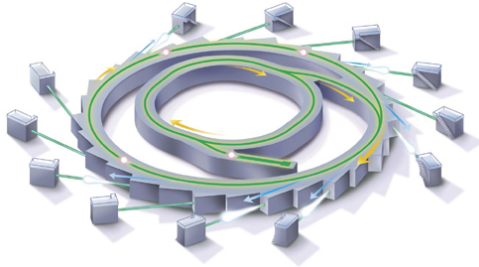
- A big research tool to look at really small things
- A microscope that uses X-rays instead of visible light
- A really fancy X-ray machine
- *(don't repeat any of that, work won't have me back)*

How does it work?



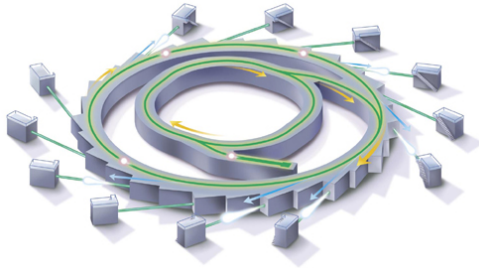
- Accelerate electrons to 99.99% speed of light

How does it work?



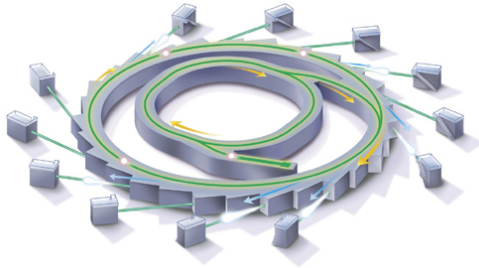
- Accelerate electrons to 99.99% speed of light
- Force the electrons to travel in a circle

How does it work?



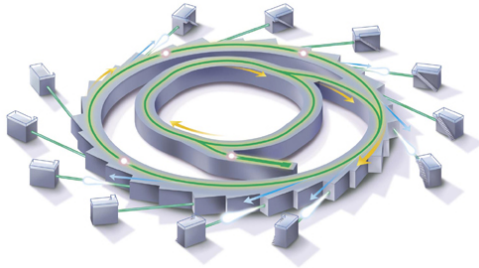
- Accelerate electrons to 99.99% speed of light
- Force the electrons to travel in a circle
- When the electrons are forced to turn, they release vast amounts of X-ray energy

How does it work?



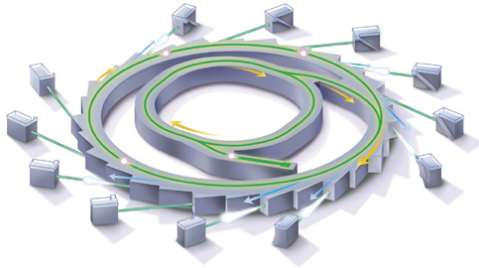
- Accelerate electrons to 99.99% speed of light
- Force the electrons to travel in a circle
- When the electrons are forced to turn, they release vast amounts of X-ray energy
- Filter this X-ray energy to make it parallel, a known energy

How does it work?



- Accelerate electrons to 99.99% speed of light
- Force the electrons to travel in a circle
- When the electrons are forced to turn,
  they release vast amounts of X-ray energy
- Filter this X-ray energy to make it parallel, a known energy
- Aim it at a sample, affect the sample (specifics later)

How does it work?



- Accelerate electrons to 99.99% speed of light
- Force the electrons to travel in a circle
- When the electrons are forced to turn,
  they release vast amounts of X-ray energy
- Filter this X-ray energy to make it parallel, a known energy
- Aim it at a sample, affect the sample (specifics later)
- Detect an aspect of the sample.

Filtering the X-rays

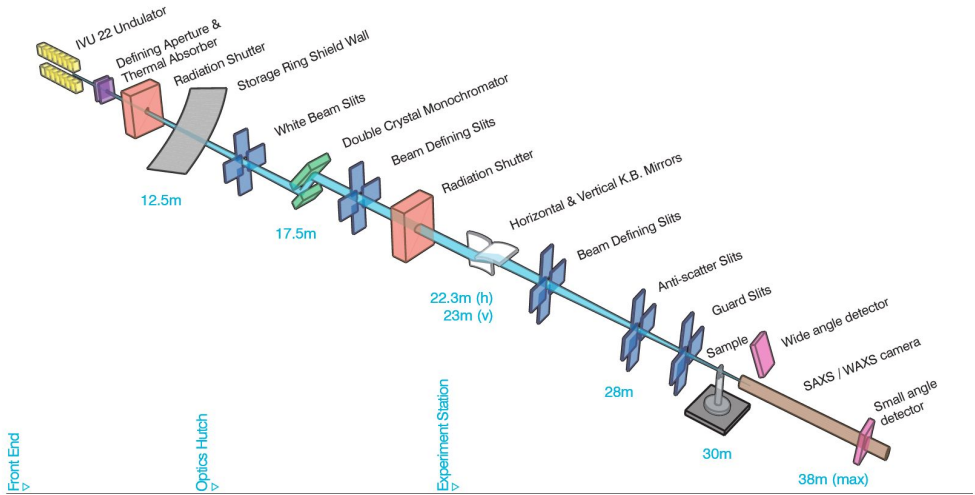


Figure: Aus Synchrotron

My Directorial Debut

A walk around the synchroton...

How do X-rays interact with the sample?

Pick your power level, tickle the atoms in just the right way...

- Absorption
- Phase Contrast
- Diffraction
- Spectroscopy
- Fluorescence
- Tomography
- Micro particle/void sizing
- ...

Absorption

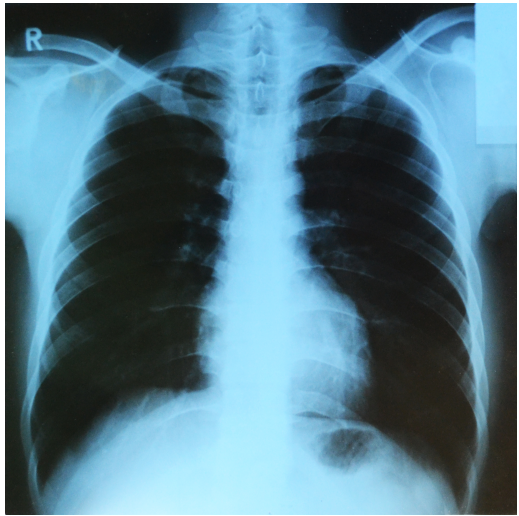


Figure: Wikipedia

Phase Contrast - How?

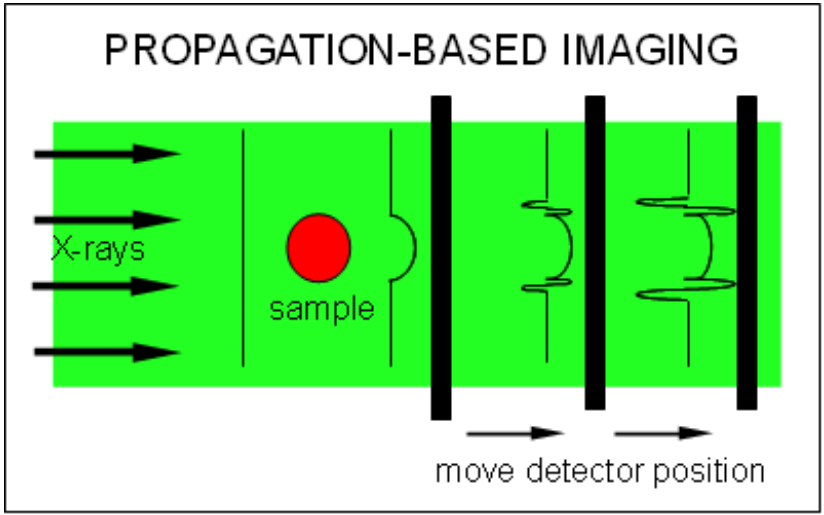


Figure: Wikipedia

Phase Contrast - Example

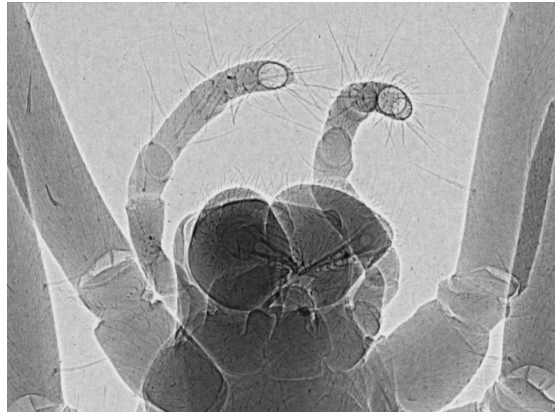


Figure: Wikipedia

Diffraction - How ?

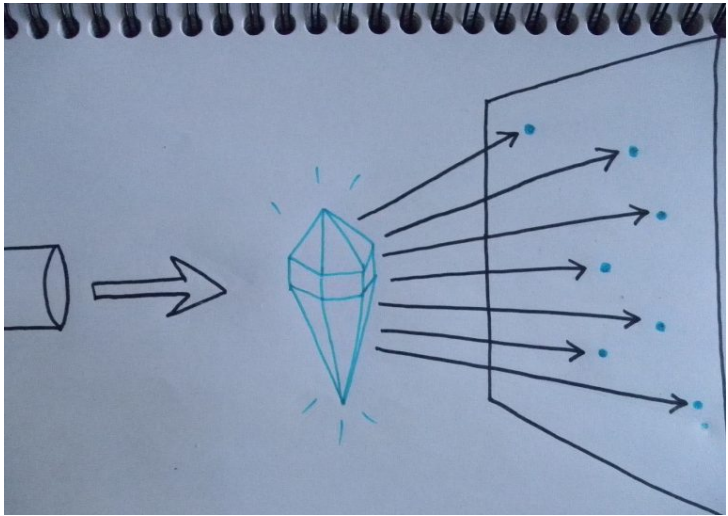


Figure: PhysicsOpenLab

Diffraction - Example

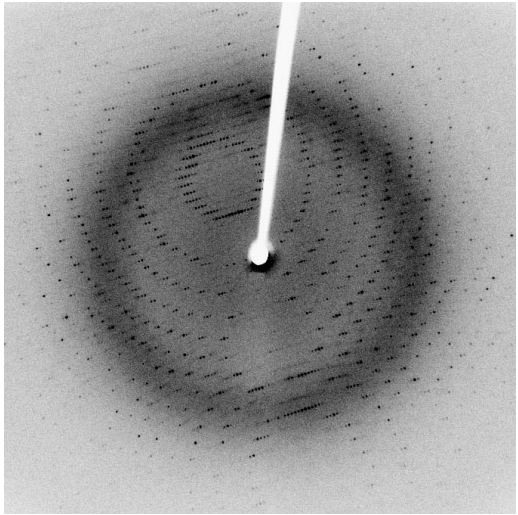


Figure: Wikipedia

Tomography - How ?

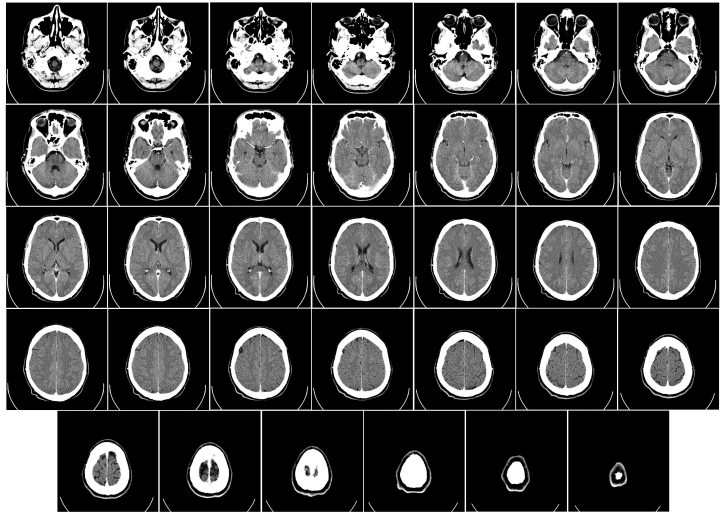


Figure: Wikipedia

Tomography - Example

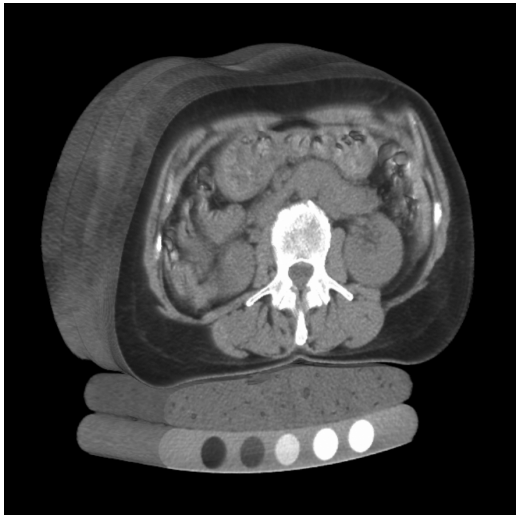


Figure: Wikipedia

Why's it so..big?

- X-rays scatter in air, so a lot of the beams are run in vacuum. This makes everything..difficult.
- Accelerators use a lot of power, they need to be cooled with water to stop them melting.
- A lot of the filtering processes have to dump unwanted x-rays into blocks of material, these blocks need cooling or they'll melt.
- The bigger the storage ring, the more x-ray beams can be produced, and the more experiments can be conducted at the same time.
- The medical beamline is far away so it can spread out and scan the entire patient in one sweep.
- Safety means things are cladded in thick concrete and lead.

What's it used for?

- Medical imaging, diagnostics, cancer treatment
- Microscopic samples, single cells
- Cultural history
- Stress and strain on materials
- Battery technology
- Chemical and biology structures

Typical Experiment Run

- Months in advance, researchers submit experiment proposal

Typical Experiment Run

- Months in advance, researchers submit experiment proposal
- If accepted, planning commences with beamline staff

Typical Experiment Run

- Months in advance, researchers submit experiment proposal
- If accepted, planning commences with beamline staff
- Researchers book onsite accommodation

Typical Experiment Run

- Months in advance, researchers submit experiment proposal
- If accepted, planning commences with beamline staff
- Researchers book onsite accommodation
- On arrival, researchers are allotted specific hours (day & night)

Typical Experiment Run

- Months in advance, researchers submit experiment proposal
- If accepted, planning commences with beamline staff
- Researchers book onsite accommodation
- On arrival, researchers are allotted specific hours (day & night)
- Researchers prepare and load their samples

Typical Experiment Run

- Months in advance, researchers submit experiment proposal
- If accepted, planning commences with beamline staff
- Researchers book onsite accommodation
- On arrival, researchers are allotted specific hours (day & night)
- Researchers prepare and load their samples
- Researchers run their experiment

Typical Experiment Run

- Months in advance, researchers submit experiment proposal
- If accepted, planning commences with beamline staff
- Researchers book onsite accommodation
- On arrival, researchers are allotted specific hours (day & night)
- Researchers prepare and load their samples
- Researchers run their experiment
- Everything goes perfectly the first time, and no rerun is ever required

Typical Experiment Run

- Months in advance, researchers submit experiment proposal
- If accepted, planning commences with beamline staff
- Researchers book onsite accommodation
- On arrival, researchers are allotted specific hours (day & night)
- Researchers prepare and load their samples
- Researchers run their experiment
- Everything goes perfectly the first time, and no rerun is ever required
- Experimental data is available for download or local analysis via ASCI Desktop

Samples?

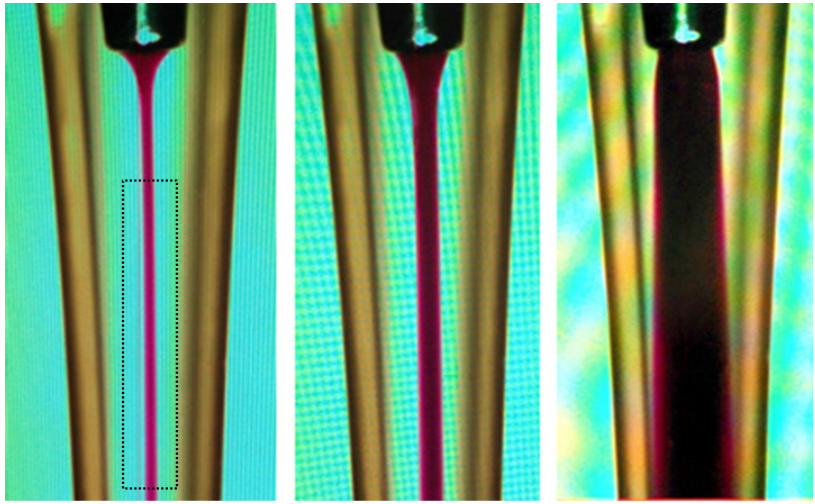
Pretty much anything that can fit:

- Gas
- Solid
- Liquid

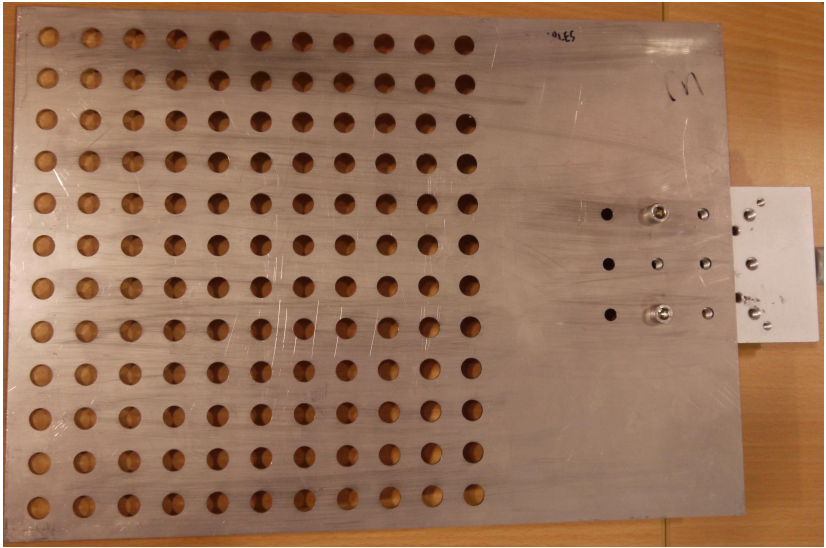
Samples can be put under different:

- Pressures
- Temperatures
- Voltages
- Radio waves

Sample Holders - Liquid



Sample Holders - Solid



BR—GHT Project

- Substantial funding from the Australian Government and Research Partners
- Eight new beamlines with new features
- Trying to build the hw & sw from similar components
  - get more consistency, improve all beamlines at once by sharing software
- BR—GHT+ is trying to share the common systems improvements with the current beamlines
- We can learn off existing beamlines

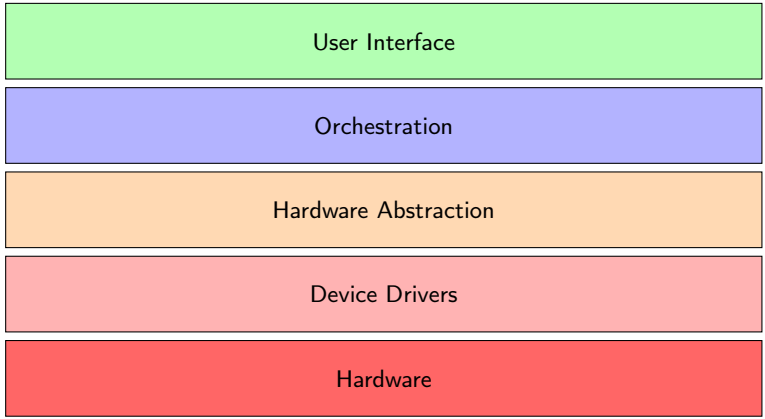
What users are we targeting?

- First timers all the way to chief scientists
- Sleep deprived
- Remote and local
- Standard procedure vs special sample environment

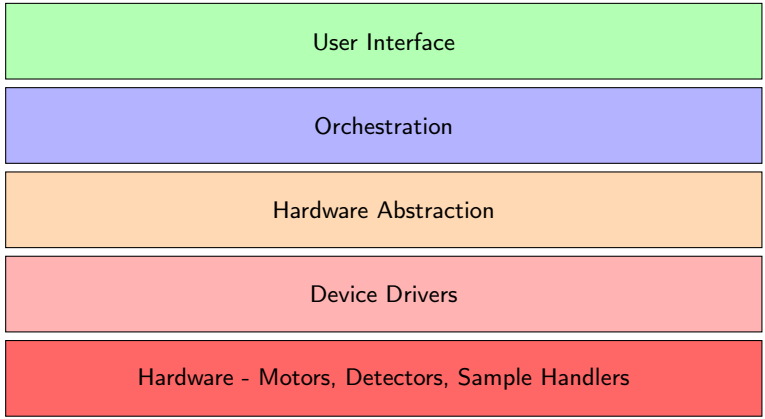
Data

- With some of the current and new beamlines, too much data to transfer
- Data must be left on site, we must provide analysis tools
- These tools must be available remotely

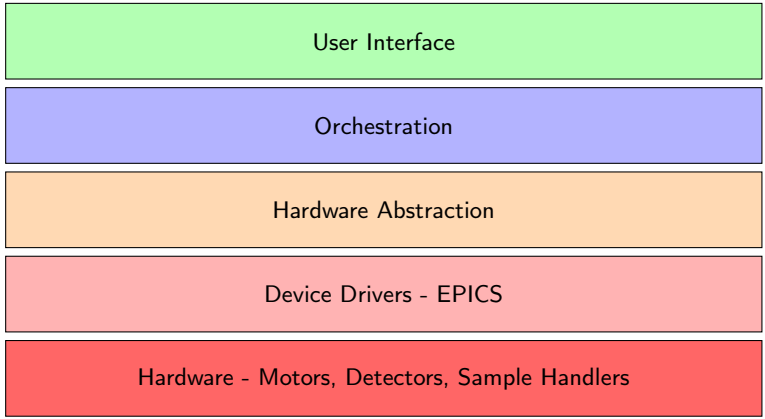
Technology Stack



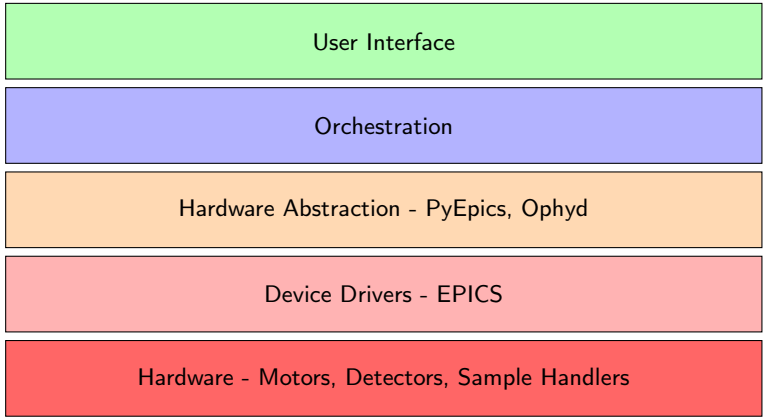
Technology Stack



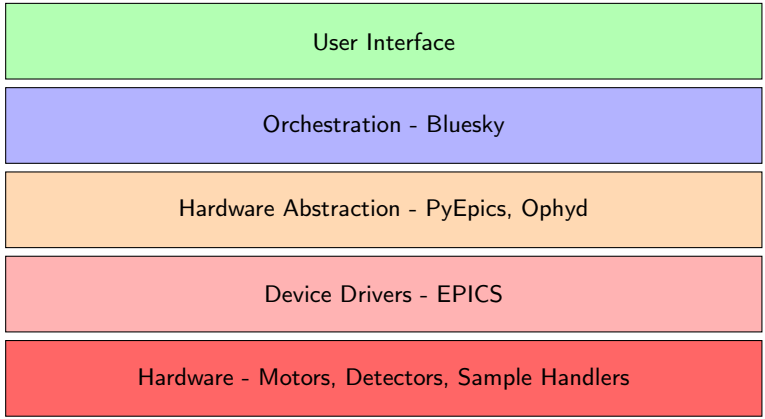
Technology Stack



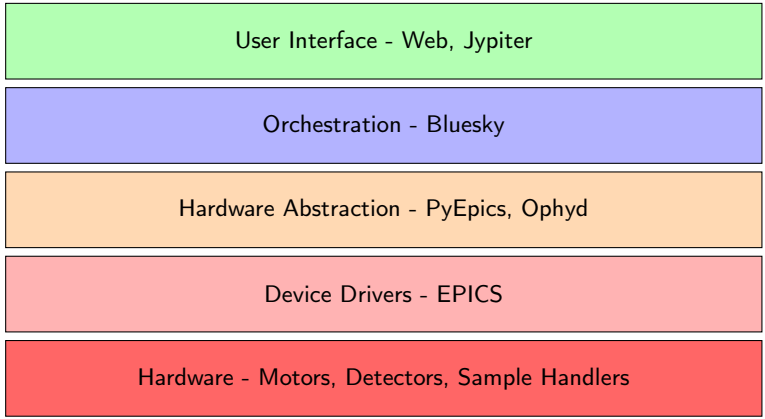
Technology Stack



Technology Stack



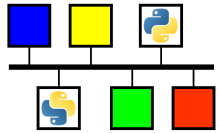
Technology Stack



Device Drivers - EPICS

- Open Source C library
- ANSTO hosted a world wide conference of users recently
- Exposes hardware devices on a network bus
- Defines a wide variety of records
  - Analogue in/out
  - Binary in/out
  - Calculations
  - Motors
  - Sensors
  - Custom

Hardware Abstraction - PyEpics



- Open Source C/Python library
- provides a Python interface to EPICS network records

Hardware Abstraction - Ophyd

Ophyd:

- Open Source Python library
- uses PyEpics to talk to EPICS devices
- encapsulates low level device quirks
- provides a high level API for all devices:
  - `trigger()` for 'do your thing', whatever that is
  - `read()` for getting data from a device
  - `describe()` for getting metadata about `read()` results, e.g. units
  - `stage()` and `unstage()` for get ready and stand down
  - `configure()`, `read_configuration()` and `describe_configuration()`
- Allows individual devices to be organised into hierarchies:
  - one 3D position motor instead of three X, Y, Z motors
  - gross and precision motors controlled as one positional motor

Orchestration - Bluesky

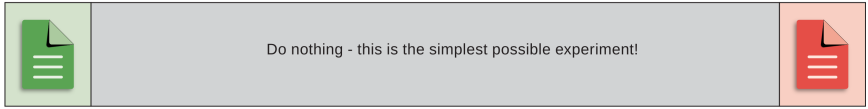
- Open Source Python library
- Orchestrates a collection of Ophyd devices via a *Plan*
- Can handle any sort of data type
- Automates experiments, while allowing human oversight

Bluesky - Plans

- Plans are a sequence of steps on Ophyd devices
- Plans can move motors, open shutters, trigger sensors etc.
- All these things take time, hence Bluesky is asynchronous
- Plans can be built up with other plans
- Handles interruptions well
- Each step adds data **and metadata** to the experiment *document*

Bluesky - Plan - Example 1

Example 1: Simplest Possible Run



Run Start: Metadata about this run, including everything we know in advance: time, type of experiment, sample info., etc.

Event: Readings and timestamps

Event Descriptor: Metadata about the readings in the event (units, precision, etc.) and the relevant hardware

Run Stop: Additional metadata known at the end: what time it completed and its exit status (success, aborted, failed)

Figure: NSL-II

Bluesky - Plan - Example 2

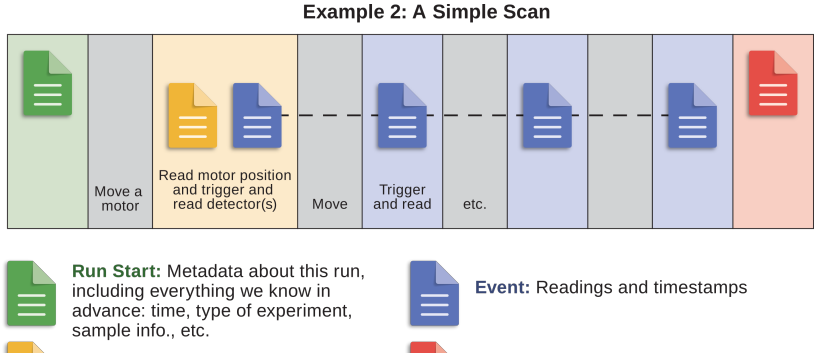


Figure: NSL-II

Bluesky - Plan - Example 3

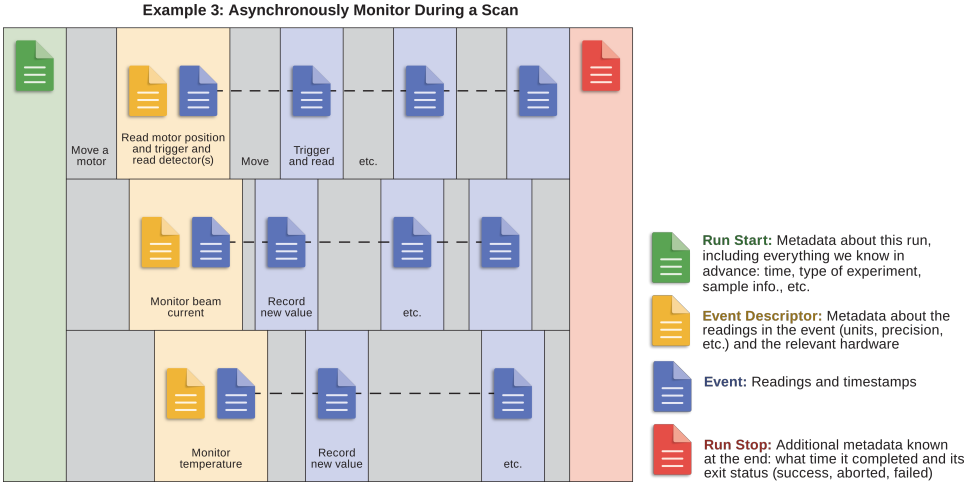


Figure: NSL-II

More about Me...

- I am a CLI lover

More about Me...

- I am a CLI lover
- I am **NOT** good at GUIs

User Interface - Web, Jypiter

- Excited about the prospect of tools like Pyodide, QT WebAssembly backend
- If you're not developing for the web (HTML/JS) or WebAssembly, you better have funky hardware.

This Page Intentionally left blank

Please hang around for the post credit scene

Outcomes - Microbeam Radiation Therapy

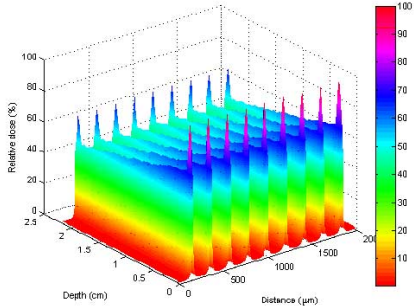
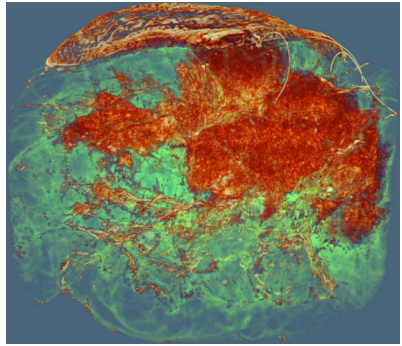


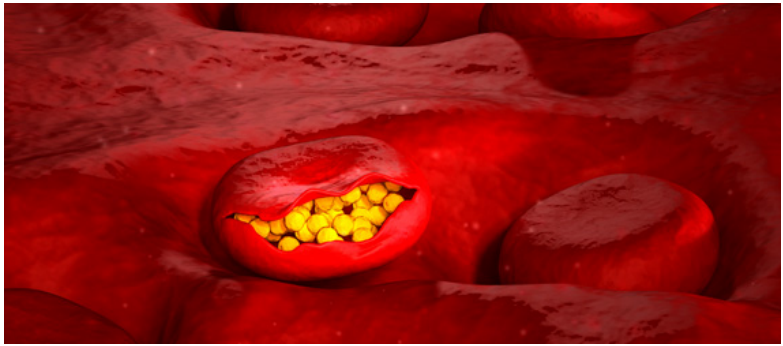
Figure: ESRF

Figure: ESRF

Outcomes - Phase-Contrast Computed Tomography Mammography



Outcomes - Malaria First Contact



Outcomes - Degas's Portrait of a Women

Figure: The Conversation

Figure: The Conversation

Outcomes - Red Bellied Parrot PCD Vaccine

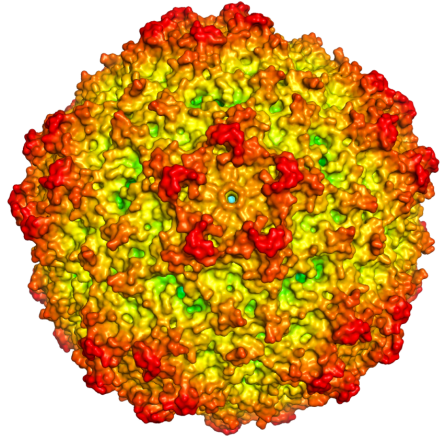


Figure: ABC Australia

Outcomes - Micro nutrients in Grain

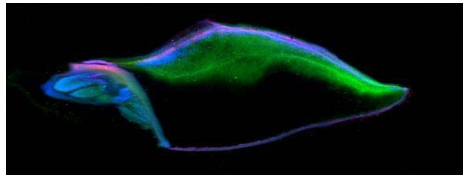


Figure: The Conversation, iron (red), copper (green), zinc (blue)

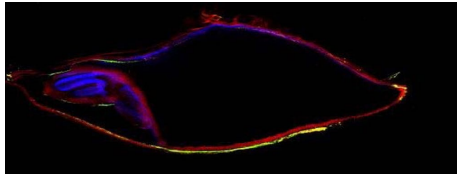


Figure: The Conversation, potassium (red), calcium (green), manganese (blue)