Advanced X-ray Tomography:

Building Bridges between Computational Science and Real-World Experiments

Friday, November 29, 2013

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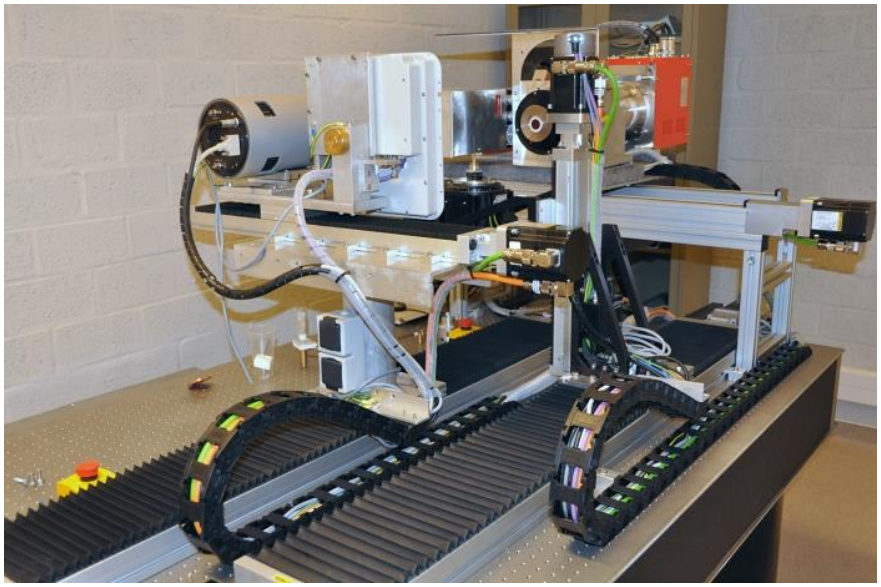
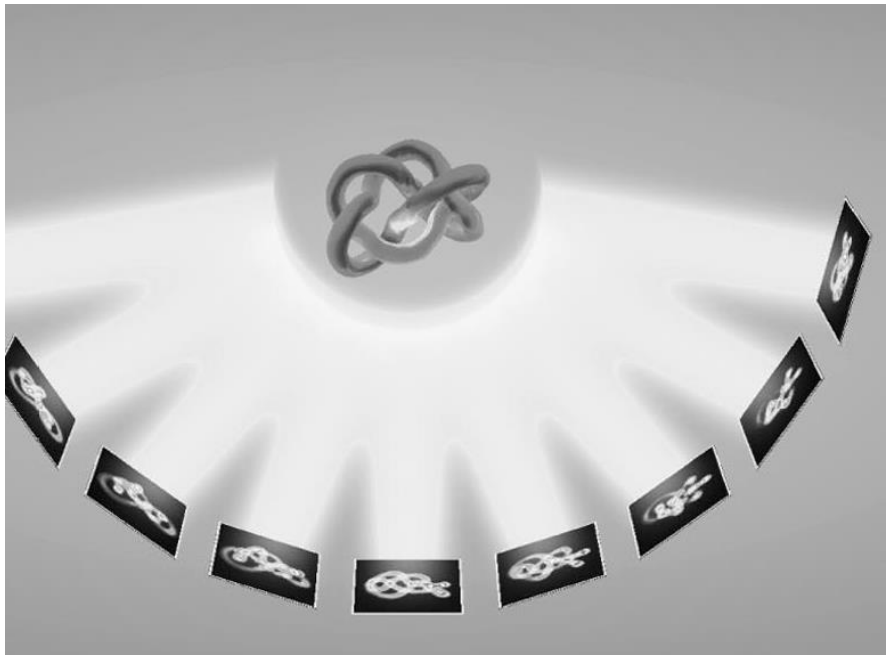
Advanced X-ray imaging

- Synchrotrons

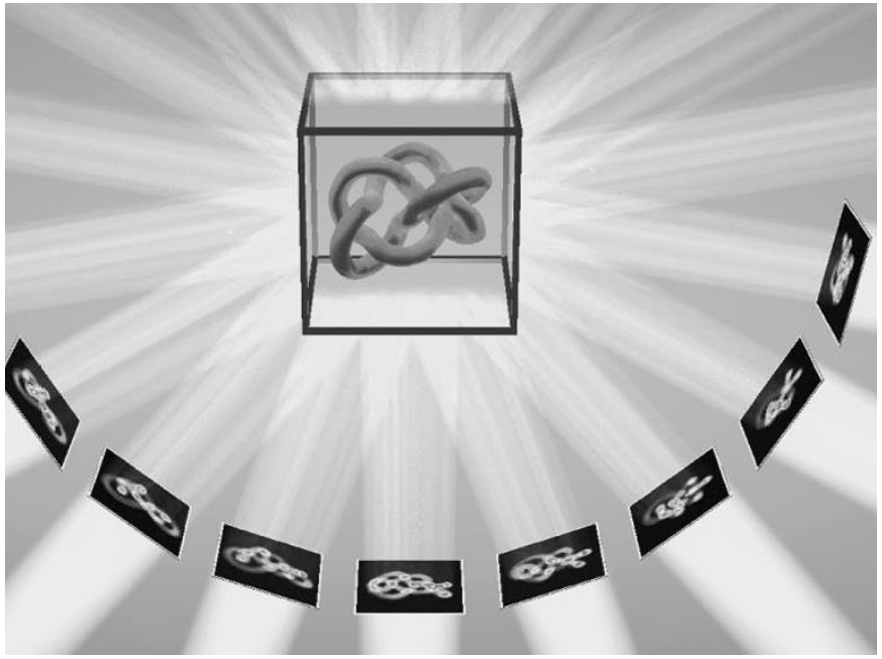
- Advanced lab setups



Tomography



Projections

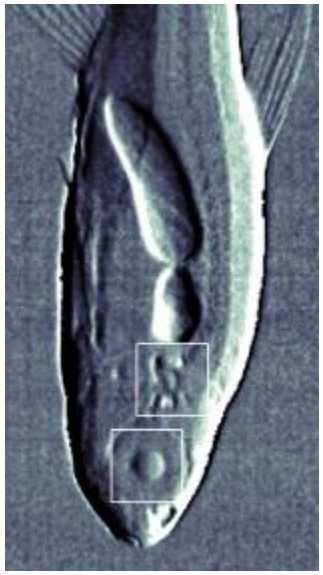


Reconstruction

X-ray Tomography: contrast generation

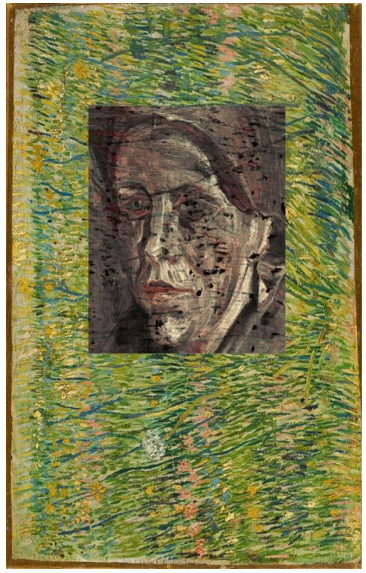
Absorption

Phase



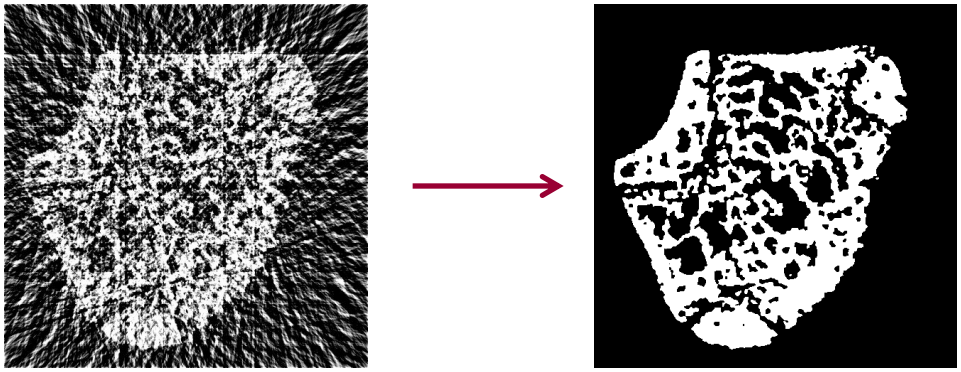
Diffraction

Fluorescence



Tomography: Reconstruction

- Classical algorithms known for more than 50 years
- Recently: breakthroughs in limited data reconstruction
  - Compressive Sensing
  - Discrete Tomography



Slice of rat femur, reconstructed from 20 projections using classical methods (left) and discrete tomography (right)

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Advanced X-ray tomography: challenges

- Mechanical instabilities
- Nonlinear image formation
- Dose and time constraints

Standard algorithms are used, which were never designed for these challenges

Why does almost everyone still use classical methods?

- Methods are parameter-less
- Easy to understand
- Easy to implement
- Computationally efficient

- Only way to convince users is to make a breakthrough in image quality

Current landscape

- Two separate communities
  - Experimental X-ray imaging
  - Mathematical imaging / Algorithm development
- Desire to collaborate, but also reluctance to enter new fields
- Little interaction between both communities
- Different focus, need to align the questions

We need to bridge this gap

EXTREMA: a COST Action

- EU Network grant for 2013-2017
- Goal: to establish an active, interdisciplinary research network that bridges the gap between the experimental X-ray tomography community and the mathematical image reconstruction community
- Instruments:
  - Workshops
  - Short Term Scientific Missions (STSMs)
  - Training Schools
  - MC + Working Groups

About COST

- Separate funding entity in Brussels, funded by FP7 / H2020
- 300 running networks in 9 domains
- Administration for each network is localized at a Grantholder Institute

Aim of the network

- To bridge the gap between both communities
  - Active, interdisciplinary research network
  - Broad representation of both fields

- to enable the development of next generation X-ray tomography techniques and algorithms
  - Tailored algorithms
  - Combine state-of-the-art from both fields

How to reach the objectives by networking

- Working Groups
  - WG structure that encourages collaboration
- Joint workshops
  - Lead to common frame of reference
- STSM's
  - Mainly between groups from both communities
- Training schools
  - Aimed at cross-fertilization between both fields
- Events with industry
  - To showcase research results from an early stage

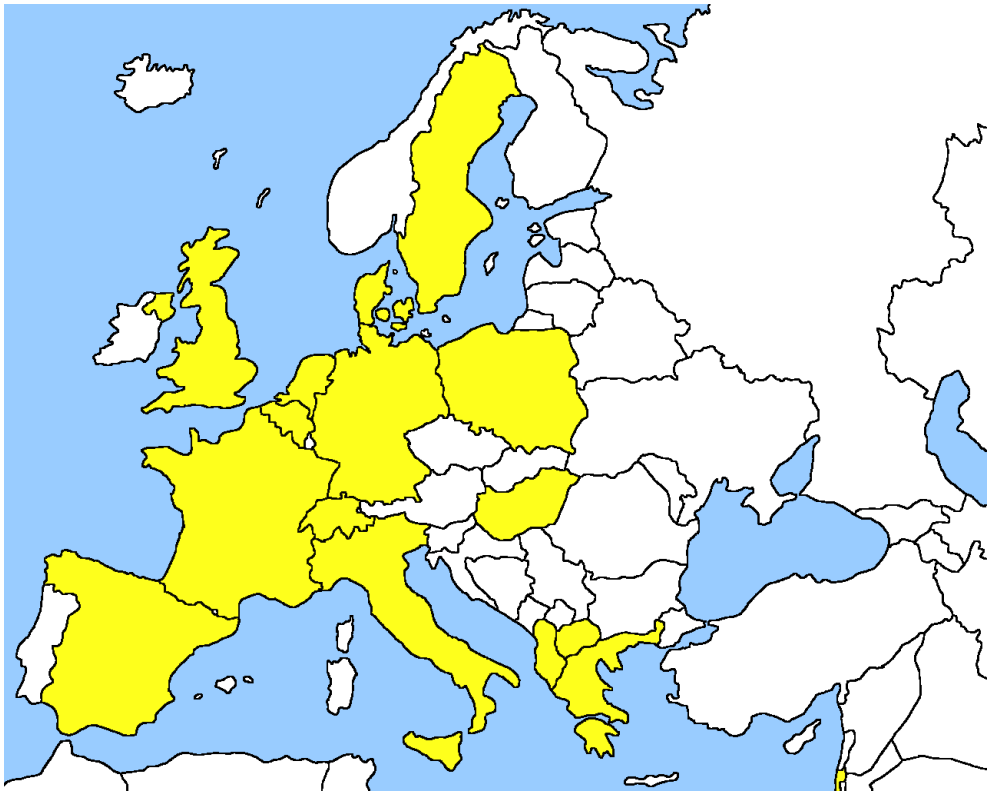
“2D” Working Groups

	Software and data exchange W1	Quantitative modelling W2	Algorithm development W3
Absorption and phase contrast T1			
Diffraction contrast T2			
Fluorescence contrast T3			

Scientific Focus

- Focused on the development of state-of-the-art software and algorithms
  - For various X-ray imaging modalities
  - Computational solutions to experimental problems
- Requires accurate experiments, models, and algorithms
  - And expert knowledge in each of these fields
- Concerted effort between experimentalists, mathematicians, algorithm developers

Current interest



Key figures:

- 80 participants
- 20 countries

- 50 experimental
- 30 algorithmic

- 7 synchrotrons

- Interest is still expanding and comes from both communities, as well as industry

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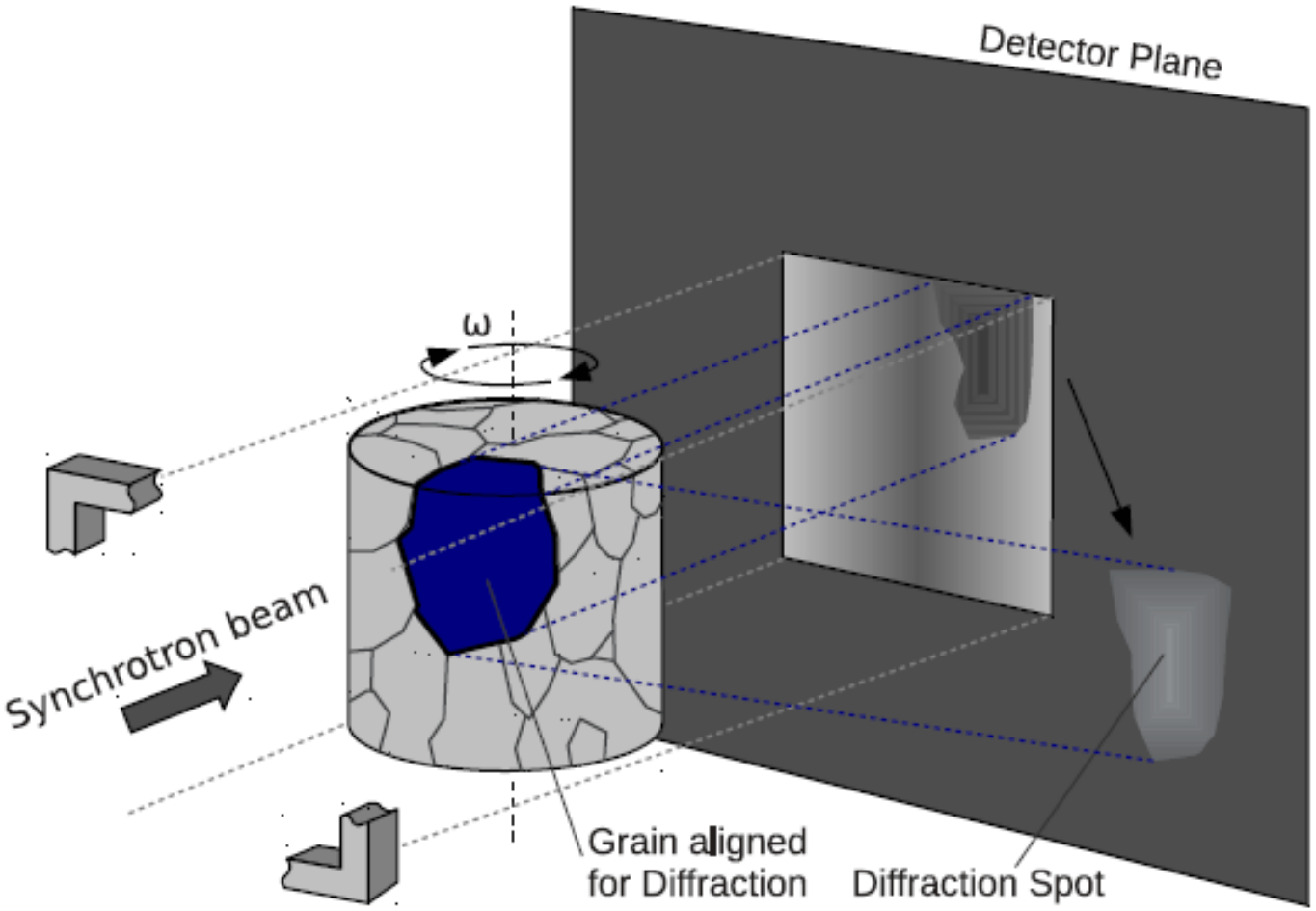
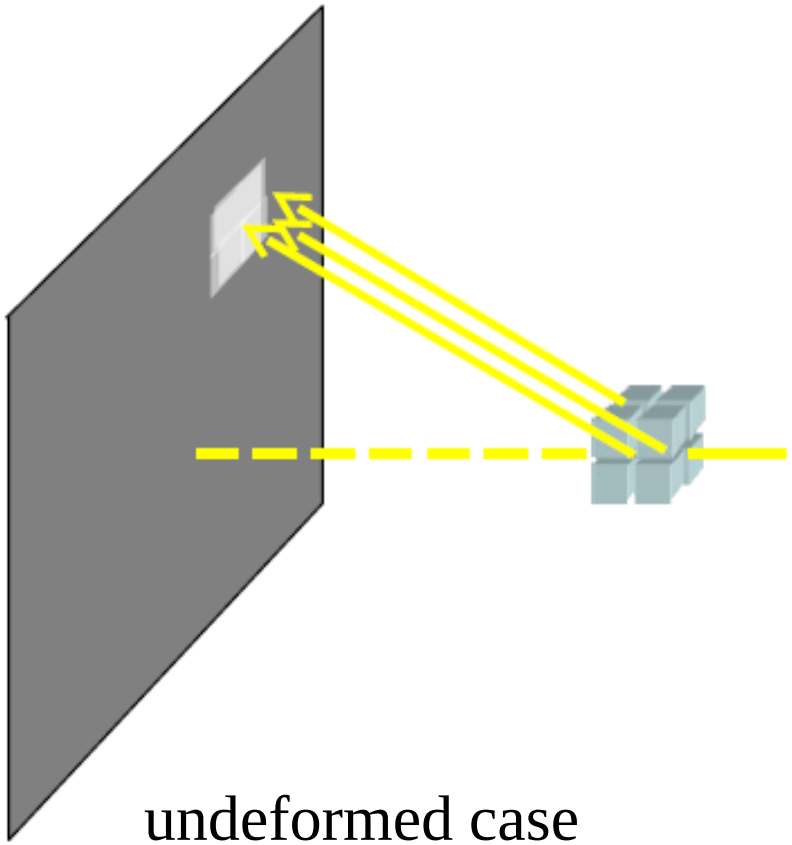
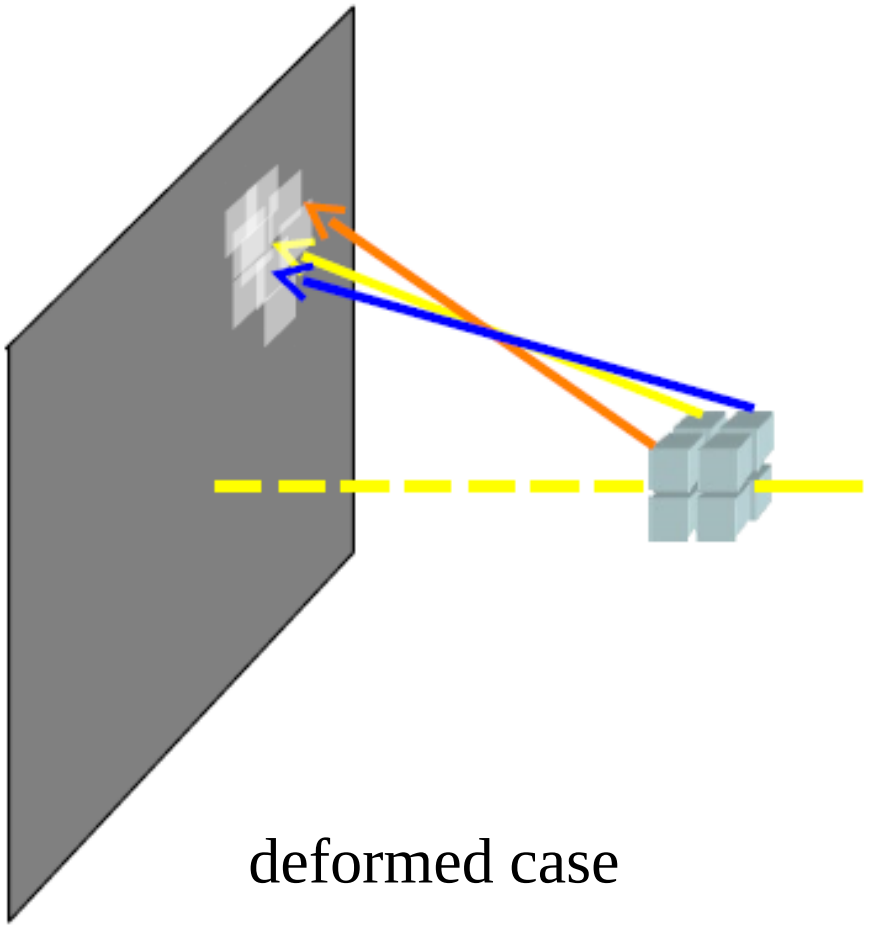
Example I: X-ray diffraction tomography



Example I:
X-ray diffraction tomography

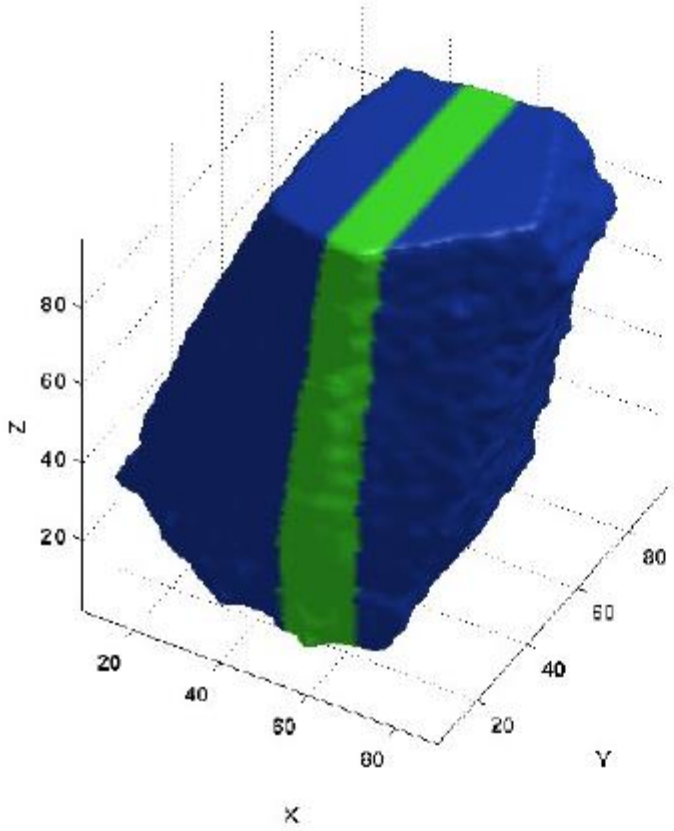


undeformed case

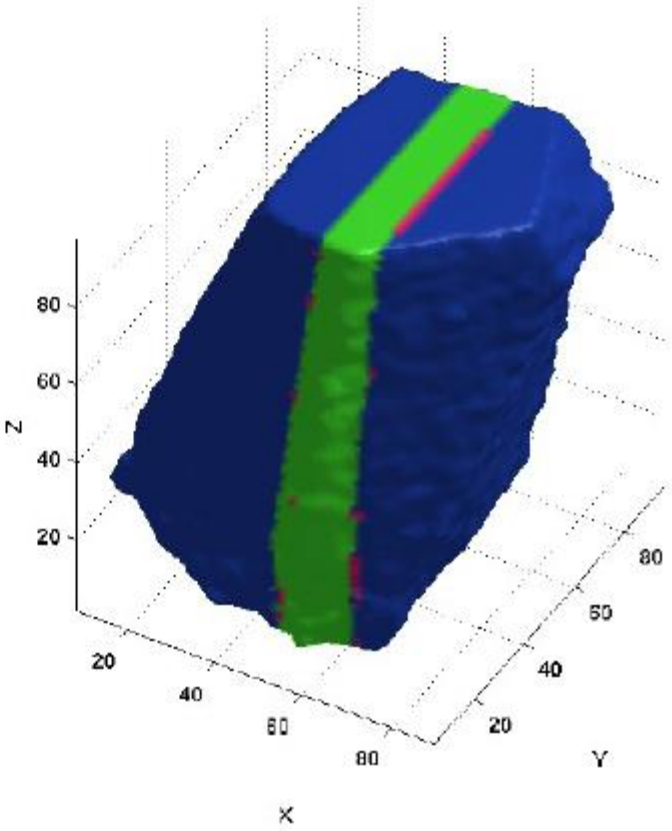


deformed case

Example I: X-ray diffraction tomography



Twin boundary (original)



Twin boundary (reconstruction)

Joint work between CWI and Nicola Vigano, ESRF

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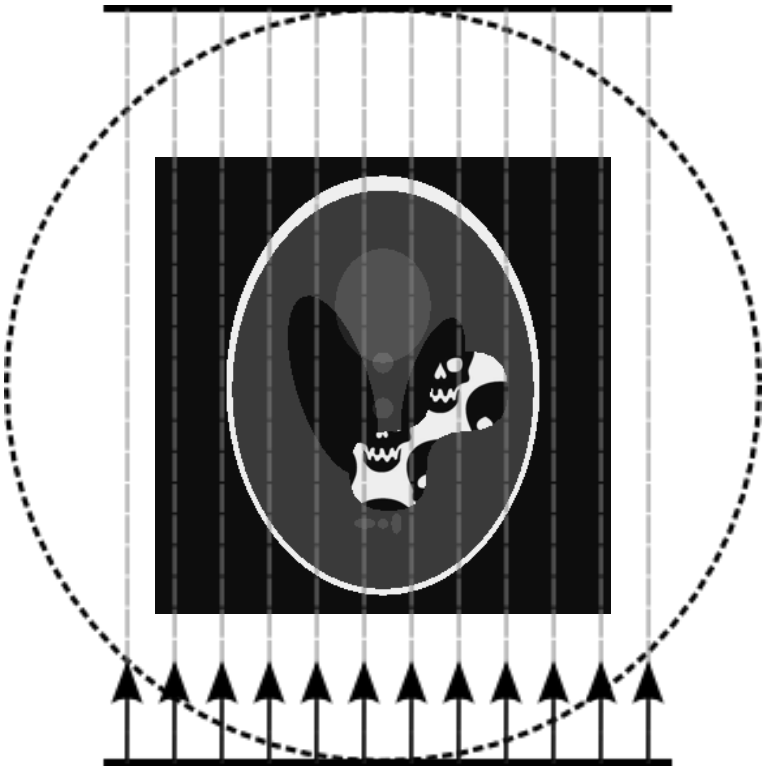
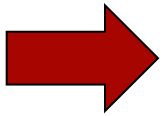
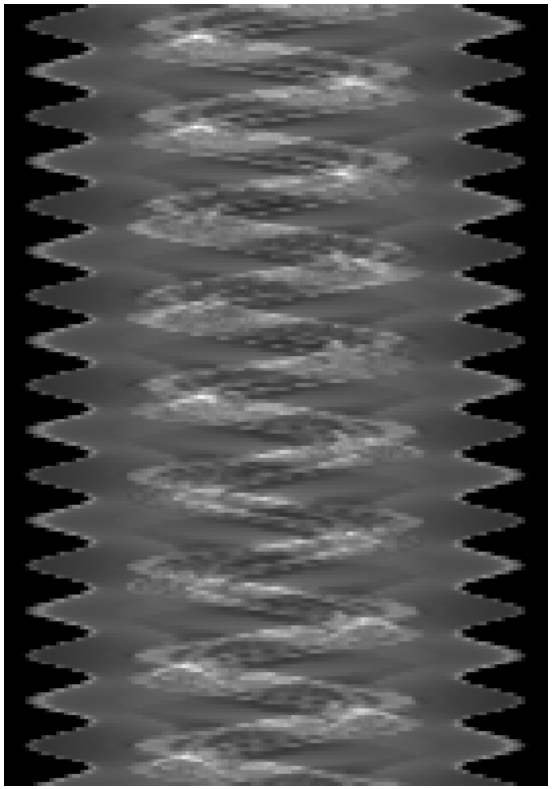
Example II: 4D Tomography





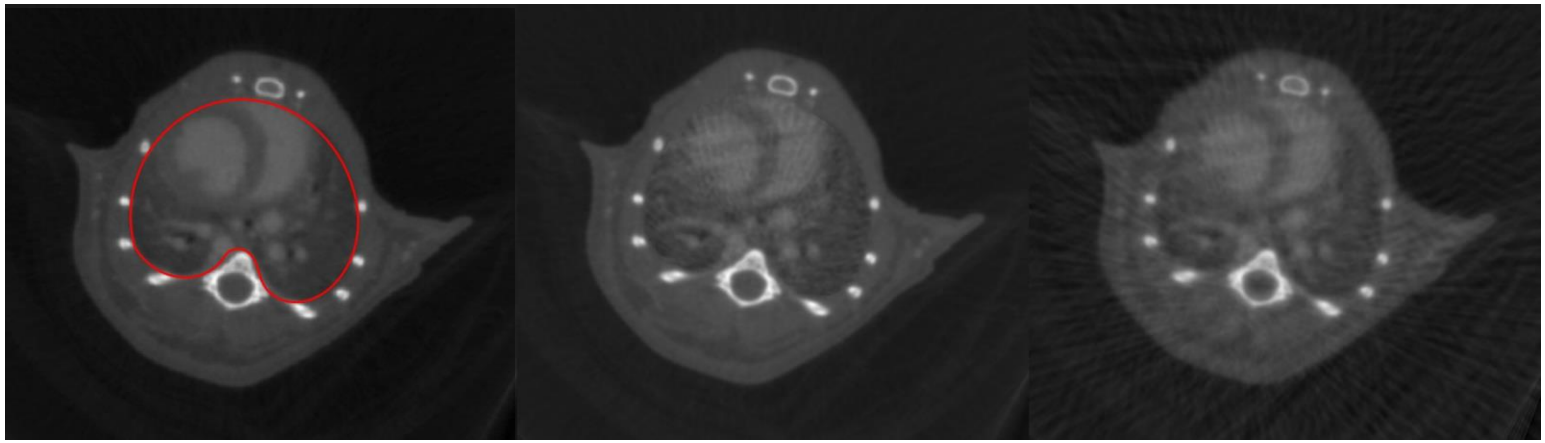


4D tomography: challenges

- Many experimental challenges
- Bandwidth/throughput limitations
- Reconstruction from limited data
- ... Huge amounts of data
- Exploit prior knowledge
- Exploit temporal correlations
- Optimize the acquisition of projections
- Reconstruct in real-time

Example II: 4D Tomography

Full dataset | 1/5th rSIRT | 1/5th conventional



Joint work between CWI and Geert van Eyndhoven, Univ. Antwerp

Conclusions

- Major challenges in advanced X-ray imaging
- Mathematics and algorithms can solve these problems
- Both communities are willing, but miss the coordinating platform
- CWI now has a leadership role in bringing these communities together