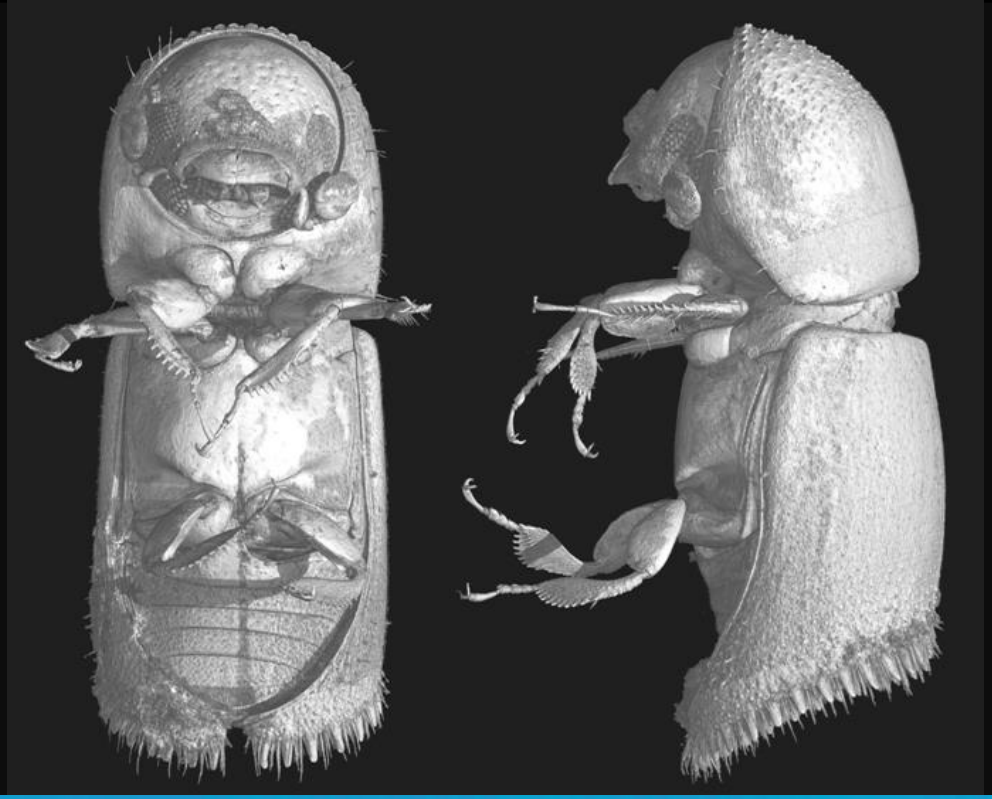

Miocene insect fossilised in opaque amber from Cape York (Paul Tafforeau, ESRF, Susan Hand, UNSW)

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

Sherry Mayo, Tim Gureyev & Darren Thompson
CSIRO

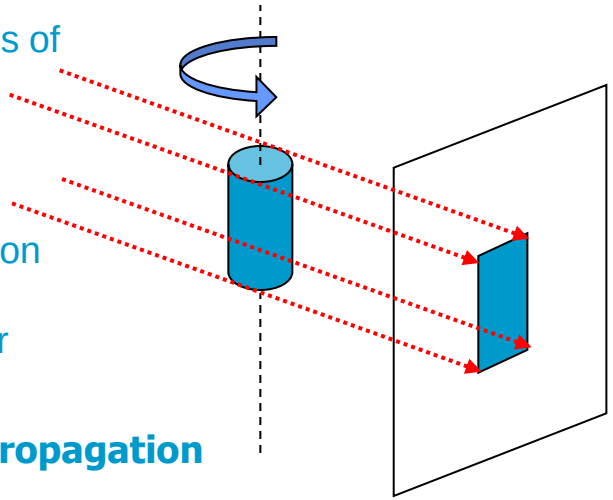
CSIRO

Micro-CT and Phase-Contrast

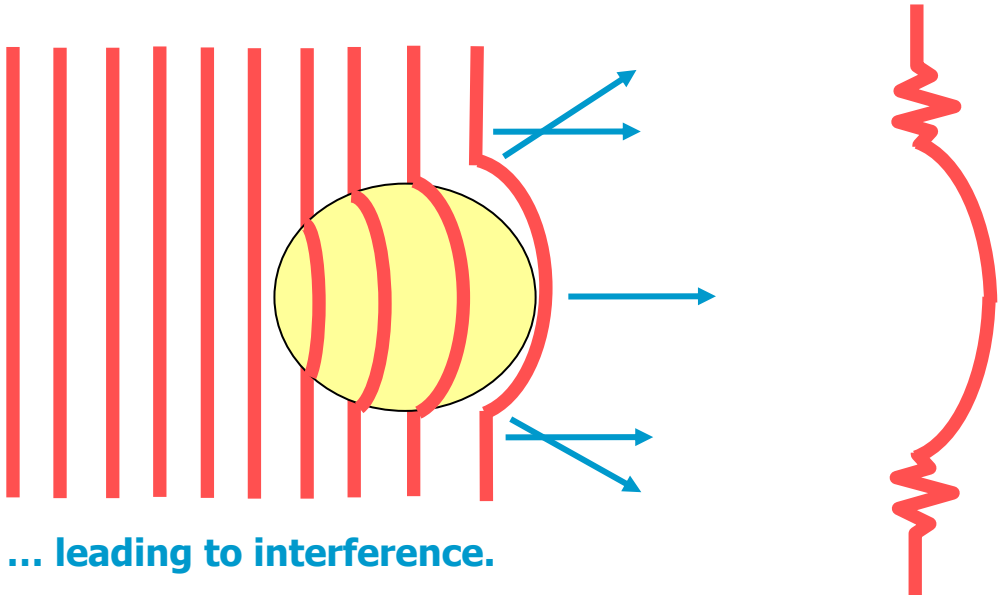
Micro-CT forms a 3D digital reconstruction of an object from a series of x-ray transmission images acquired at different rotation angles.

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).

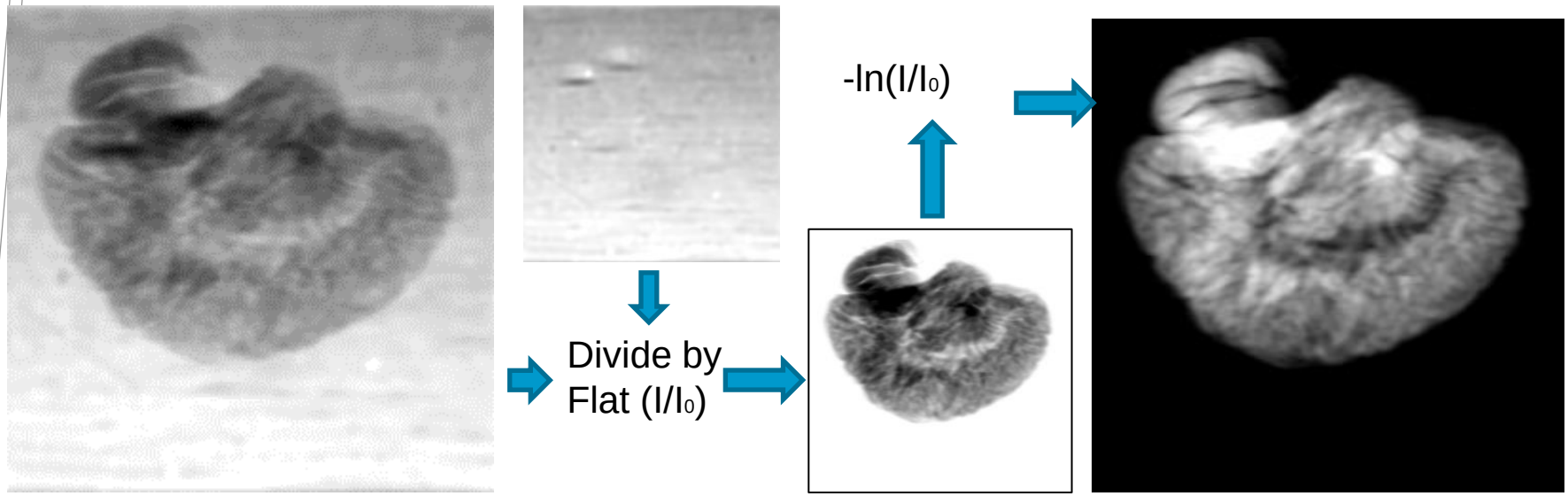


A phase gradient represents a change in direction of propagation …



… leading to interference.

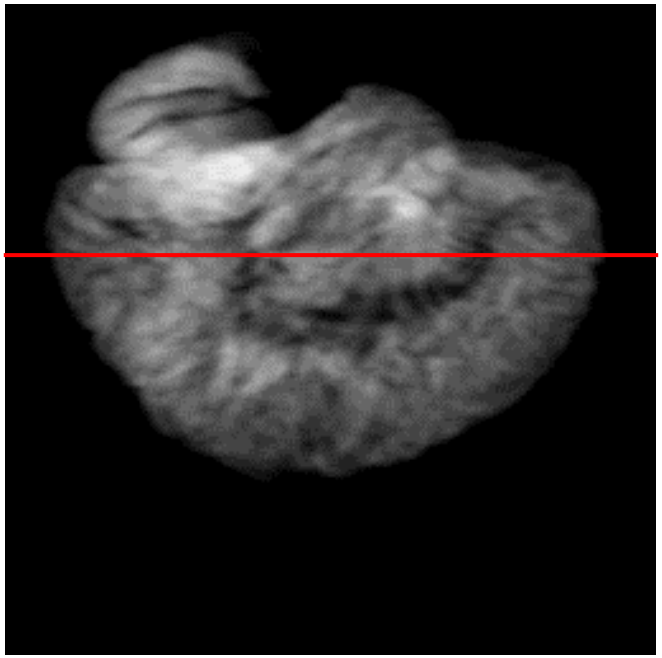
Tomographic reconstruction - using Beers law



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

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

Tomographic reconstruction – making sinograms



100 pixels

Angle

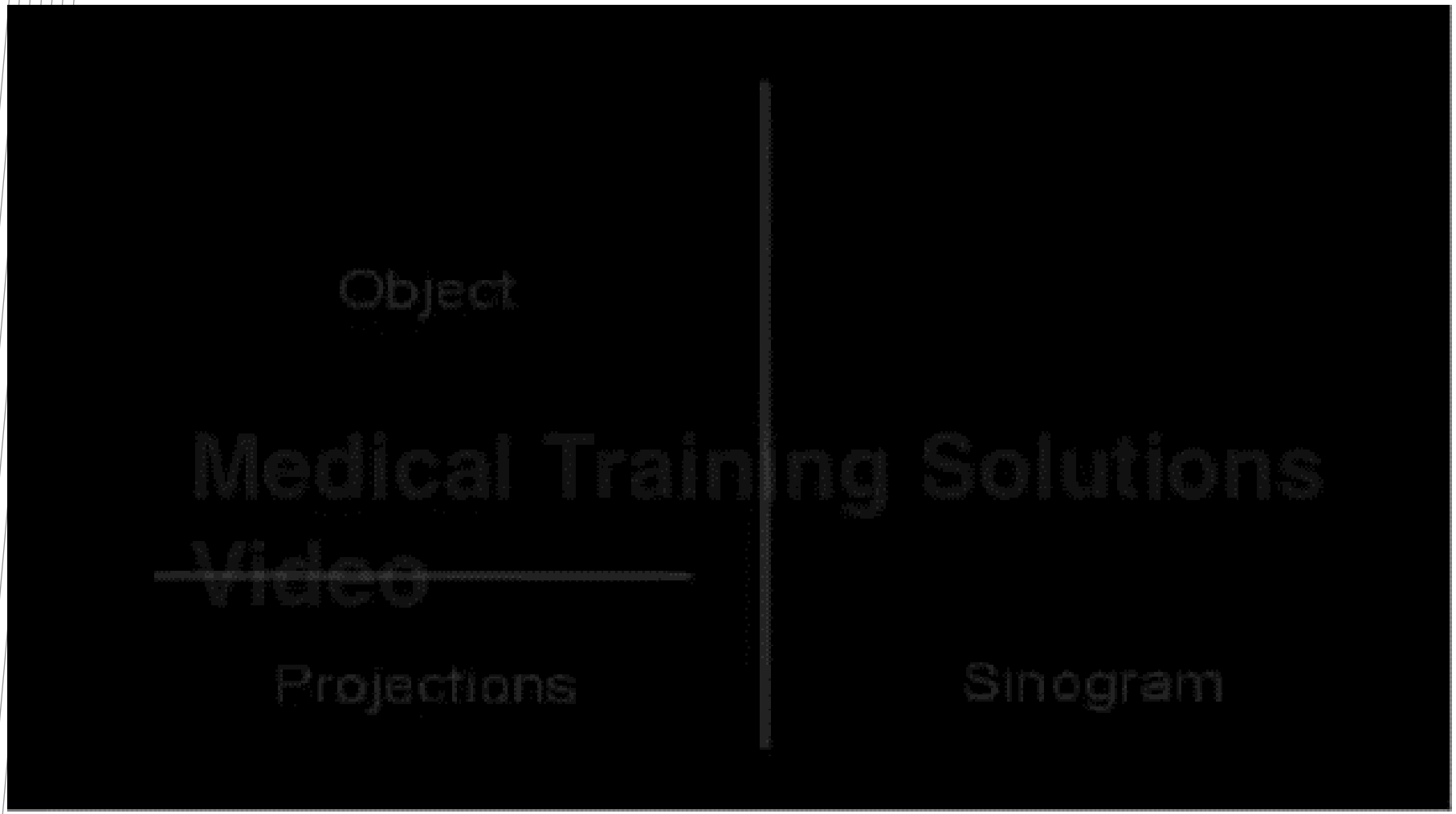
Sino100.tif

Compiled from 100th row each image in sequence

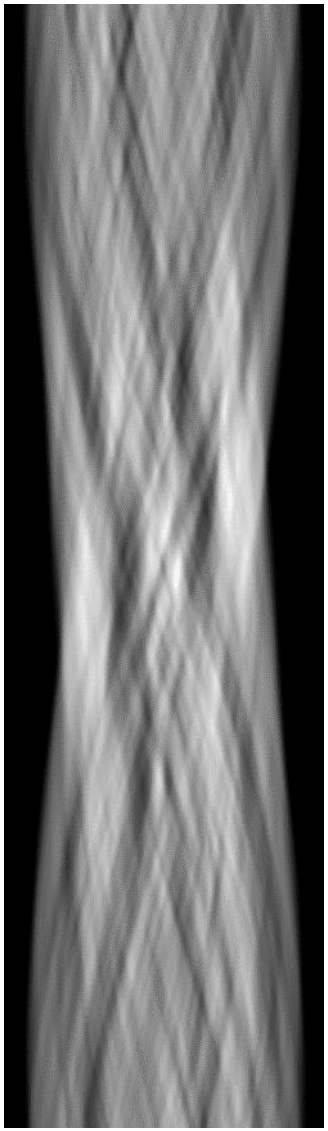
For each row-number in the image a corresponding sinogram is compiled by taking that row from all the images in the sequence.

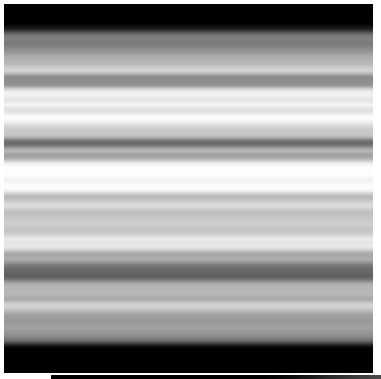
Each sinogram contains all the information for a given cross section of the object

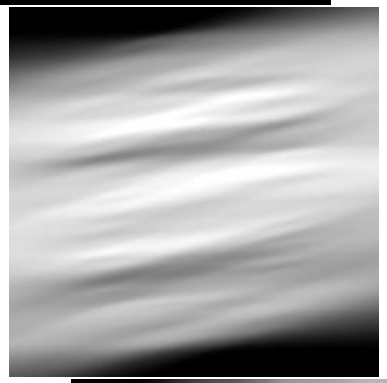
Quick movie on back projection

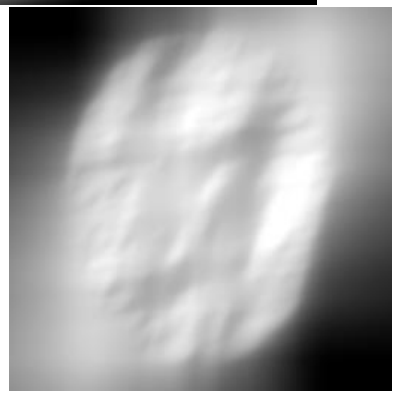


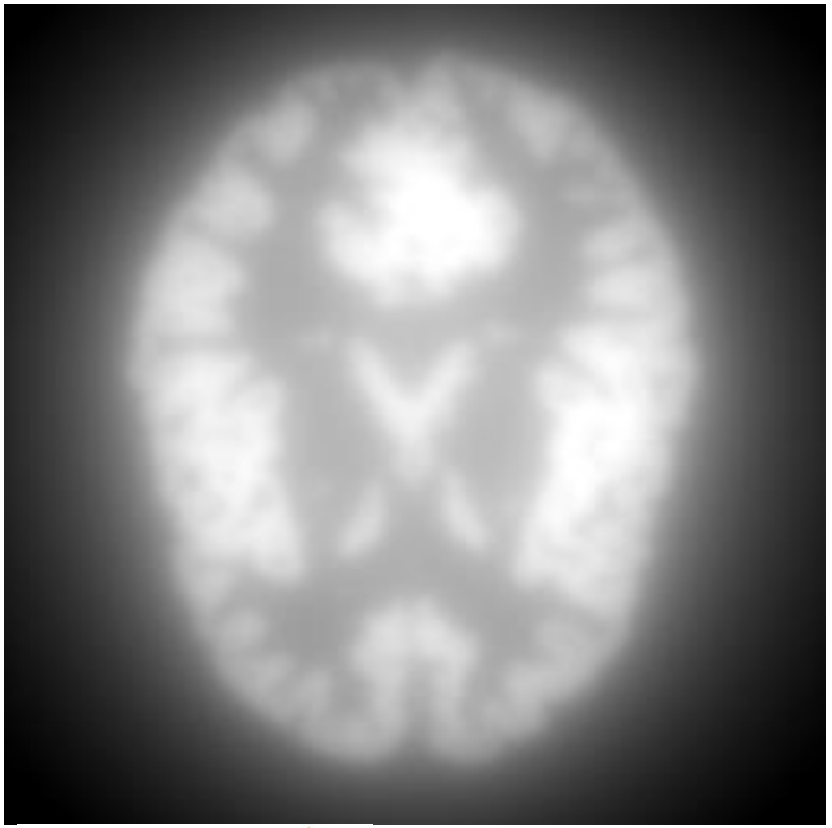
Back-projection – reconstructing a cross-section







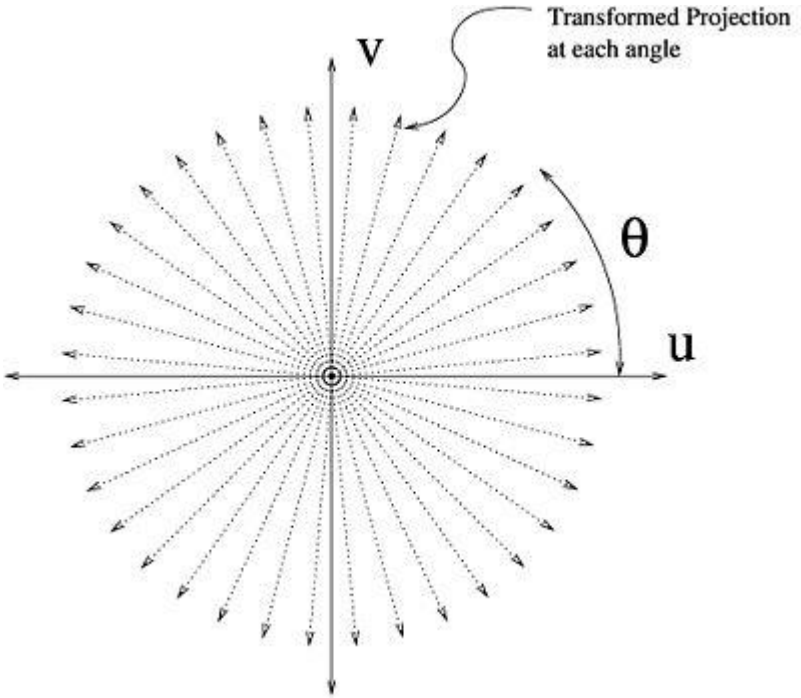




Hmm.. Looks a bit fuzzy

What we're doing in Fourier space…

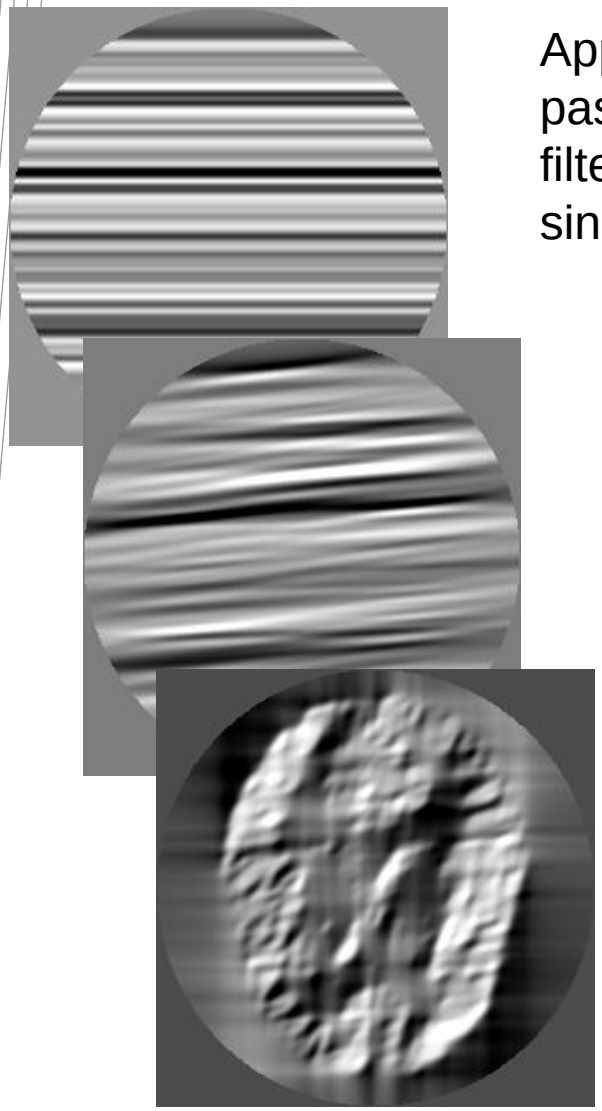
Fourier transform of cross section



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!

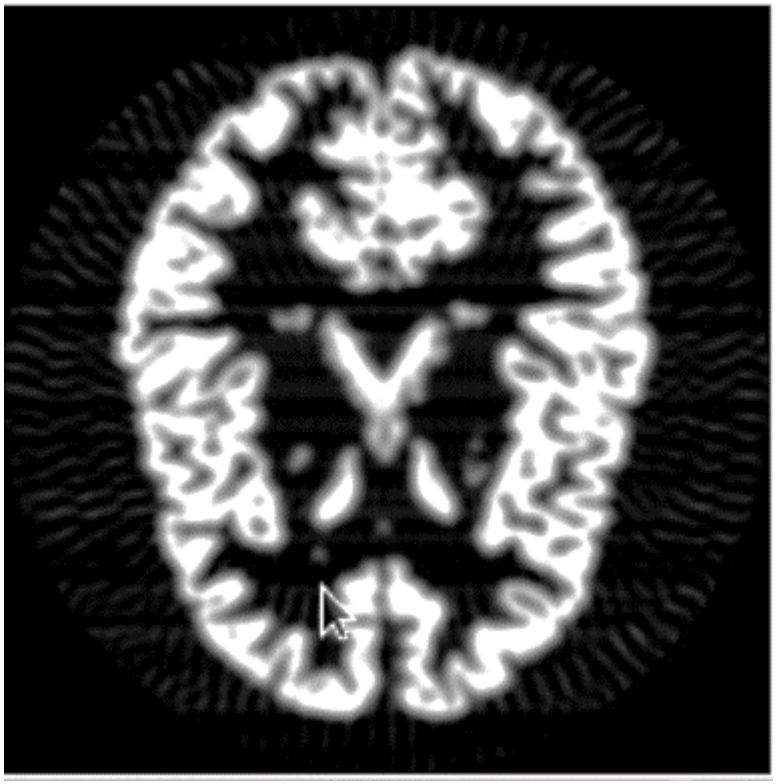


Apply a high-pass ramp* filter to the sinogram first.

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

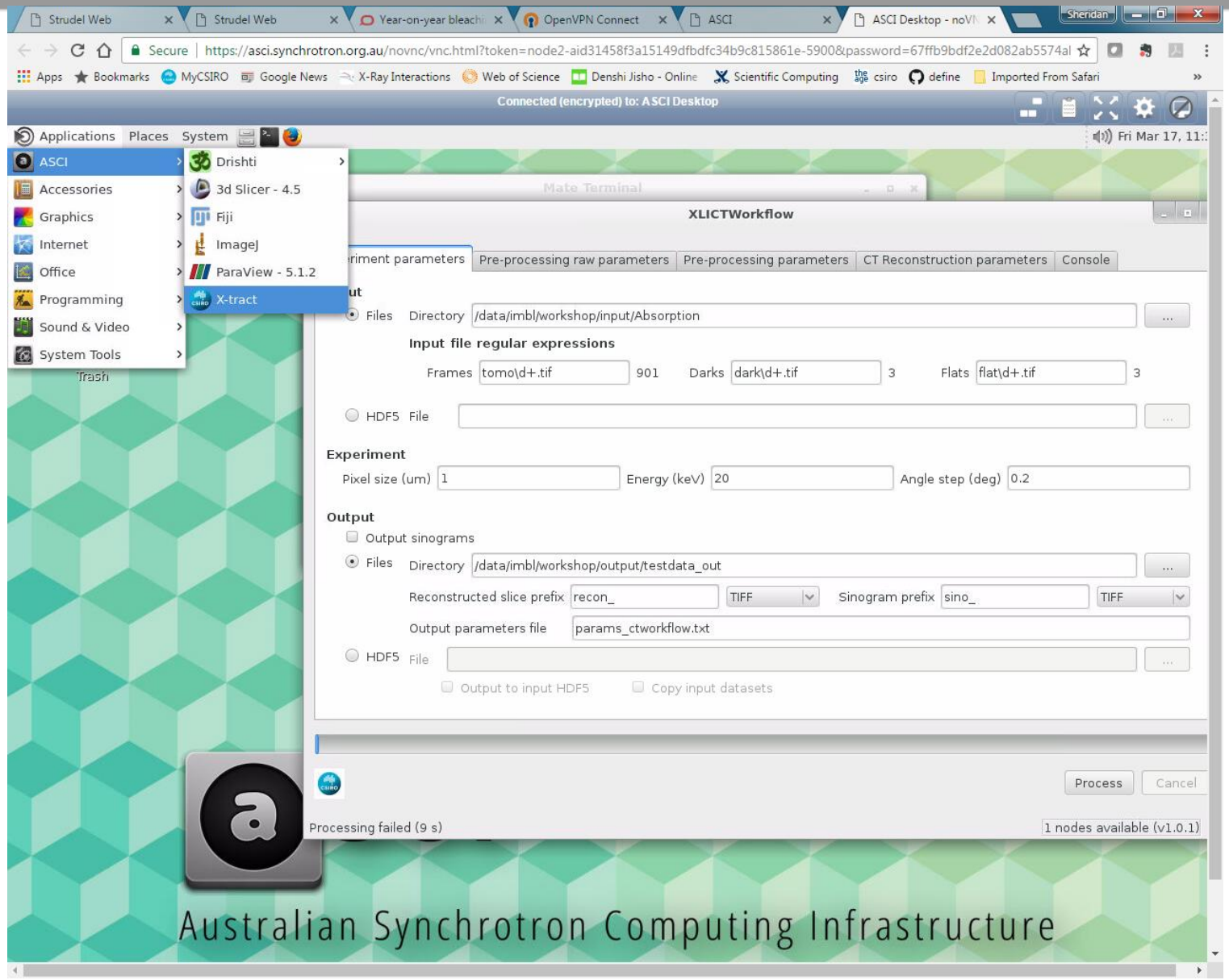
A brief aside about sampling

900 views – rather oversampled



90 views – somewhat under-sampled

XLI CT Workflow on ASCI



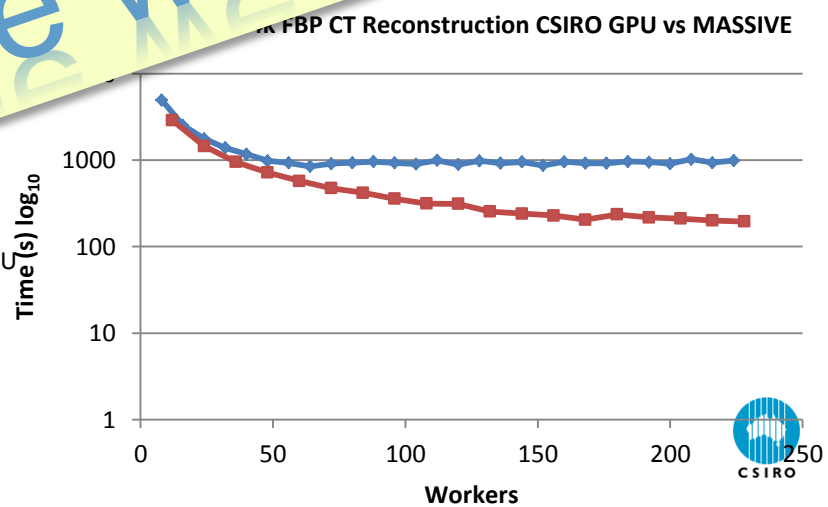
Speed up in parallel mode for single machine and CSIRO and MASSIVE clusters

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

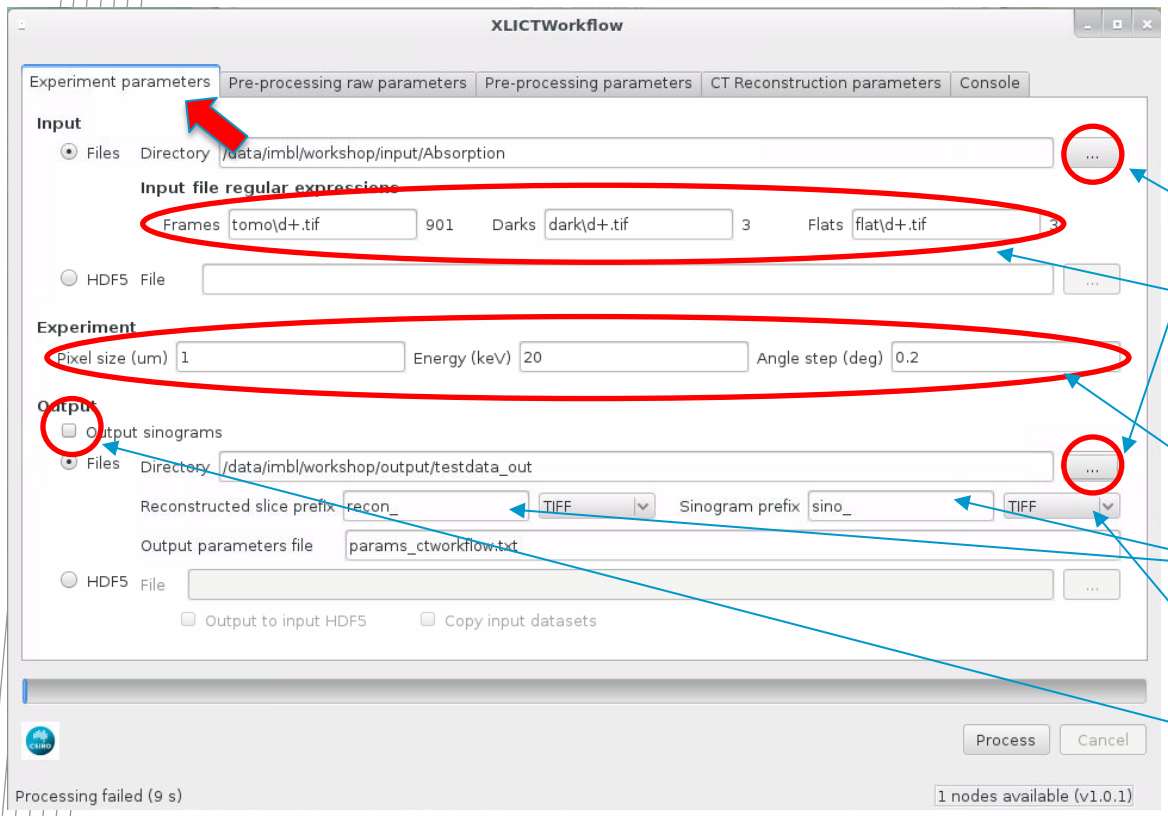
Speedup for parallelised operation on cluster… number of nodes initially.

Ultimately it is limited by IO a… a big difference.

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



XLICT Workflow – first pane

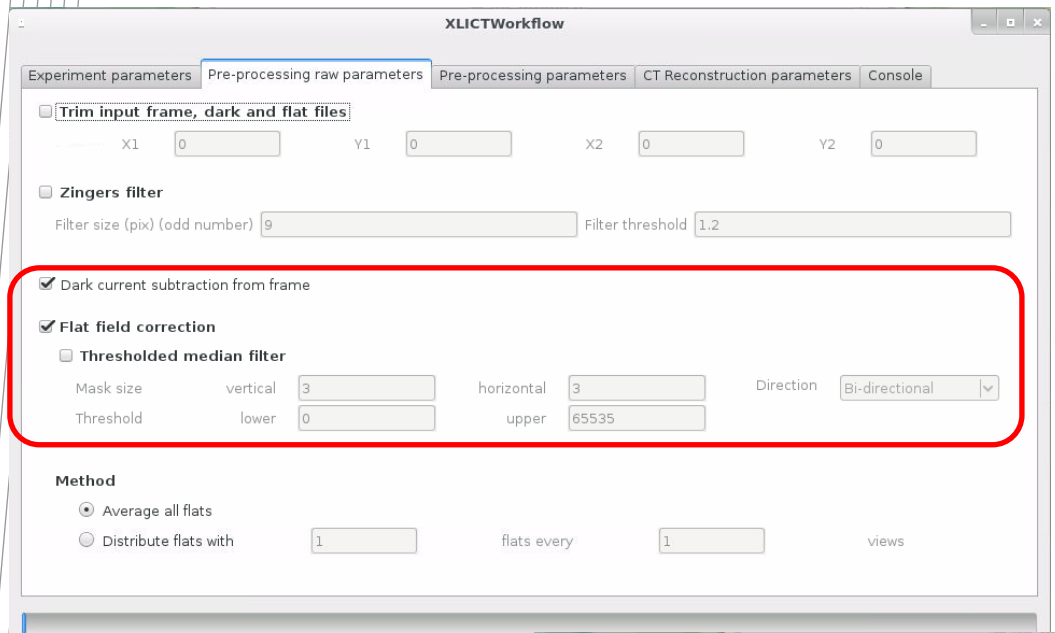


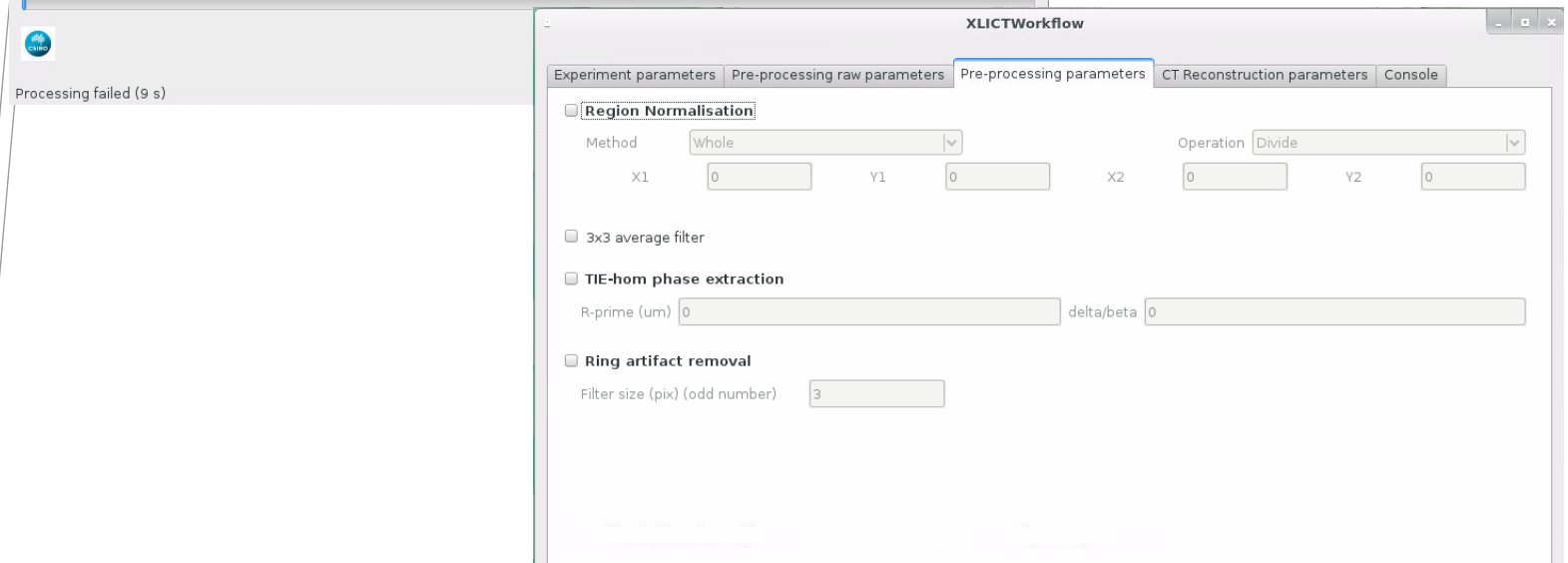
In this workflow we can set up basic parameters for the data:

- 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 **<u>remember to substitute your own output directory</u>**.

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





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

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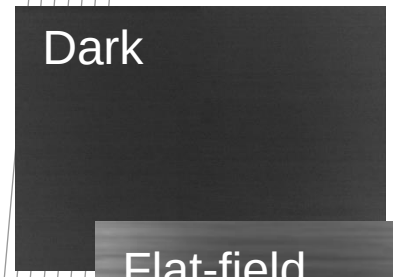
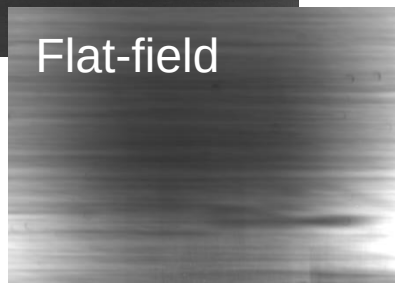
X-TRACT for Tomography
1. Preprocessing – CCD artifact corrections

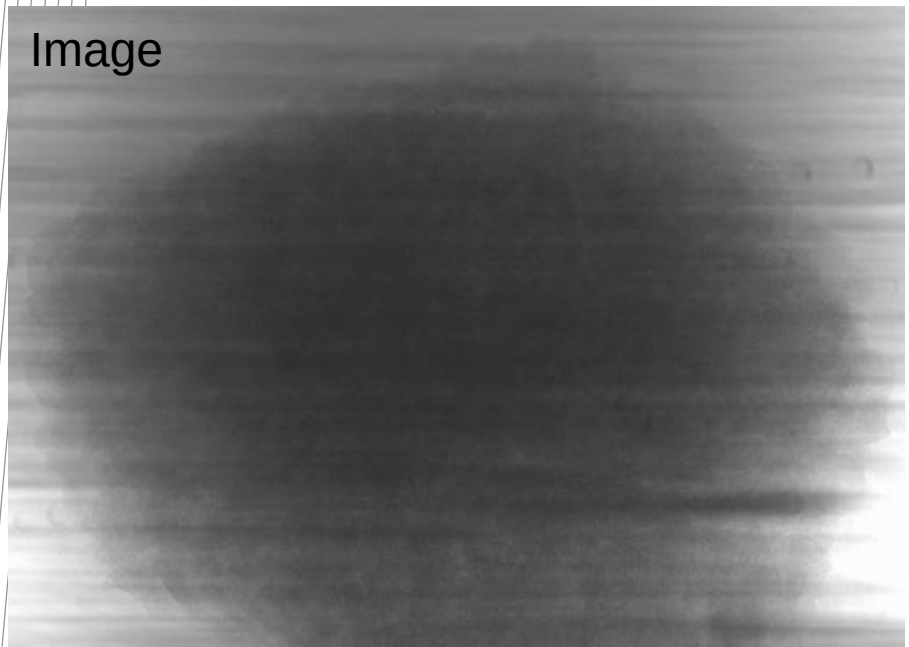


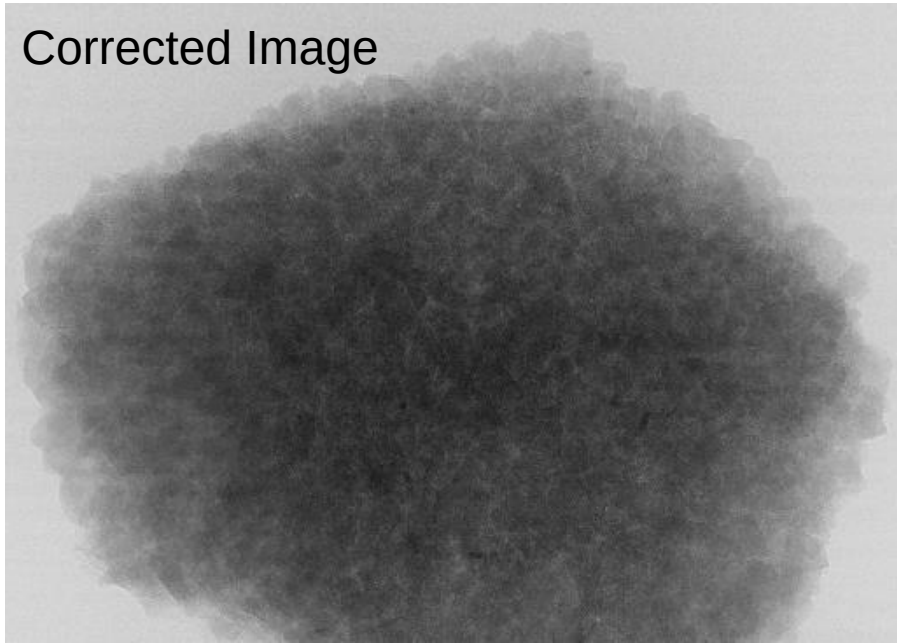


Correcting CCD/Illumination artefacts:

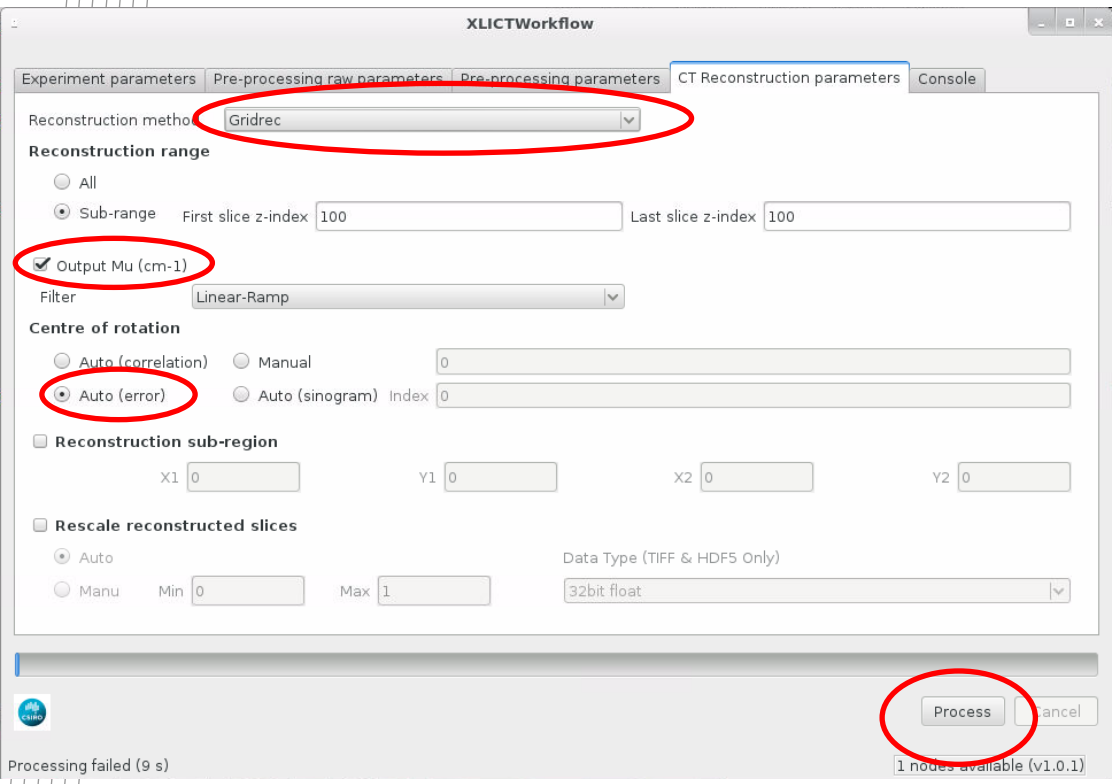
1) Dark current (the CCD signal with no illumination)
   Several dark current files are collected at the beginning/end of a data collection
2) Flat-field (The x-ray illumination distribution)
   Flat-field files are often collected at regular intervals during data collection

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





XLICT Workflow – third pane - reconstruction



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

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Thank you

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