Massively Parallel Iterative Reconstruction

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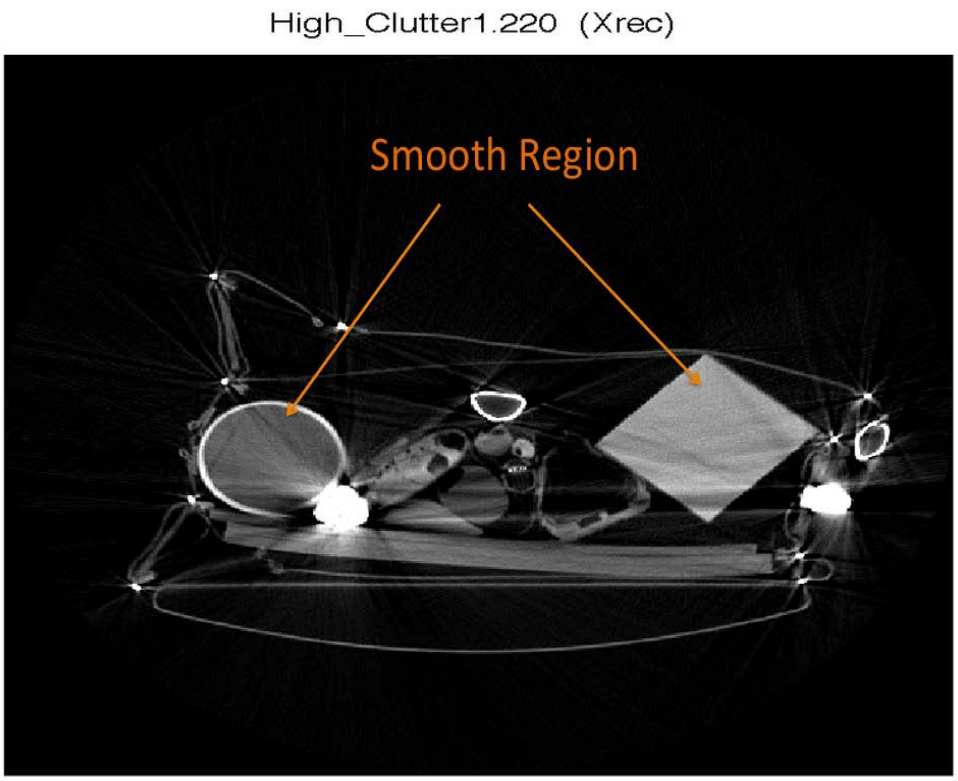
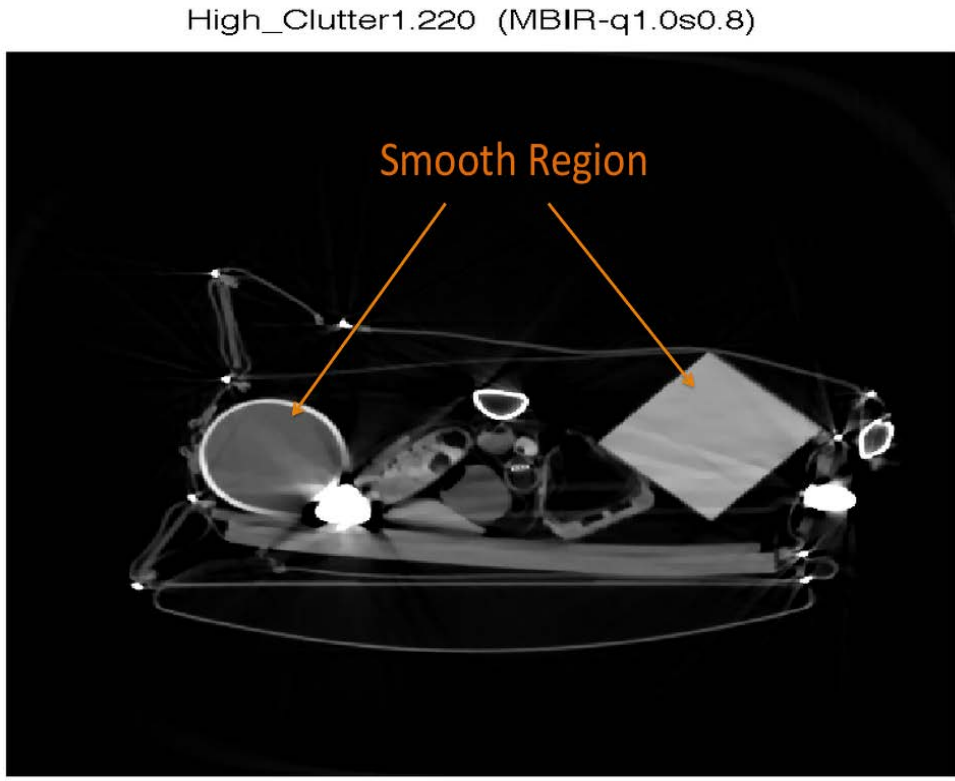
Model Based Iterative Reconstruction (MBIR)

- Advantages:
  - leads to more accurate detection of explosives and reduce false alarm in CT security imaging.
  - Has wide applications in security imaging, scientific imaging, and medical imaging.
- Disadvantages:
  - very computationally demanding!

- Super-Voxel algorithm
  - 188x speedup on 68 cores, 2015x speedup on 29920 cores
  - Dramatically improves memory reuse and parallel operations

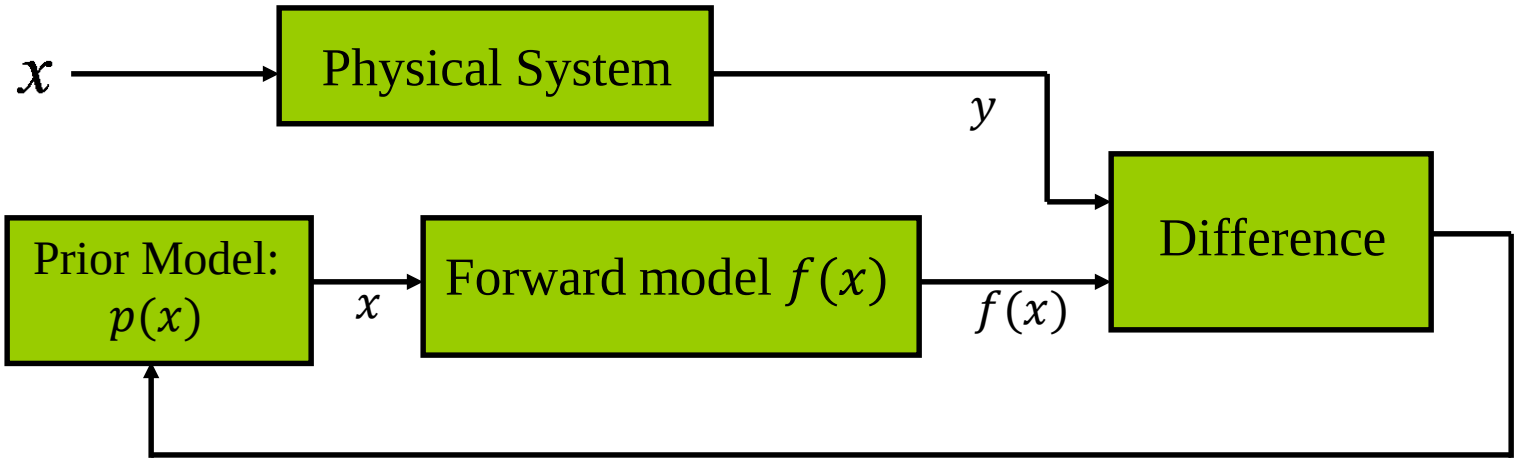
Image Quality Comparison





An Example Slice from ALERT task order 3 (TO3) dataset, obtained from an Imatron C-300 Scanner

MBIR Formulation

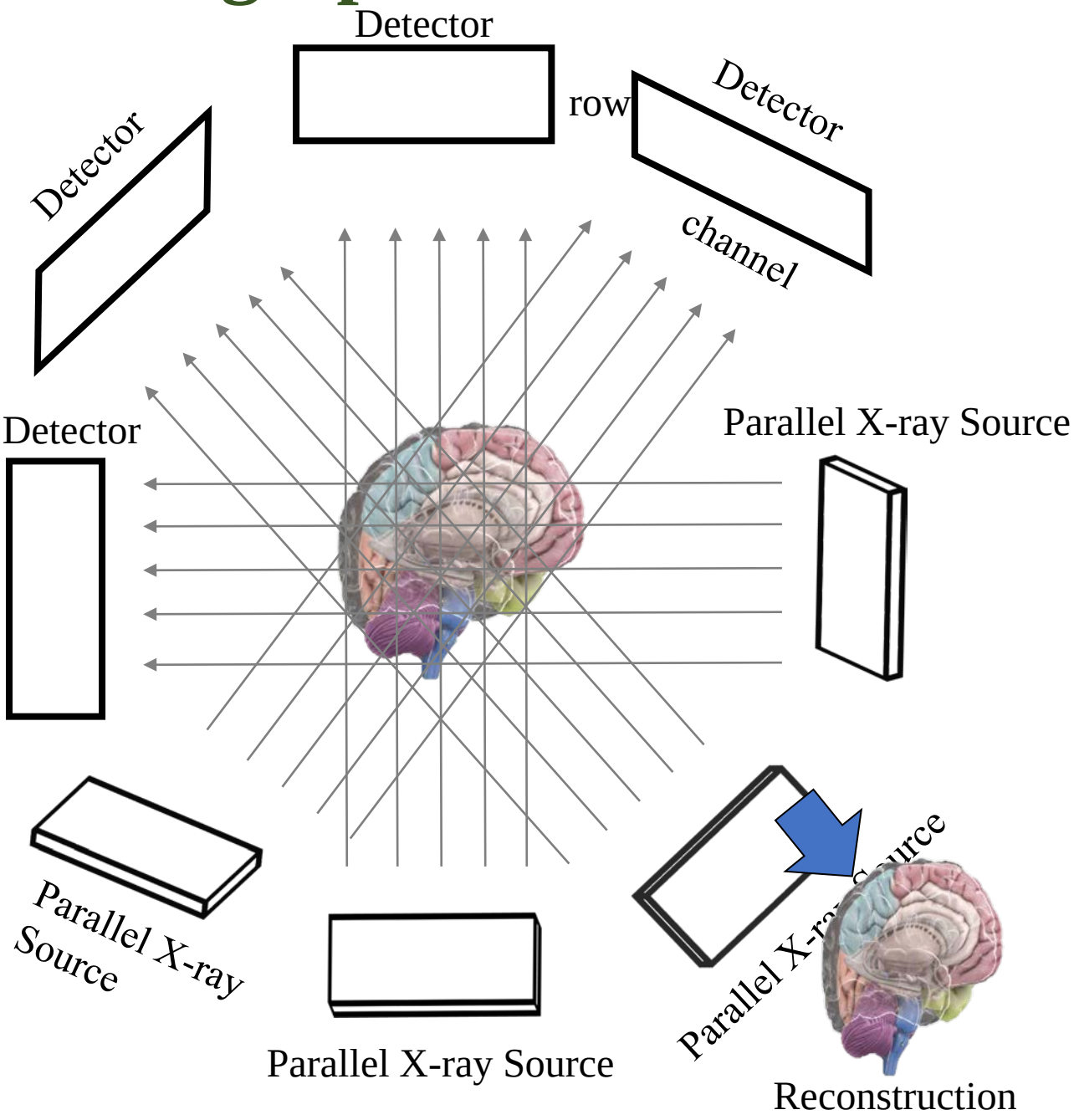


forward model prior model

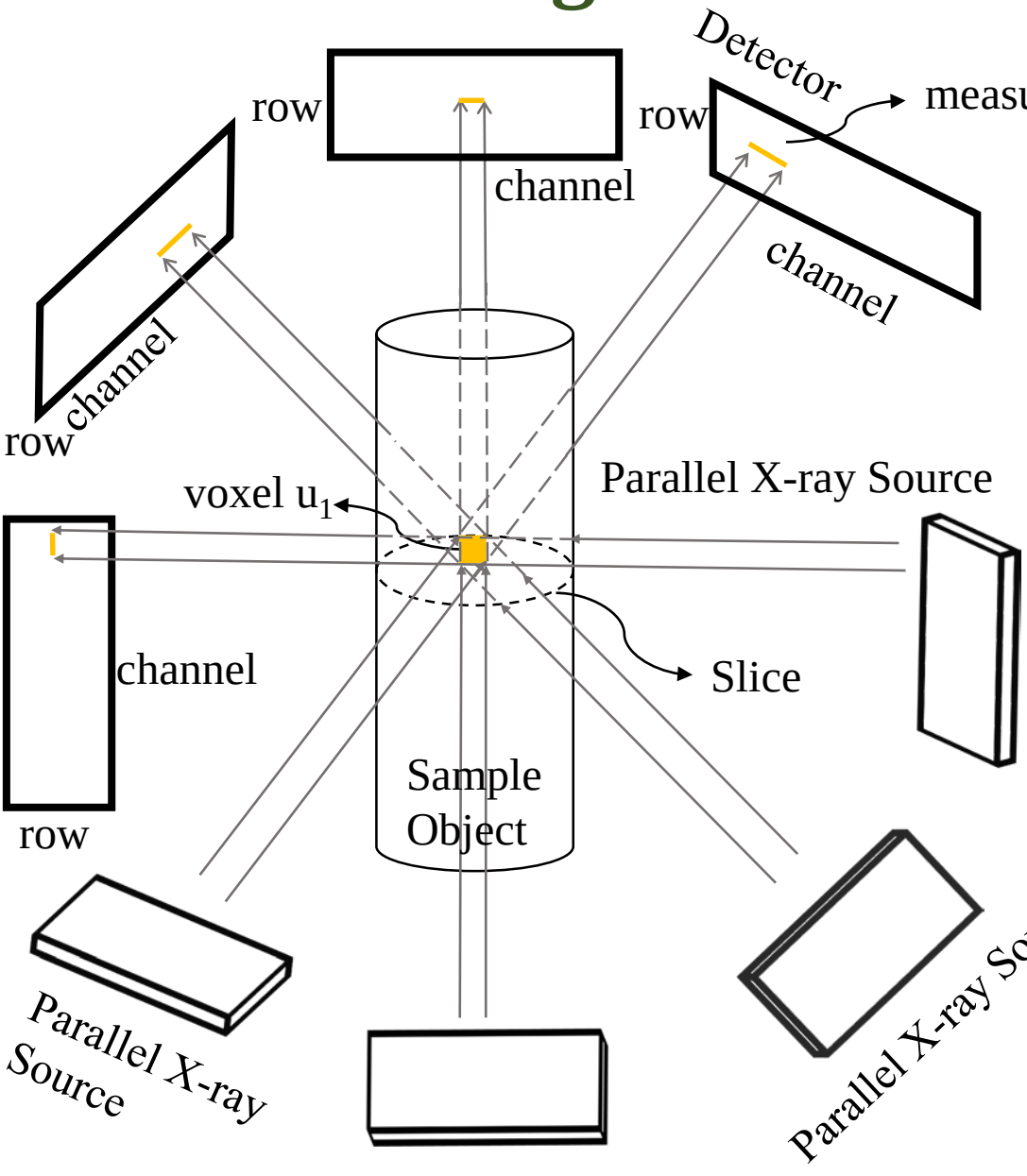
$$\hat{x} \leftarrow \arg\min_{x} \{\|y - Ax\|_{\lambda}^{2} + u(x)\}$$

So why is MBIR so computationally demanding?

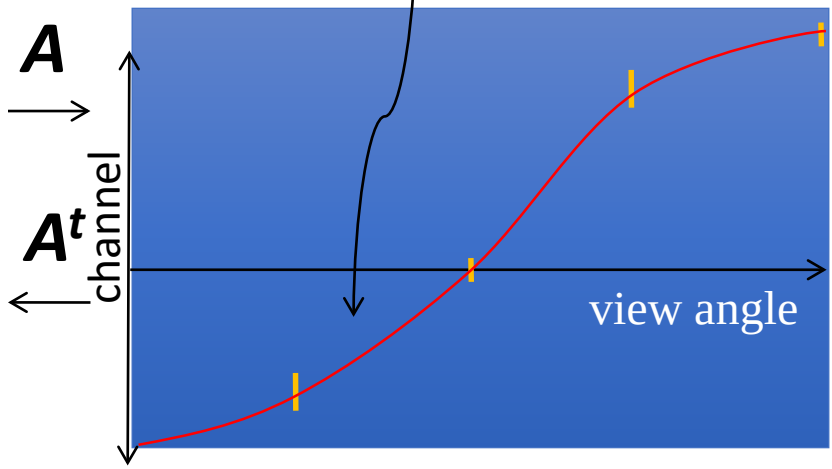
Tomographic Reconstruction



Irregular Memory Layout



relevant measurements for given voxel

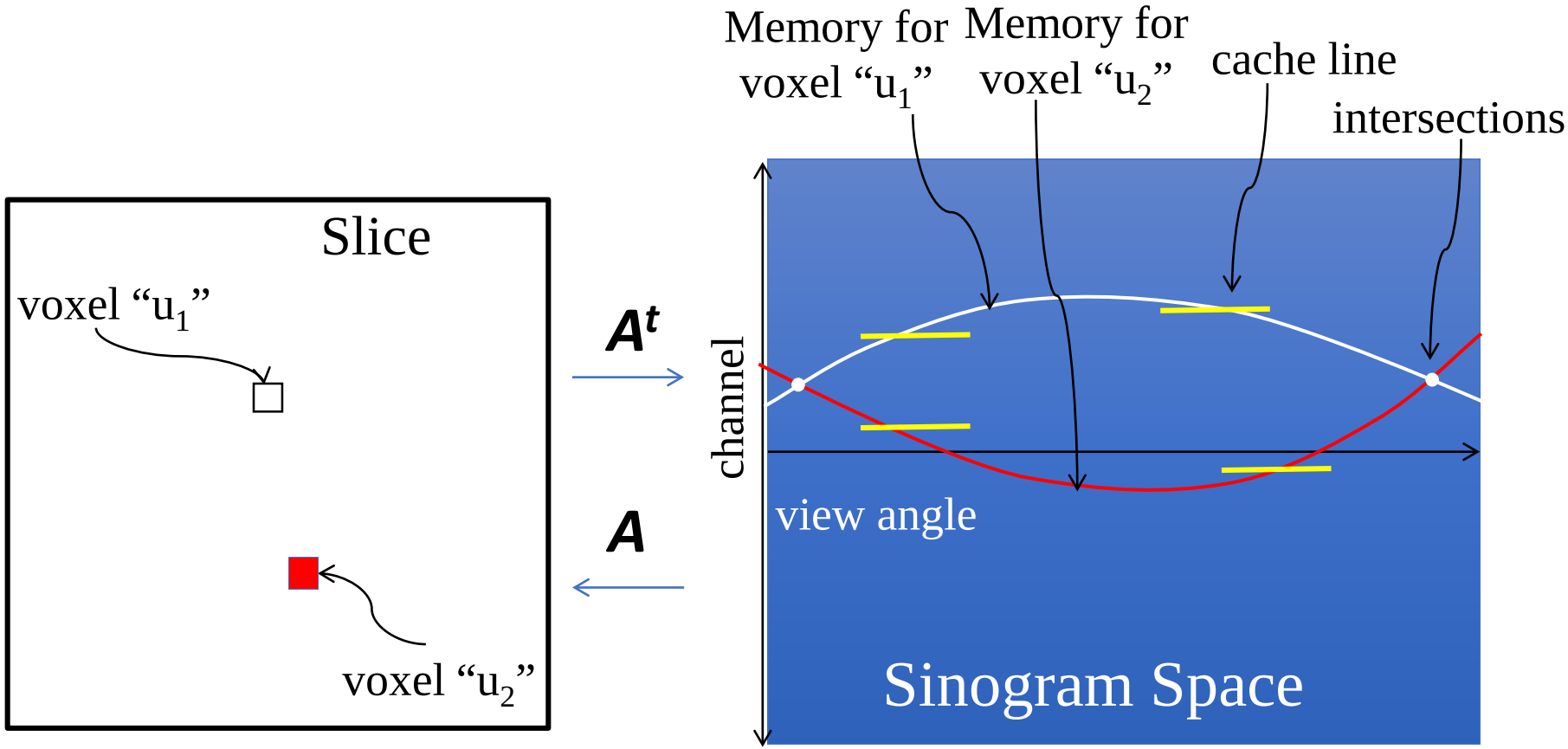


Sinogram Space

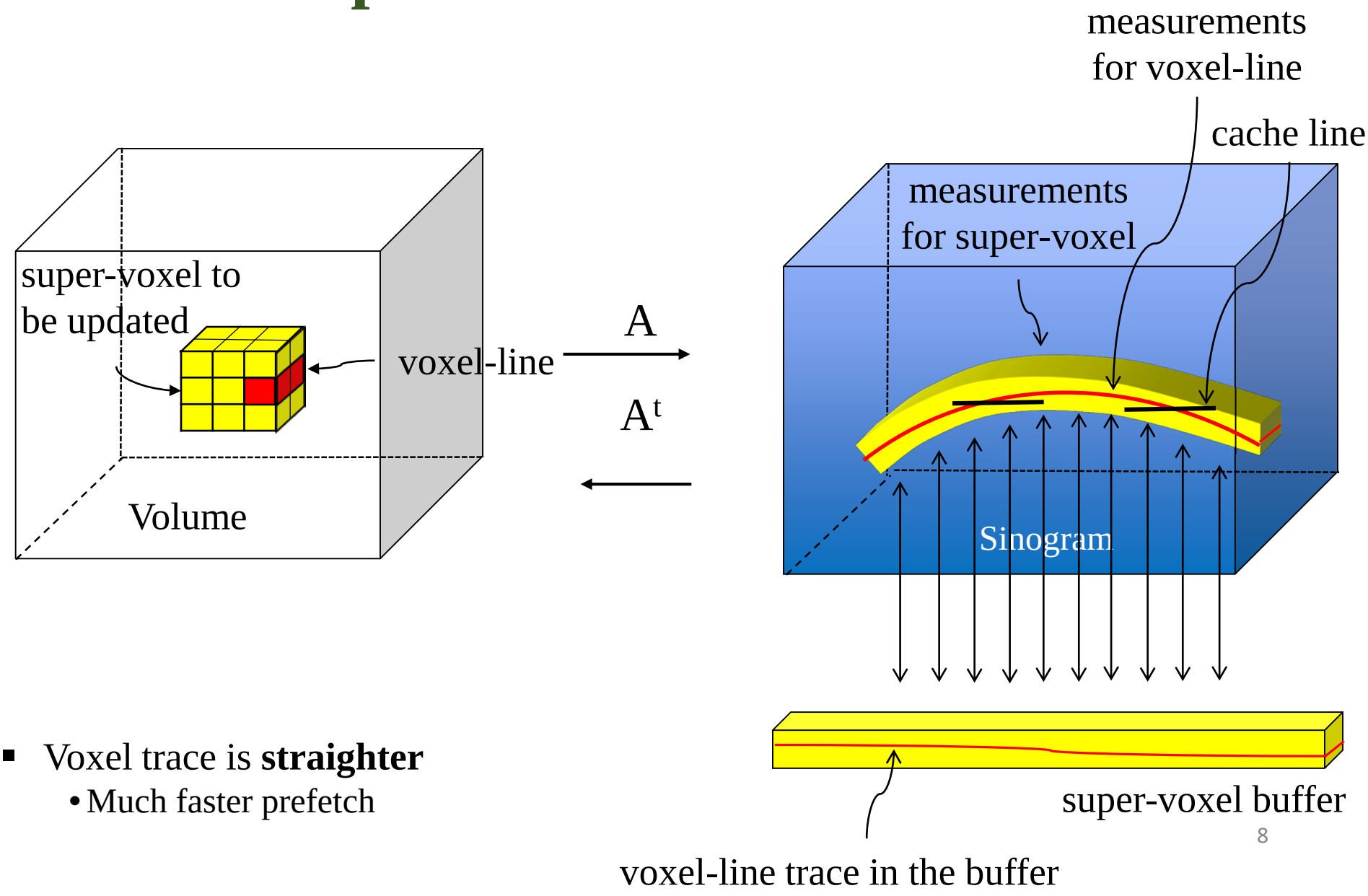
- Observation: sinusoidal path

Limitations of Baseline MBIR

- Update voxels
  - Inefficient cache utilization
  - Difficult to parallelize

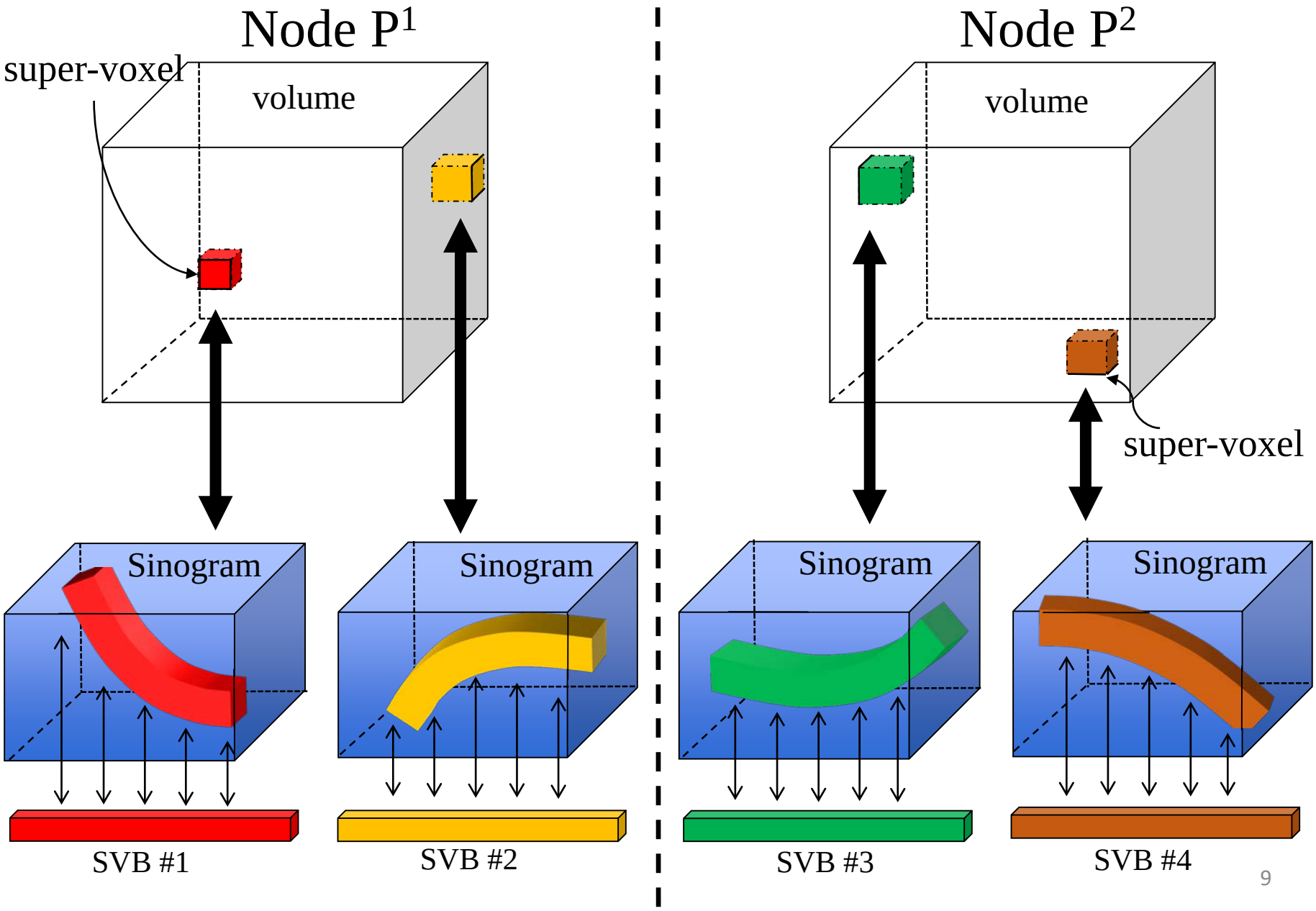


Super-Voxel In 3D Volume



- Voxel trace is **straighter**
  - Much faster prefetch

Hierarchical Parallelism



TO3 Dataset Speedup

- Dataset (TO3 dataset):
  - 1024 channels; 720 views; parallel view
  - 512 x 512 x 3200 reconstruction
- Computer:
  - NERSC supercomputer from Berkeley National Lab (knights landing clusters)
  - Each node: 68 cores Intel processors
- Algorithm: the baseline MBIR, and the super-voxel algorithm

Nodes	1 Node	4 Nodes	40 Nodes	440 Nodes
Cores	68 Core	272 Cores	2720 Cores	29920 Cores
baseline	45033.6	32035.2	Not Applicable	Not Applicable
Super-Voxel	239.1	59.1	18.0	15.9
Speedup	188.34	542.05	1779	2015