

Miocene insect fossilised in opaque amber from Cape York (Paul Tafforeau, ESRF, Susan Hand, UNSW)

An Introduction to X-TRACT for tomographic reconstruction and phase-retrieval

Sherry Mayo, Tim Gureyev & Darren Thompson
CSIRO

Micro-CT and Phase-Contrast

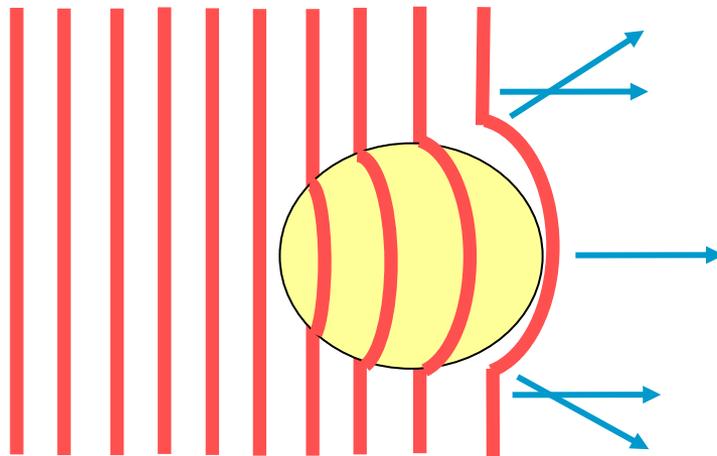
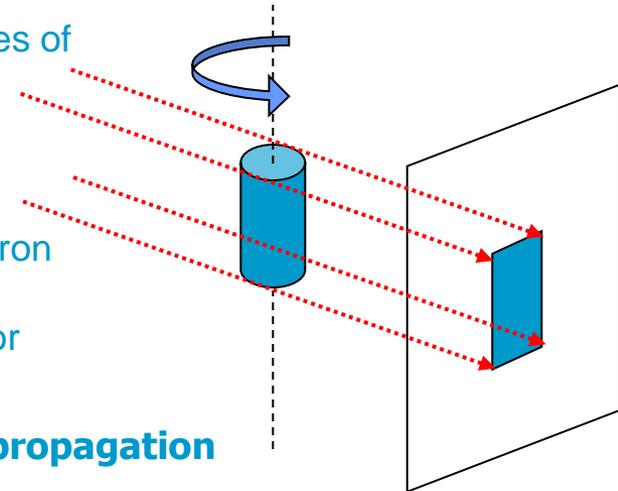
Micro-CT forms a 3D digital reconstruction of an object from a series of x-ray transmission images acquired at different rotation angles.

The 3D digital dataset can then be digitally dissected to examine internal structure without damage to the sample.

Conventional CT uses only absorption contrast but with a synchrotron source we also benefit from phase contrast which arises from **refraction** of x-rays. This can be made visible using propagation or gratings (amongst others).

A phase gradient represents a change in direction of propagation

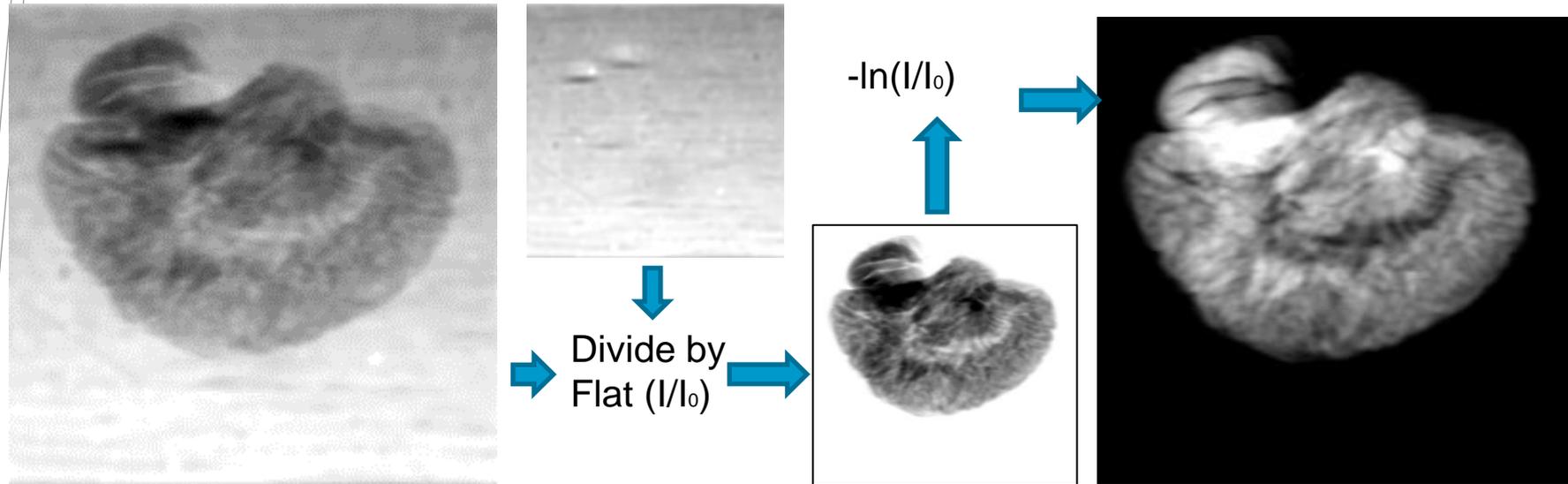
...



... leading to interference.



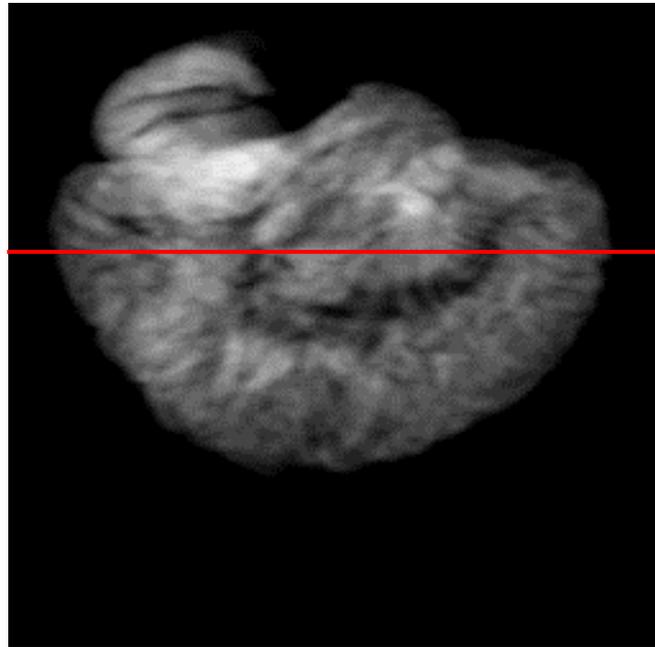
Tomographic reconstruction - using Beers law



$$I = I_0 e^{-\int \mu dt}$$

$$\int \mu dt = -\ln(I/I_0)$$

Tomographic reconstruction – making sinograms



100
pixels

Angle



Sino100.tif

Compiled
from 100th
row each
image in
sequence

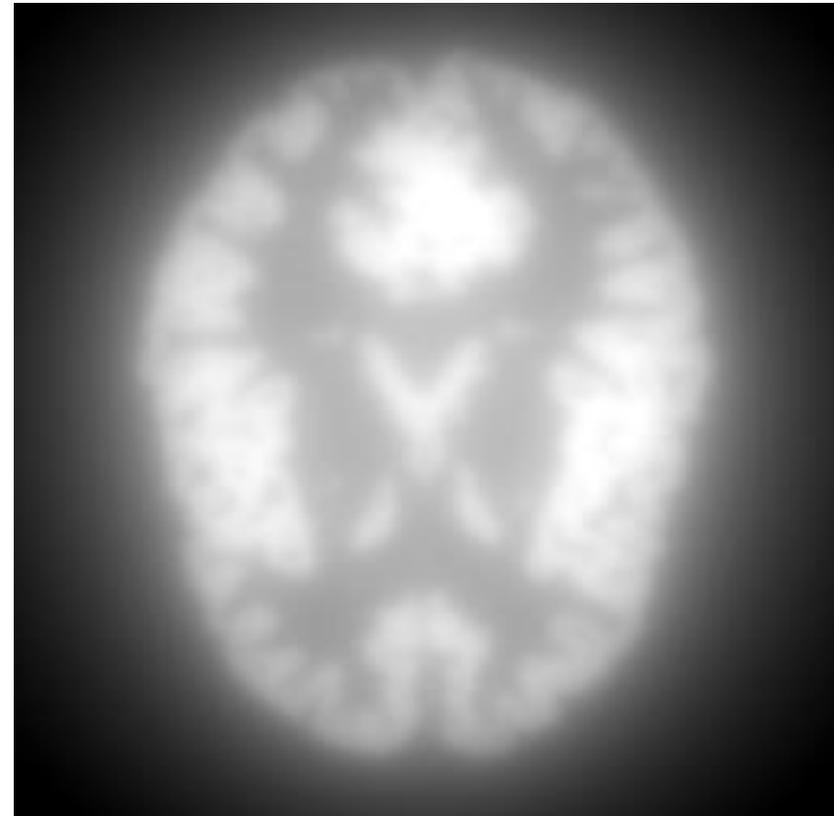
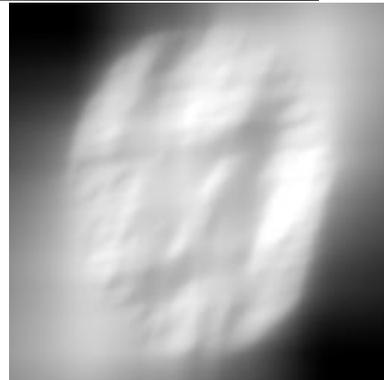
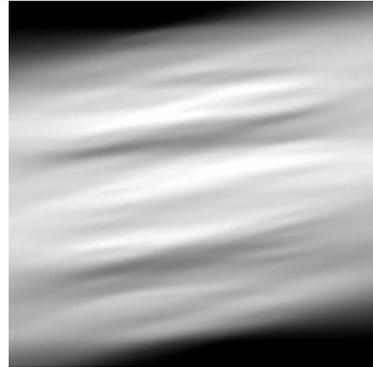
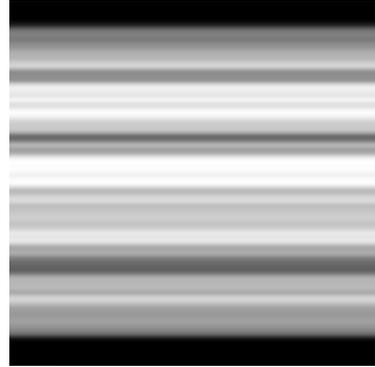
For each row-number in the image a corresponding sinogram is compiled by taking that row from all the images in the sequence.

Each sinogram contains all the information for a given cross section of the object

Quick movie on back projection



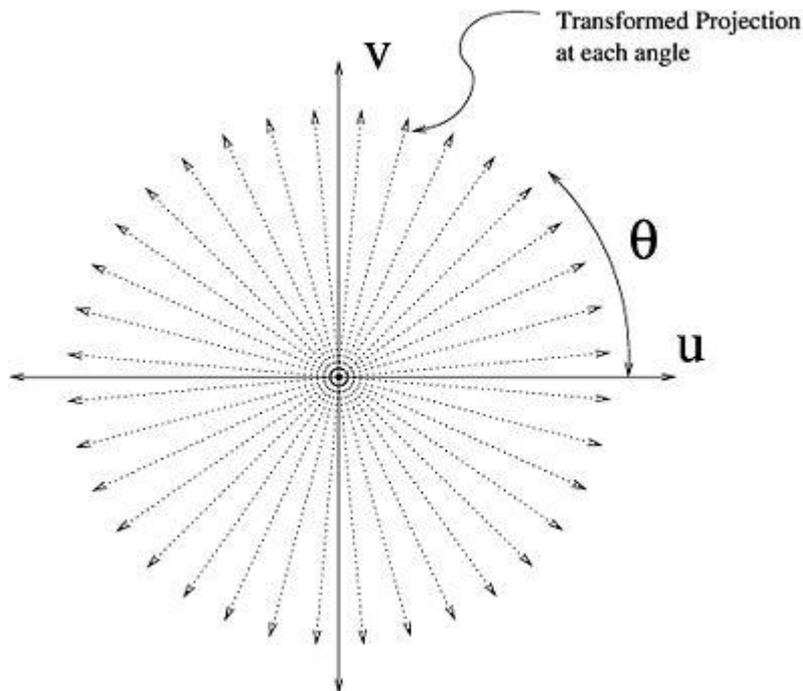
Back-projection – reconstructing a cross-section



Hmm.. Looks
a bit fuzzy

What we're doing in Fourier space...

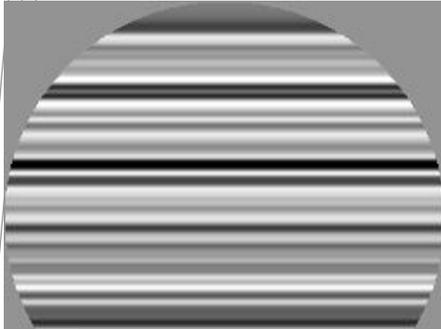
Fourier transform of cross section



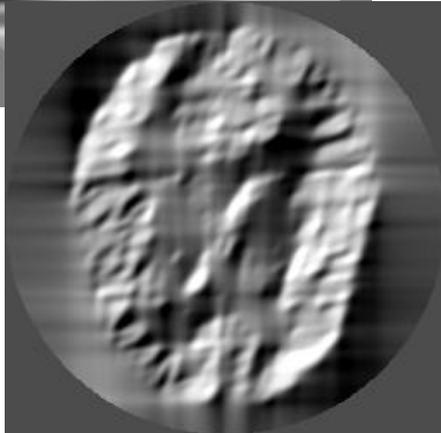
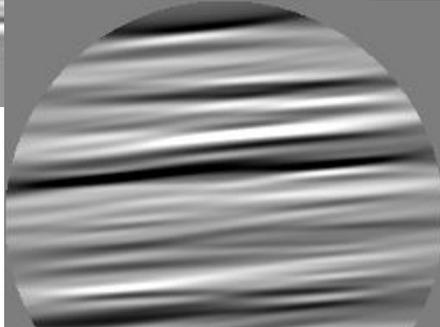
High-pass filtering compensations for the excess information at low spatial frequencies compared to high frequencies.

The simplest ramp filter multiplies Fourier space components in proportion to their spatial frequency.

Voila! Filtered back-projection!



Apply a high-pass ramp* filter to the sinogram first.



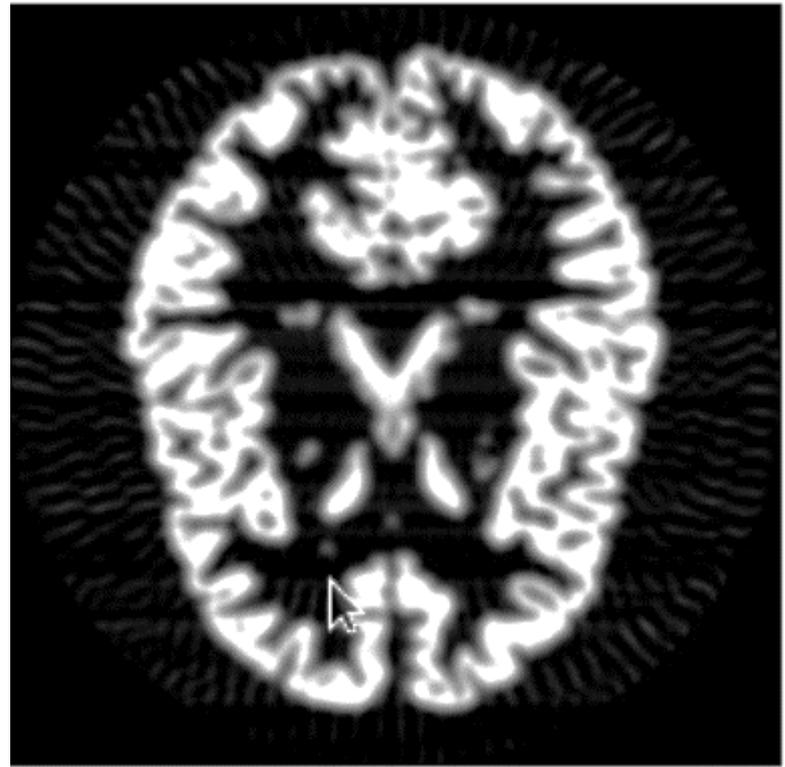
*or Shepp-Logan/
Hann/Cosine/Hamming...
filter



A brief aside about sampling



900 views – rather oversampled



90 views – somewhat under-sampled

XLI CT Workflow on ASCI

The screenshot displays a web browser window with the URL <https://asci.synchrotron.org.au/novnc/vnc.html?token=node2-aid31458f3a15149dfbdfc34b9c815861e-5900&password=67ffb9bdf2e2d082ab5574al>. The browser is connected to the ASCI Desktop. The desktop environment shows a file manager window with the 'X-tract' application selected. The XLI CT Workflow application is open, showing the following configuration:

- Input file regular expressions:** Frames: `tomo\d+.tif` (901), Darks: `dark\d+.tif` (3), Flats: `flat\d+.tif` (3).
- Experiment:** Pixel size (um): 1, Energy (keV): 20, Angle step (deg): 0.2.
- Output:** Output sinograms: ; Files: Directory: `/data/imbl/workshop/output/testdata_out`; Reconstructed slice prefix: `recon_`; TIFF: ; Sinogram prefix: `sino_`; TIFF: ; Output parameters file: `params_ctworkflow.txt`.

A status bar at the bottom indicates "Processing failed (9 s)" and "1 nodes available (v1.0.1)".

Speed up in parallel mode for single machine and CSIRO and MASSIVE clusters

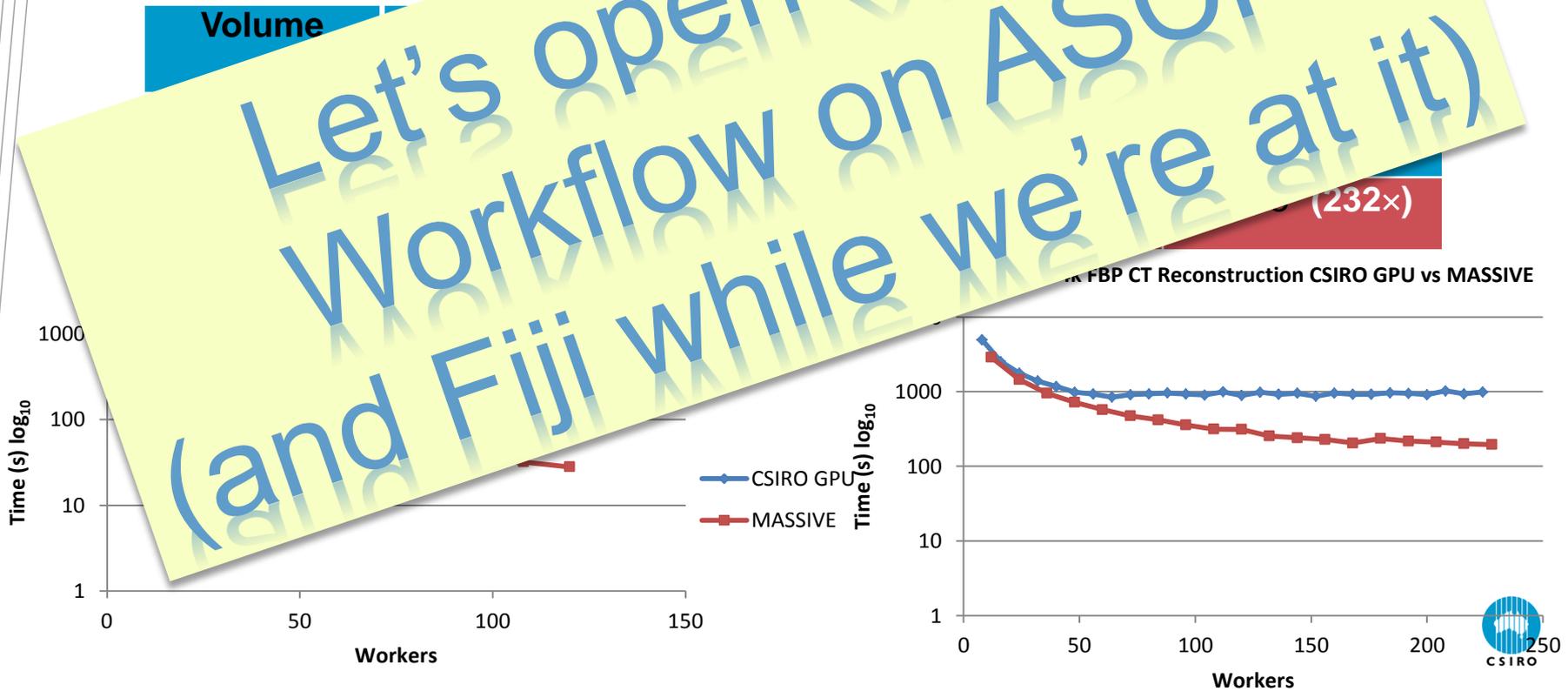
Considerable speed-up even on a single machine using multi-threading and especially GPU

Speedup for parallelised operation on cluster number of nodes initially.

Ultimately it is limited by IO and network a big difference.

Volume

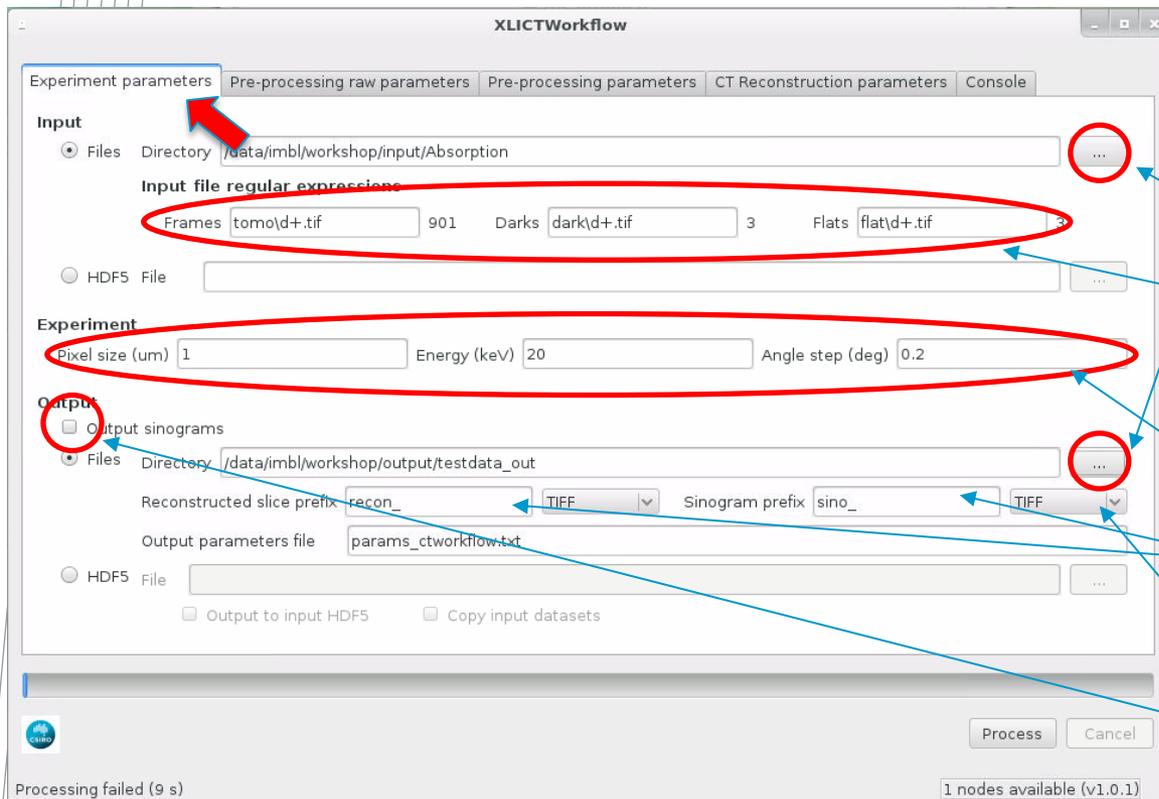
Let's open XLI CT Workflow on ASCI (and Fiji while we're at it)



XLICT Workflow – first pane

In this workflow we can set up basic parameters for the data:

- Input and output directories
- File name patterns (regular expressions)
- Pixel size, energy, angle step
- Output filenames
- Output file type
- Option of saving sinograms



Set your own XLI CT Workflow 'Experiment parameters' tab like this but **remember to substitute your own output directory.**

XLI CT Workflow – 2nd and 3rd panes: preprocessing

XLICTWorkflow

Experiment parameters | Pre-processing raw parameters | Pre-processing parameters | CT Reconstruction parameters | Console

Trim input frame, dark and flat files

X1: 0 Y1: 0 X2: 0 Y2: 0

Zingers filter

Filter size (pix) (odd number): 9 Filter threshold: 1.2

Dark current subtraction from frame

Flat field correction

Thresholded median filter

Mask size: vertical: 3 horizontal: 3 Direction: Bi-directional

Threshold: lower: 0 upper: 65535

Method

Average all flats

Distribute flats with: 1 flats every: 1 views

The settings in these panes are all about correcting for various imaging artefacts to produce clean normalised sinograms (and if necessary applying phase retrieval)

To start with lets just use the flat-field and dark-current corrections

XLICTWorkflow

Experiment parameters | Pre-processing raw parameters | Pre-processing parameters | CT Reconstruction parameters | Console

Region Normalisation

Method: Whole Operation: Divide

X1: 0 Y1: 0 X2: 0 Y2: 0

3x3 average filter

TIE-hom phase extraction

R-prime (um): 0 delta/beta: 0

Ring artifact removal

Filter size (pix) (odd number): 3

Processing failed (9 s)

X-TRACT for Tomography

1. Preprocessing – CCD artifact corrections

Dark

Flat-field

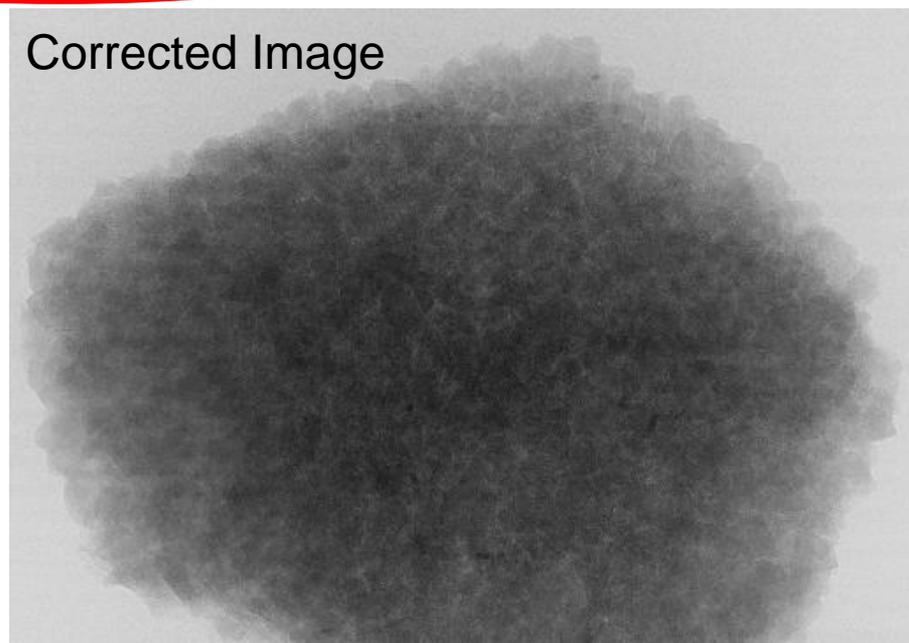
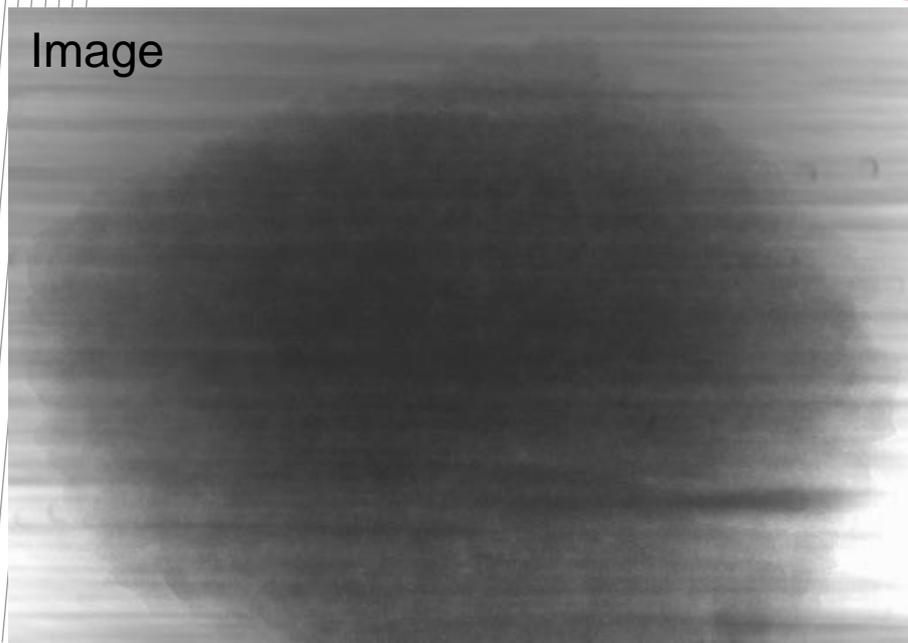
Correcting CCD/Illumination artefacts:

- 1) Dark current (the CCD signal with no illumination)
Several dark current files are collected at the beginning/end of a data collection
- 2) Flat-field (The x-ray illumination distribution)
Flat-field files are often collected at regular intervals during data collection

$$\text{Corrected Image} = \frac{\text{Image} - \text{Dark}}{\text{Flat-field} - \text{Dark}}$$

Image

Corrected Image



XLICT Workflow – third pane - reconstruction

XLICTWorkflow

Experiment parameters Pre-processing raw parameters Pre-processing parameters **CT Reconstruction parameters** Console

Reconstruction method: **Gridrec**

Reconstruction range

All

Sub-range First slice z-index: 100 Last slice z-index: 100

Output Mu (cm-1)

Filter: Linear-Ramp

Centre of rotation

Auto (correlation) Manual 0

Auto (error) Auto (sinogram) Index: 0

Reconstruction sub-region

X1: 0 Y1: 0 X2: 0 Y2: 0

Rescale reconstructed slices

Auto Manu Min: 0 Max: 1 Data Type (TIFF & HDF5 Only): 32bit float

Processing failed (9 s) 1 nodes available (v1.0.1)

Process Cancel

Here we can select

- Reconstruction method
- Range of slices to reconstruct
- Output in Mu format
- Centre of rotation method

Set it up as shown and hit process

X-TRACT for Tomography

1. DEMO – Reconstruction (no phase-retrieval)



Ring artefacts and Ring filter (Show original data & sino)

Zinger artefacts (Ring then zinger – zinger at 101,97)

Phase contrast & phase retrieval

Noisy

Noisy phase-contrast

general params: pixel size 10, keV 10, ang 0.2, output Mu (cm⁻¹), DC and FF

Phase retrieval: 100000 (= 10cm) delta/beta = 400

Noisy: (no PR) ringfilt: 51

Zingers: 101 and 97 have rings, filter 9, 1.05 for complete removal (but 1.1 might be more realistic in presence of noise)

Ring: more realistic 2% noise dataset



www.csiro.au

Thank you

Contact Us

Phone: 1300 363 400 or +61 3 9545 2176

Email: enquiries@csiro.au Web: www.csiro.au

