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Tomography and HPC

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Tomography - history

Wilhelm Röntgen (1845-1923)

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Tomography – CT-scan

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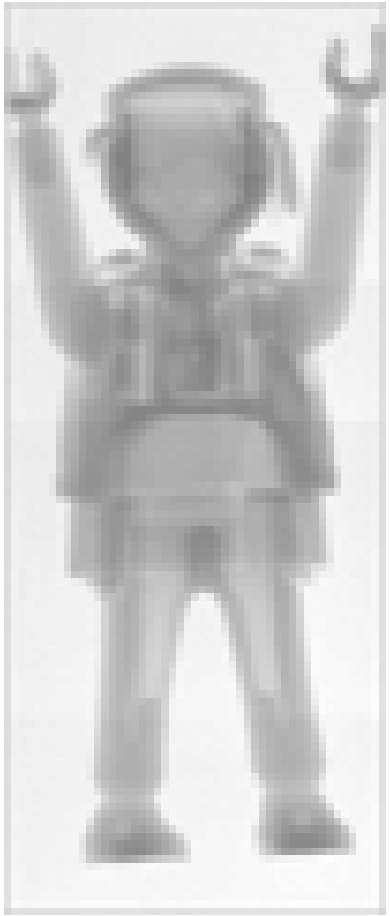
Tomography



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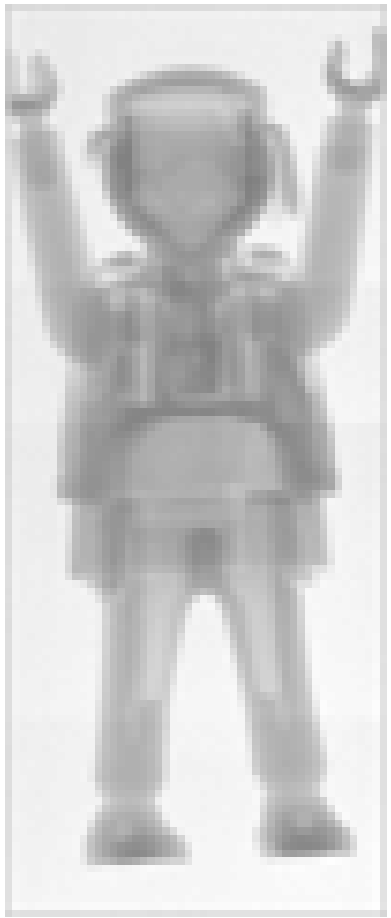
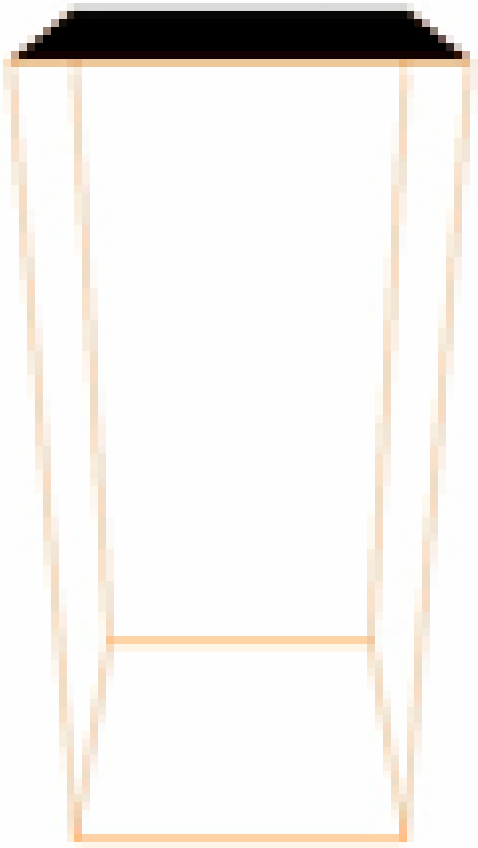
Tomographic reconstruction





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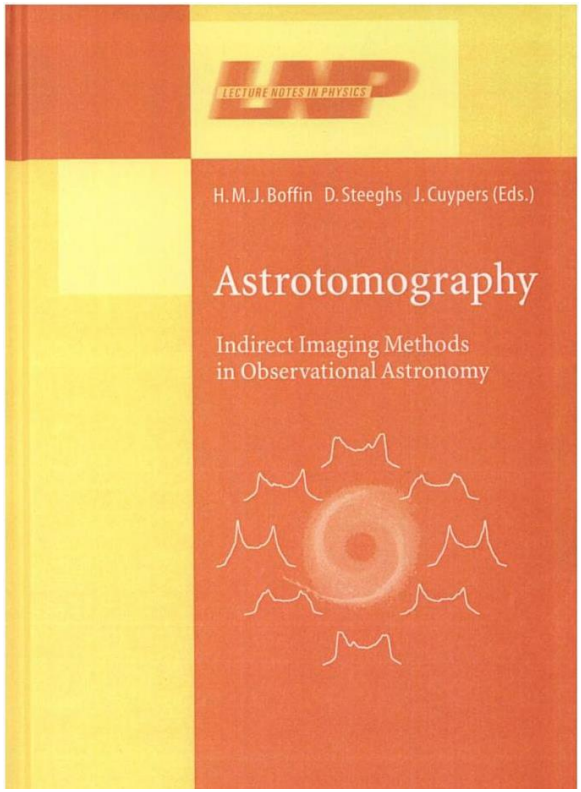
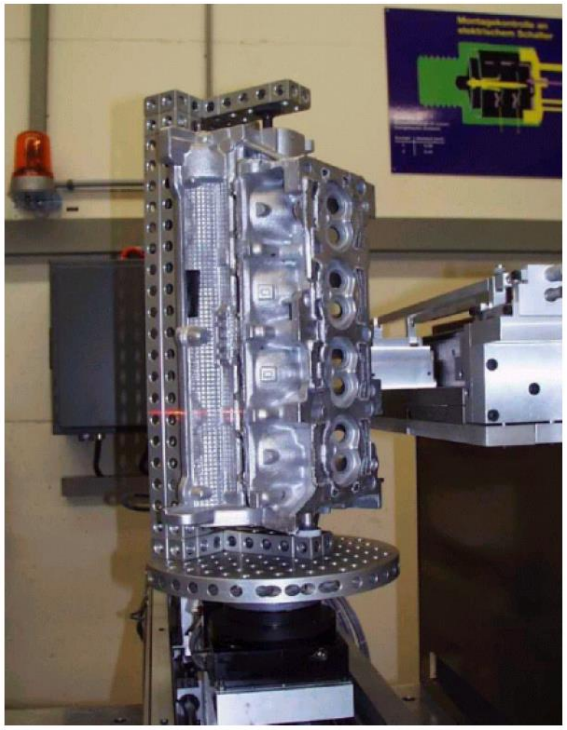
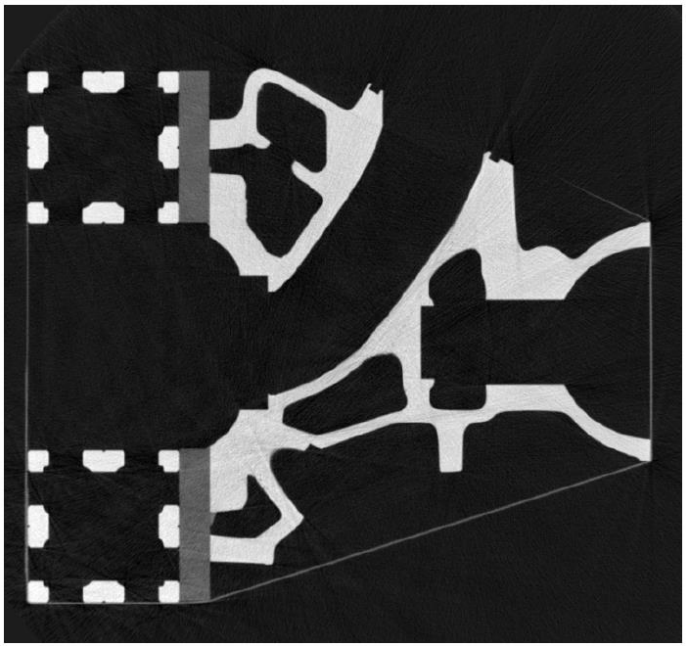
Tomography at all scales



Lightyears

Tomography at all scales

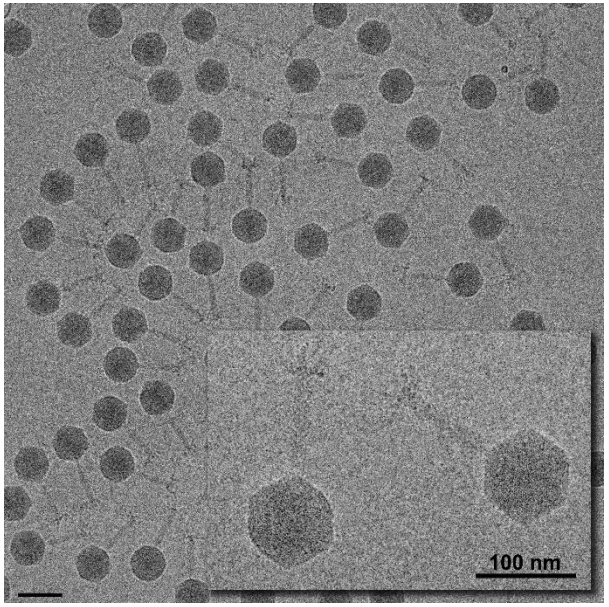




Fraunhofer Institute, Stuttgart, Duitsland

Lightyears • • • km • • • mm

Tomography at all scales



Phi-92 viruses, NeCEN

Lightyears • • • km • • • mm • • • µm • • • nm

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Reconstruction algorithms

Classical algorithms: Filtered Backprojection, FDK

- Based on filtering in Fourier domain, followed by so-called backprojection.
- Fast and fairly robust; limited flexibility.

- Time: approx 30s for 1024^3 volume, on a single modern GPU

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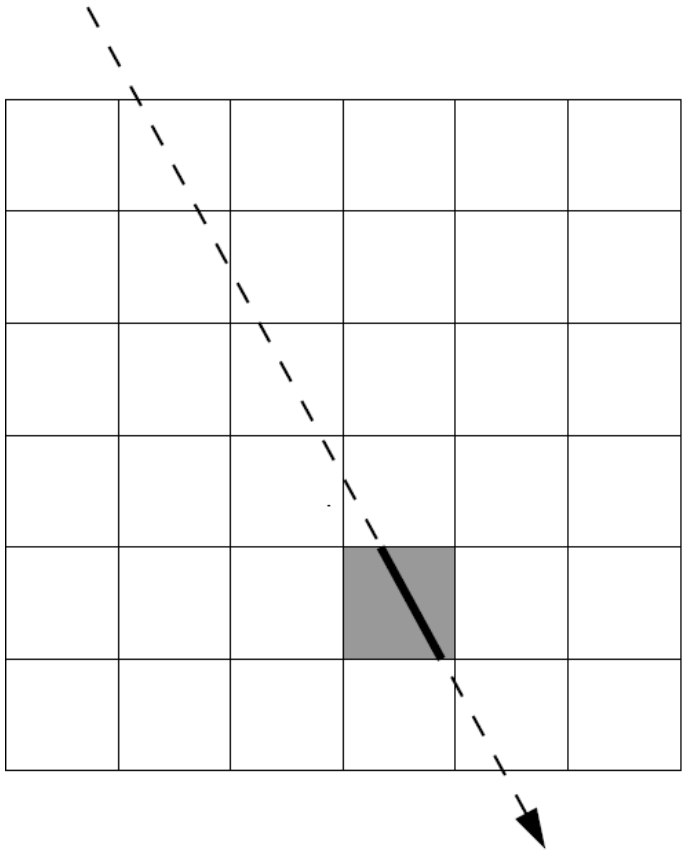
Tomography as linear equations



$$Wx = p$$

$$\sum_{j=1}^{n} w_{ij} x_j = p_i$$

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Reconstruction algorithms

Modern algorithms:

- Often based on iteratively solving a large, sparse linear system, or maximum likelihood model.

- Often underdetermined and inconsistent (noise)
- Slow, but room for introducing prior knowledge or regularization.

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Reconstruction algorithms

Modern algorithms:

- Often based on iteratively solving a large, sparse linear system, or maximum likelihood model.

- Typical data sizes: 1024^3, 2048^3, and growing.
- Size of linear system: $N^3 \times N^3$
- Reconstruction time per iteration scales as $O(N^4)$
- Time: approx 60s ***per iteration*** for 1024^3 volume, on a single modern GPU. Hours for full reconstruction.

ASTRA Toolbox

Fast and flexible GPU/CUDA building blocks for 2D/3D tomography.

Matlab and Python interface, for Windows and Linux.

Free and open source.

Developed jointly by University of Antwerpen and CWI.

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Our users

- Academic researchers
  - Tomography algorithm researchers (ourselves)
  - Experimental imagers (phycisists, biologists, engineers)
- Companies that make imaging hardware and software
  - Microscopes, X-ray scanners
- In active use at large experimental facilities, and packaged in the standard reconstruction software of a large electron microscope manufacterer

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ASTRA Toolbox on clusters

- In the process of moving from single GPU computation to multi-GPU, multi-node work

  Joint with Jeroen Bédorf (CWI)
- This results in a software toolbox that can run on:
  - workstations with a single GPU
  - servers with, say, 4 GPUs
  - GPU clusters with dozens of GPUs
- With innovative Python interface that lets users write their own algorithms on top of our toolbox.

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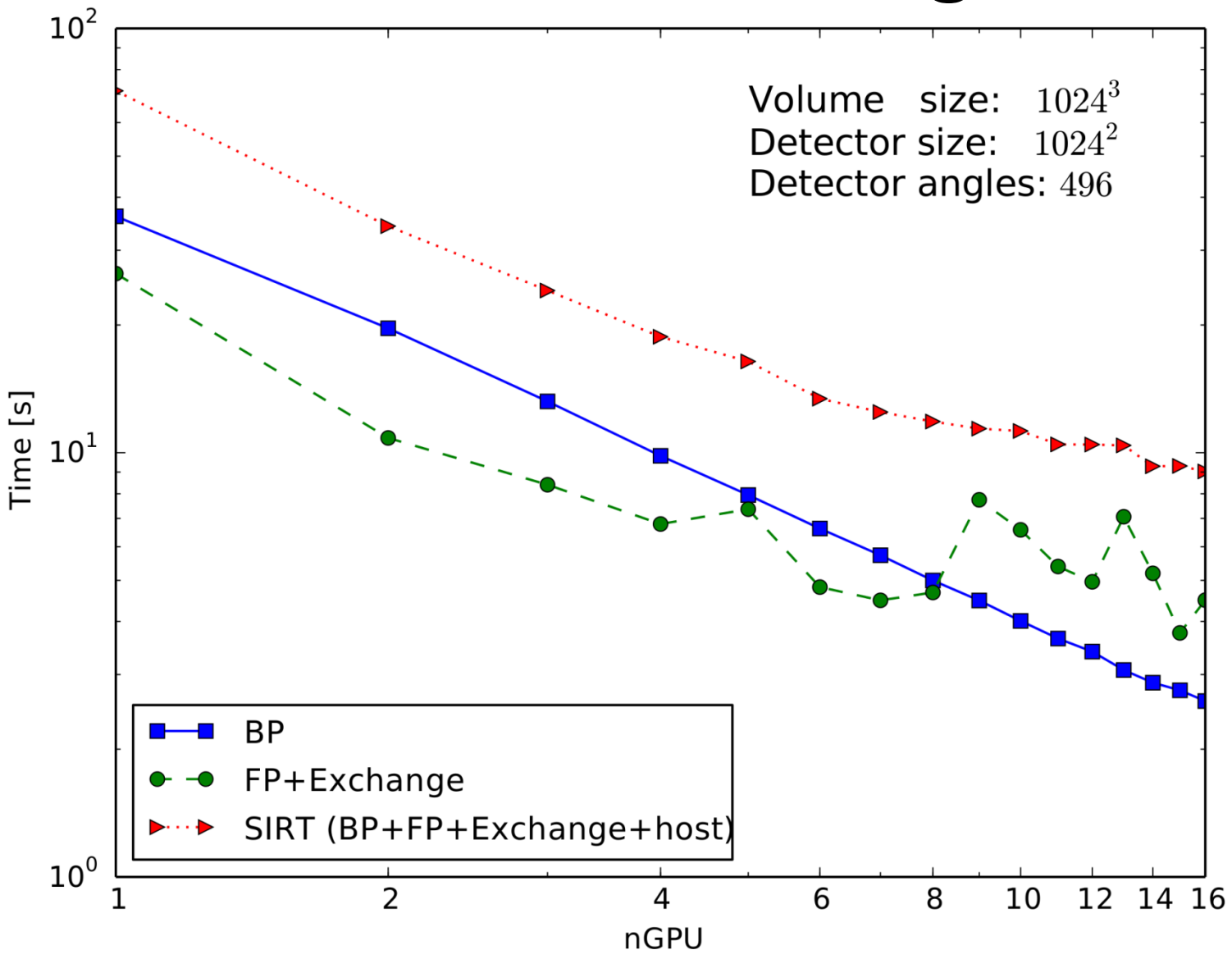
Multi-node scaling



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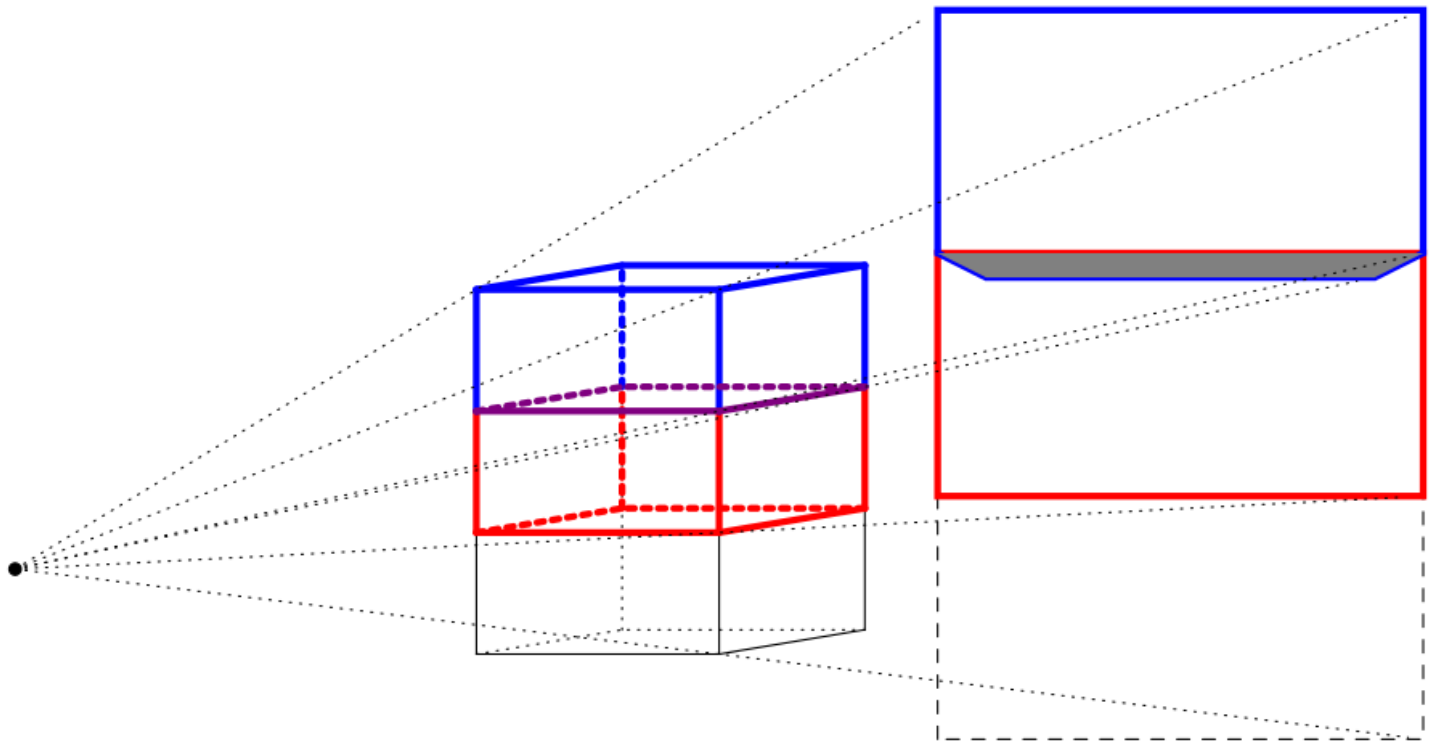
Multi-node scaling



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Ongoing research

- With more nodes, communication is bottleneck
- Improve efficiency by reducing communication:
  - Better modelling of the performance impact of different ways of distributing the volume, and optimize this.
  - Research on algorithms that need less communication
- Handle distribution of more complex geometries:
  Spiral, dual axis, ...

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