CIL
CORE IMAGING LIBRARY

The Core Imaging Library

Versatile software for Tomographic Imaging

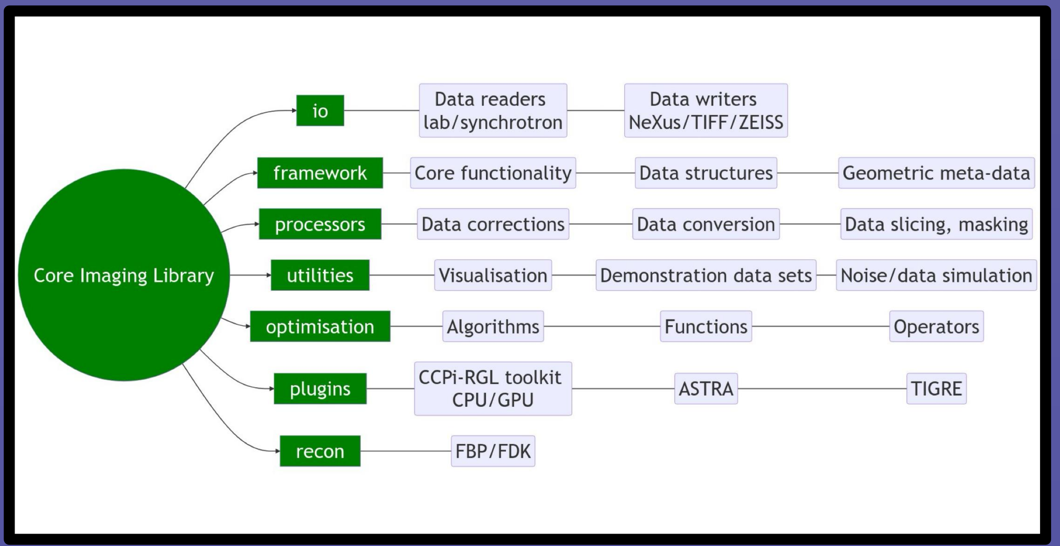
maintained by STFC with funding from CCPi and ALC

CIL Authors

CoSeC Computational Science Centre for Research Communities
ada lovelace centre
CCPi TOMOGRAPHIC IMAGING
UKRI Science and Technology Facilities Council
Scientific Computing

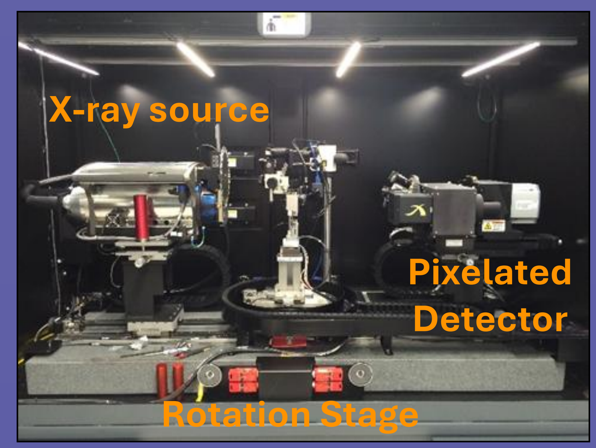
Overview & Goal

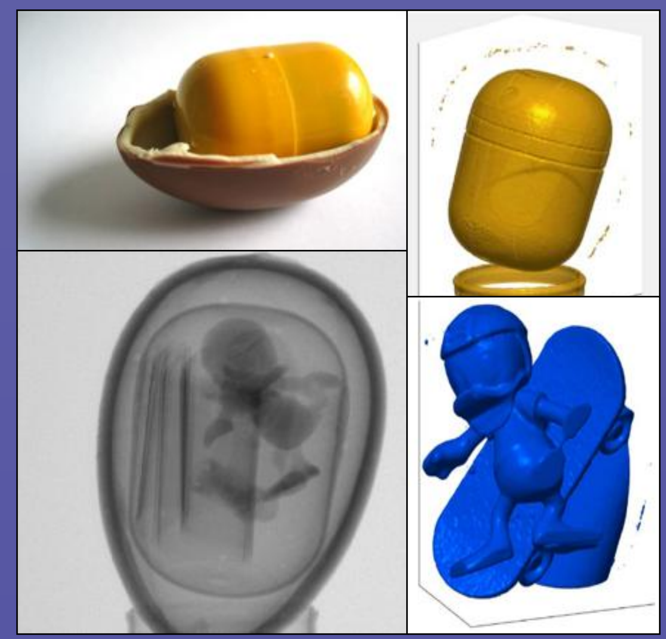
- The Collaborative Computational Project in Tomographic Imaging (https://ccpi.ac.uk/) aims to provide the UK tomography community with a software toolbox of algorithms that increases the quality and level of information extracted by computed tomography.
- The Core Imaging Library (CIL), an open-source Python framework for tomographic imaging with particular emphasis on reconstruction of challenging datasets.
- CIL provides an extensive modular optimisation framework for prototyping reconstruction methods including sparsity and total variation regularisation, as well as tools for loading, preprocessing and visualising tomographic data.



TomographicImaging/CIL

Principles of Tomography





Mathematical Optimisation

FBP $u \approx A^*(v * g)$

CGLS $\min_u \frac{1}{2}\|Au - g\|^2$

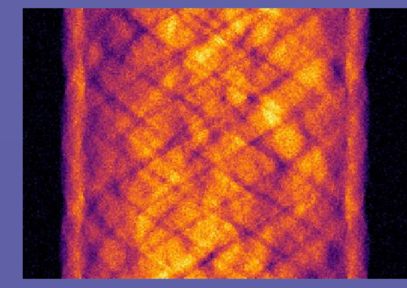
Total Variation $\min_u \frac{1}{2}\|Au - g\|^2 + \alpha\|\nabla u\|_{2,1}$

```
# Setup and run Filtered BackProjection
fbp_recon = FBP(g, backend='tigre').run()
```

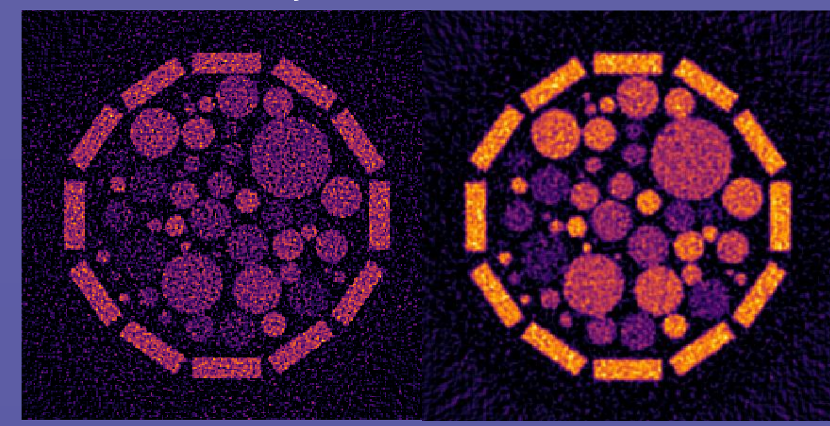
```
# Setup and run  Conjugate Gradient Least Squares
cgls = CGLS(initial = x0, operator = A, data = g)
cgls.run(1000)
```

```
# Total variation regularisation
# Primal-Dual Hybrid algorithm (PDHG)
F = BlockFunction(alpha * MixedL21Norm(), 0.5 * L2NormSquared(g))
G = IndicatorBox(lower=0)
K = BlockOperator(Gradient, A)
pdhg = PDHG( f = F,  g = G, operator = K)
pdhg.run(1000)
```

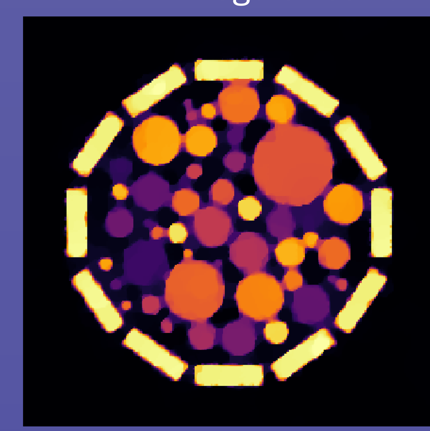
Acquired Data (Sinogram)



Filtered BackProjection CGLS



PDHG: TV regularisation

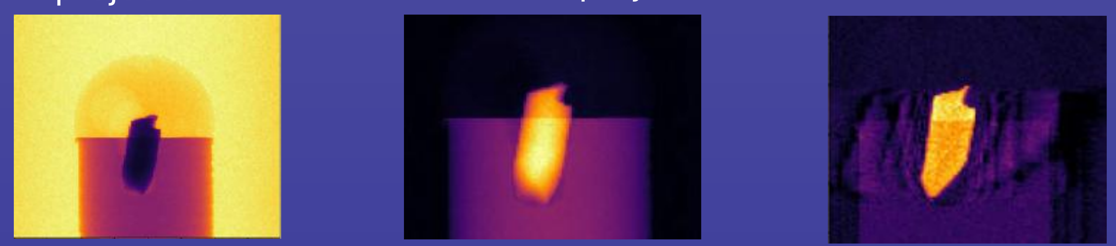


CIL applied to different and challenging imaging modalities

(a) Synchrotron Parallel beam tomographic data

- Data Readers: CIL supplies a native reader for Nikon's XTek data format, Zeiss' TXRM format, the NeXus format, as well as TIFF stacks.
- Data processors: Preprocessing tasks such as resizing (e.g. cropping or binning/downsampling) data, flat-field normalization and correction for centre-of-rotation offset.

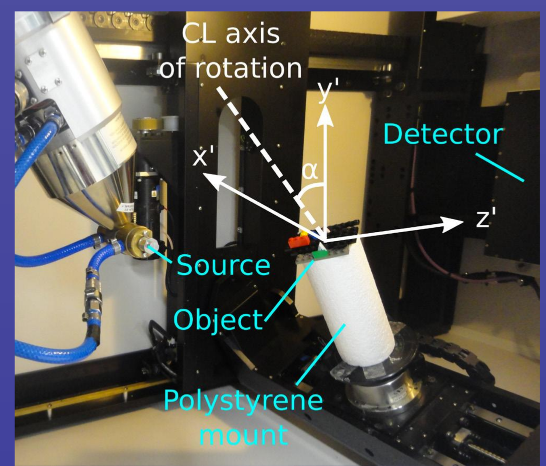
Raw transmission projection | Preprocessed transmission projection | FBP using 15 projections



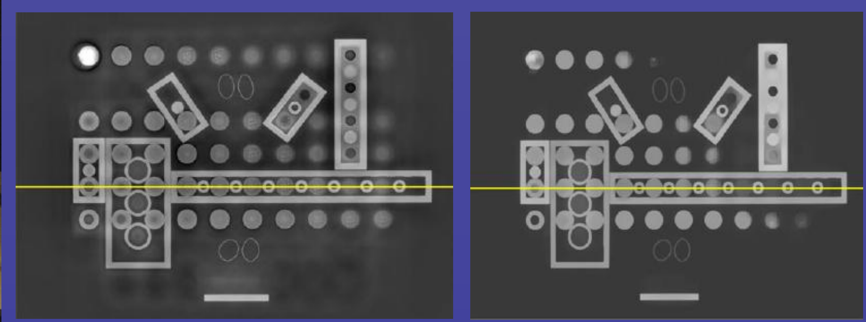
J. S. Jørgensen, E. Ametova, G. Burca, G. Fardell, E. Papoutsellis, E. Pasca, K. Thielemans, M. Turner, R. Warr, W. R. B. Lionheart and P. J. Withers (2021) , Core Imaging Library - Part I: a versatile Python framework for tomographic imaging. Phil. Trans. R. Soc. A. 379: 20200192. DOI: https://doi.org/10.1098/rsta.2020.0192

(b) Non-standard acquisition: X-ray laminography

- General acquisition geometries can be configured using CIL, e.g., Parallel, Cone Beam, Laminography.
- Fast Iterative Shrinkage-Thresholding Algorithm (FISTA) reconstruction for the LEGO dataset



Least Squares TV: Non Negativity Constraint

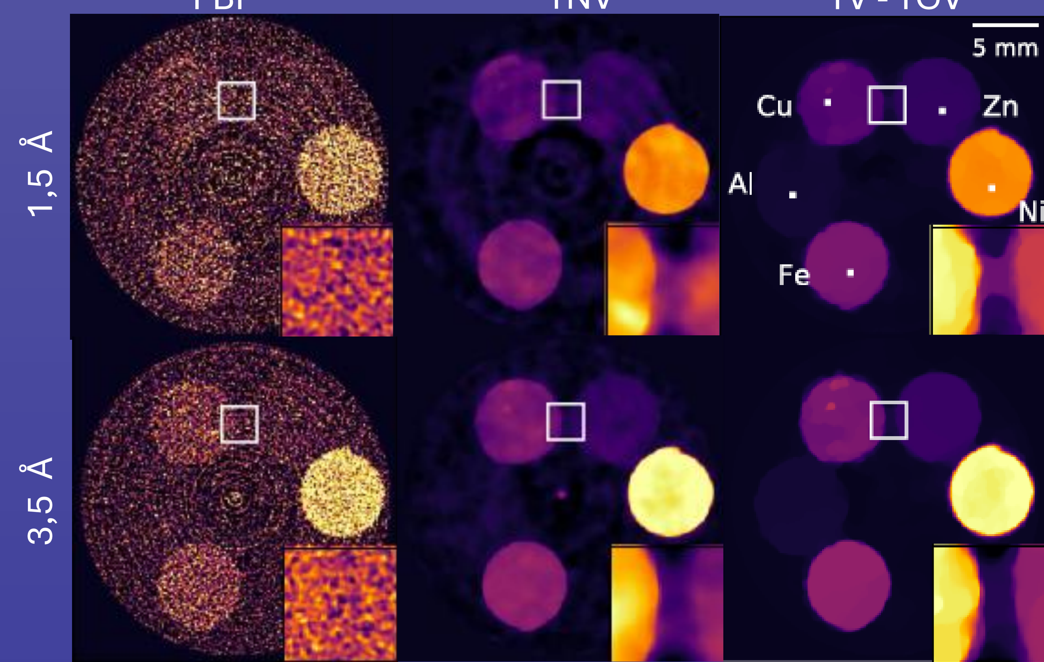


(c) Time of Flight Neutron Tomography

- Straightforward to prototype novel reconstruction methods for Neutron tomography with combined Spatial Total Variation and Spectral Total Generalised Variation.

E. Ametova, G. Burca, S. Chilingaryan, G. Fardell, J.S. Jørgensen, E. Papoutsellis, E.Pasca, R. Warr, M. Turner, W. R. B. Lionheart and P. J. Withers (2021), Crystalline phase discriminating neutron tomography using advanced reconstruction methods, J. Phys. D: Appl. Phys. 54 325502 DOI: 10.1088/1361-6463/ac02f9

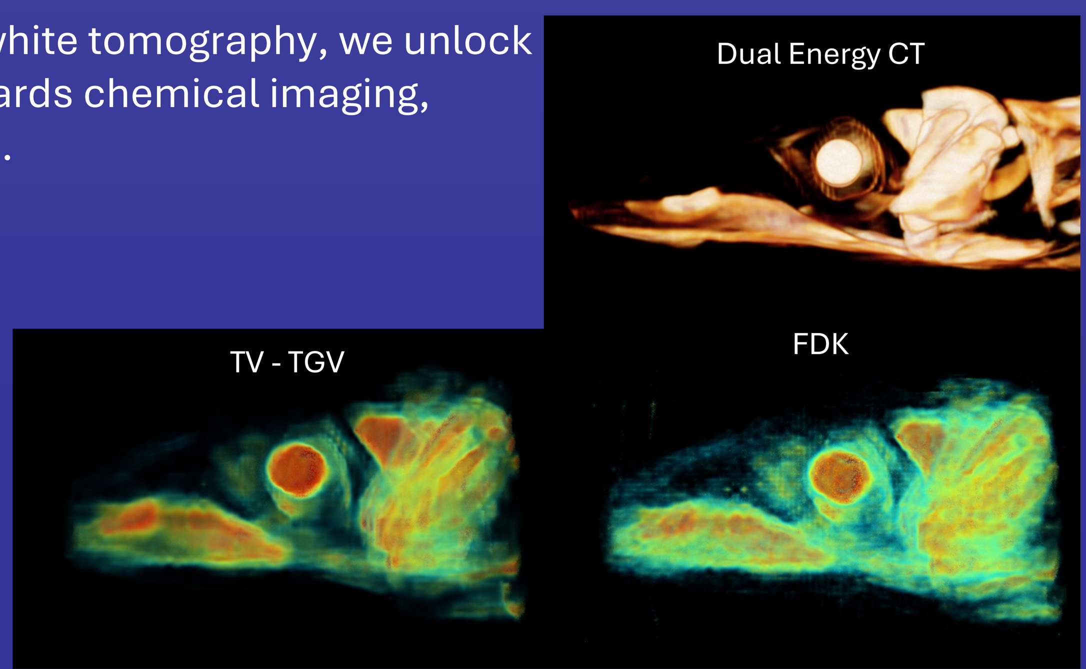
FBP TNV TV - TGV



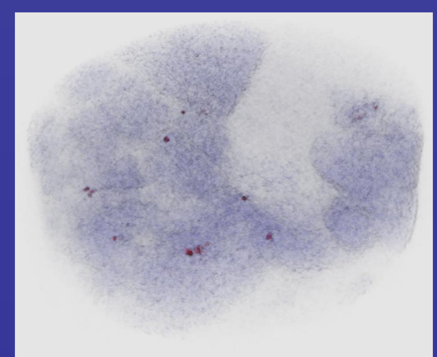
(d) Hyperspectral Tomography

- Moving beyond traditional black and white tomography, we unlock the full power of spectral imaging towards chemical imaging, structure and material decomposition.
- Enhanced Bioimaging: Lizard head segmentation comparison for dual-energy and hyperspectral CT using analytical and iterative reconstruction methods

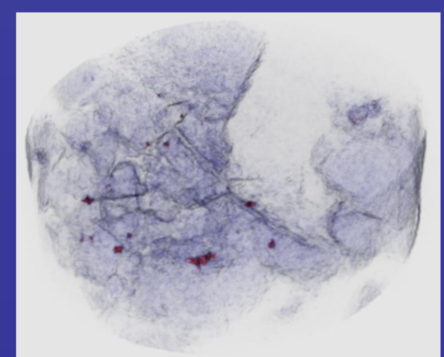
R. Warr, E. Ametova, R.J. Cernik . Gemma Fardell, S. Handschuh, J. S. Jørgensen, E. Papoutsellis, E. Pasca & P. J. Withers, Enhanced hyperspectral tomography for bioimaging by spatiospectral reconstruction. Sci Rep 11, 20818 (2021). https://doi.org/10.1038/s41598-021-00146-4



- Synergistic hyperspectral tomography reconstruction to detect chemical deposits from a gold-rich hydrothermal vein.



Simultaneous Iterative Reconstruction Technique (SIRT)

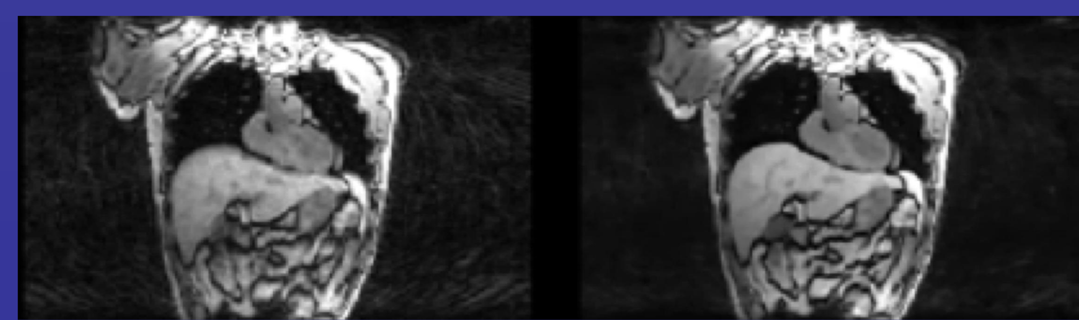


Stochastic Primal Dual Hybrid Gradient Algorithm (SPDHG)

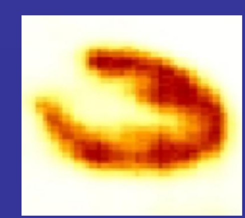
E. Papoutsellis, E. Ametova, C. Delplancke, G. Fardell, J. S. Jørgensen, E. Pasca, M. Turner, R. Warr, W. R. B. Lionheart and P. J. Withers (2021) Core Imaging Library - Part II: multichannel reconstruction for dynamic and spectral tomography. Phil. Trans. R. Soc. A. 379: 20200193. DOI: https://doi.org/10.1098/rsta.2020.0193)

(e) Motion Correction image reconstruction (MCIR) for simultaneous PET/MR

- A synergism is established with two CCPs: CIL and the Synergestic Image Reconstruction Framework (SIRF) of the CCP for Synergistic Reconstruction for Biomedical Imaging (SyneRBI) work together for medical imaging.



R. Brown, C. Kolbitsch, C. Delplancke, E. Papoutsellis, J. Mayer, E. Ovtchinnikov, E. Pasca, R. Neji, C. da Costa-Luis, A.G. Gillman, M. J. Ehrhardt, J. R. McClelland, B.Eiben and K. Thielemans (2021), Motion estimation and correction for simultaneous PET/MR using SIRF and CIL, Phil. Trans. R. Soc. A., 379: 20200208. DOI:10.1098/rsta.2020.0208



TV PET reconstruction Without MCIR (left) and with MCIR (right)