**Image Reconstruction with Accelerated Direct Demodulation Method for HXMT**

Zhuo-Xi Huo and Jian-Feng Zhou

Department of Engineering Physics and Center for Astrophysics, Tsinghua University

**HXMT: A Chinese High-Energy Astrophysics Mission**

- Hard X-ray (@20–250 keV) all-sky imaging survey with high sensitivity & high spatial resolution.
- Science Aims. Key waveband for high energy astrophysics; Black holes; Physical processes in the extreme conditions.

**On-board Detectors**

- High-Energy Detector (HE), Middle-Energy Detector (ME), and Low-Energy Detector (LE):
  - Tantalum collimators with rectangular cross sections:
  - PSF models for single collimator (1.1° × 5.7° FOV & 5.7° × 5.7° FOV) and detector (multiple collimators):

**Challenges in Image Reconstruction**

- General measurement process (modulation):
  \[ d(\omega) = \int p(\omega, x)f(x)dx + w(\omega) \]
- Non-axisymmetric kernel (PSF), rotating while translating, no shift-invariance, no convolution.
- Computational complexity for numerical modulation: \( \sim O(N^4) \).
- Worst-case memory consumption: \( 1.6 \times 10^4 \text{ TB} \) (1’s sampling interval, double-float, global-global algorithm).
- Global-local algorithm (run-time kernel generating): memory consumption solved, but complexity worsened, \( \sim O(N^6) \).
- Worst-case time consumption of a single numerical modulation: 25 yr on a 3.4 GHz × 8.
- Local-local algorithm: \( \sim O((N/N_0)^6N_0^2) \approx O(N^6) \times 300 \) (\( N_0^2 \) is number of sky regions), not enough (still takes 1 mon for a single numerical modulation, so how many for thousands of iterations?).
- No Way for PC-only astrophysicists?

**Reducing the Problem**

- Pseudo-cartesian pixel grid:
  - Left: Pixel diagram for Equidistant Cylindrical Projection (ECP) at high latitudes.
  - Right: Pixel diagram for Radial Quadrilateral Projection at high latitudes. No special scheme for spherical data except a small computational overhead for \( \sim 10ms \).
- Azimuthal clustering:

Position of each arrow indicates the pointing of detector while direction indicates the orientation. Left: un-clustered data; Right: clustered data. We have shift-invariance within a cluster, with Fast Fourier Transform: \( \sim O(n^2(\log n)^2n_c) \) (\( n \): sampling frequency in a local region; \( n_c \): number of clusters). 1 h for a single numerical modulation on all-sky data.

**Simulations**

- Simulated all-sky survey:
- Simulation in local region:

Left: Observed data with poisson noise; Right: Reconstructed image with 500 accelerated direct demodulations (in 200 s).

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http://www.hxmt.cn  
huozhuoxi03@mails.tsinghua.edu.cn