Towards distributed image reconstruction

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Image reconstruction problem

Fourier space

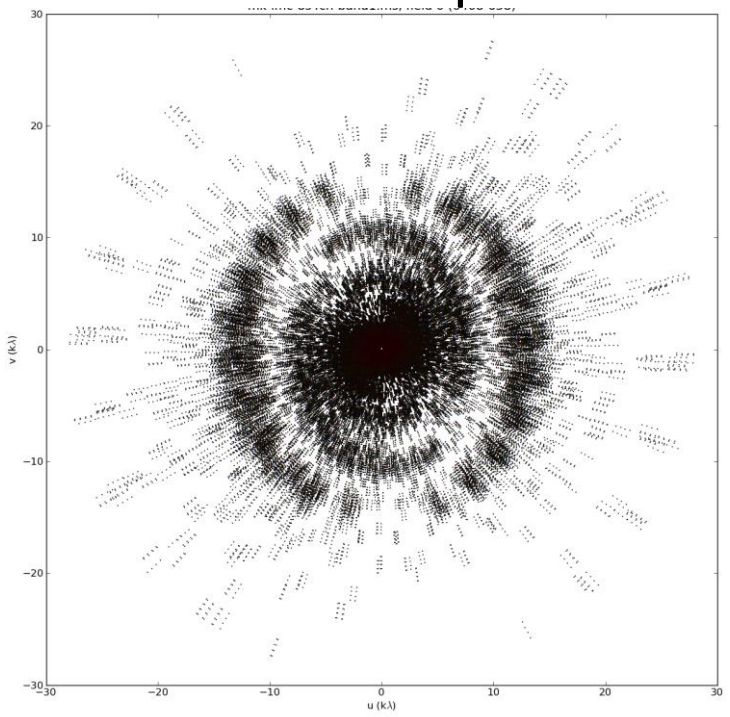
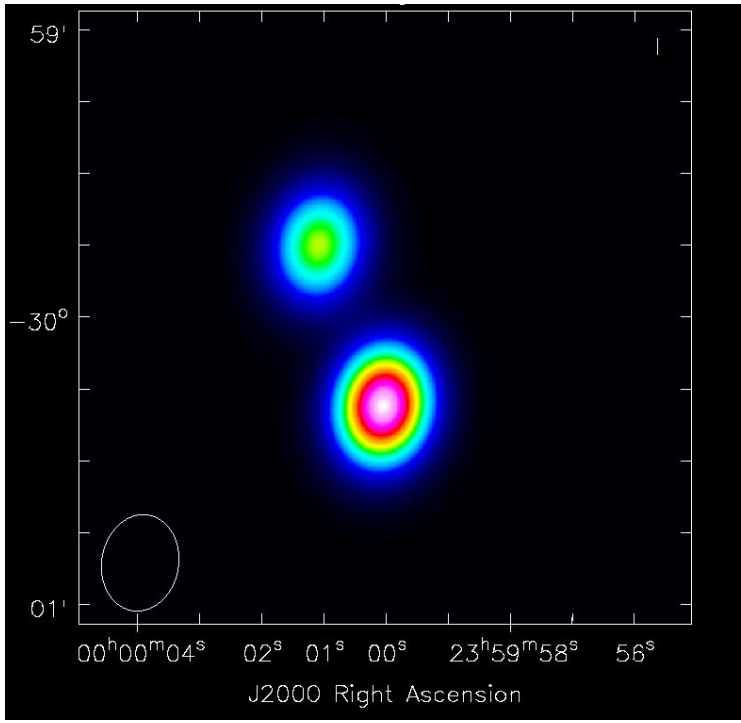
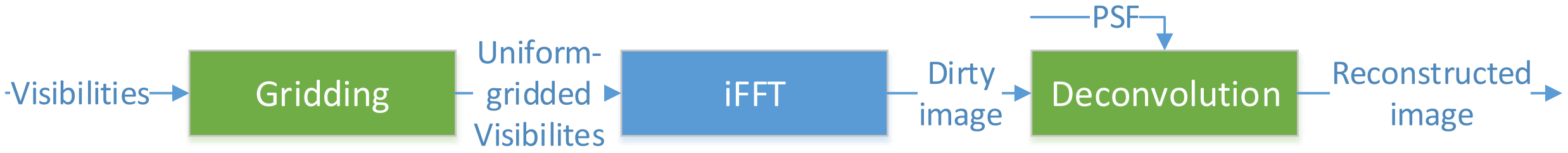
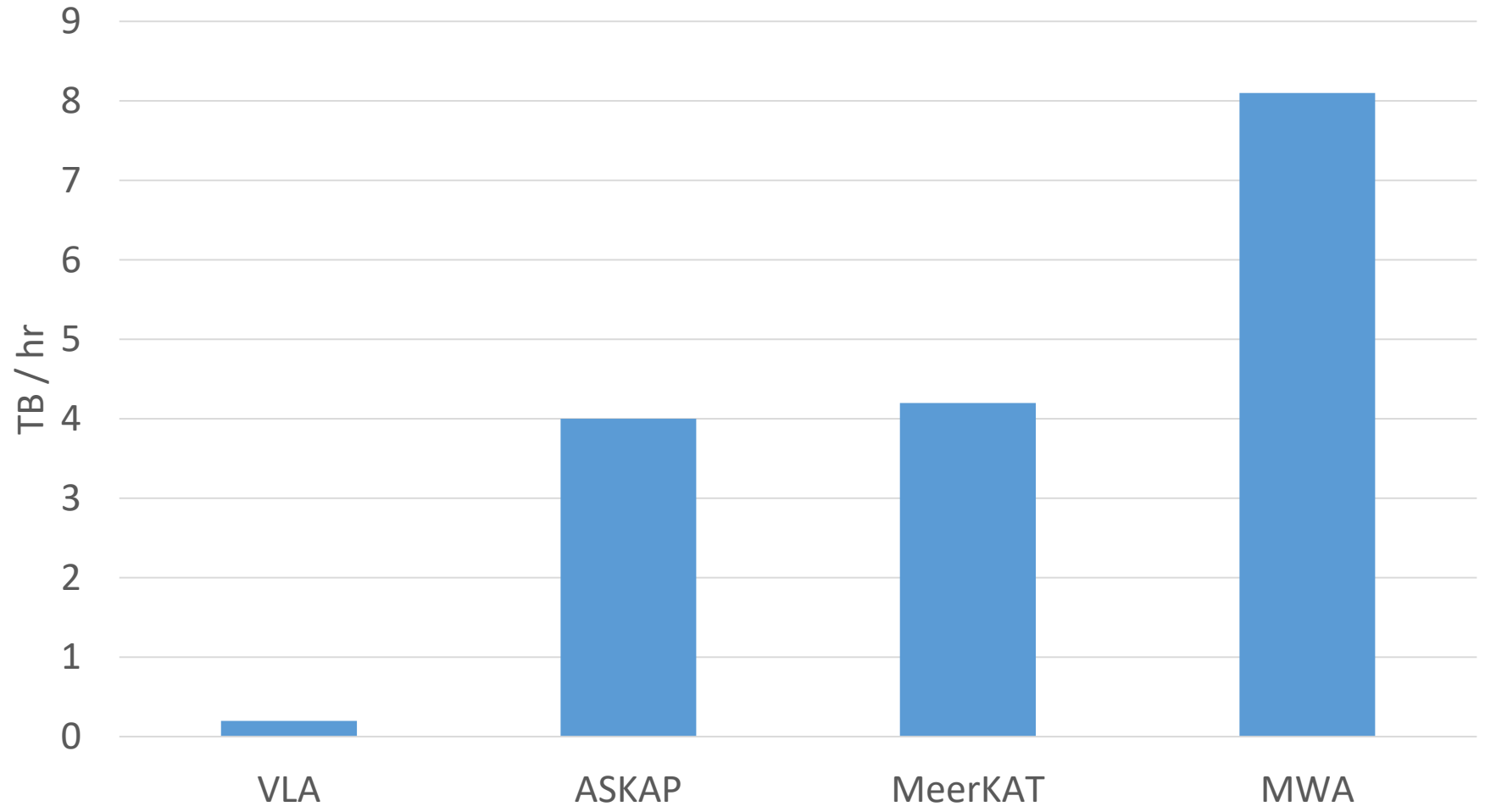


Image space





Why do we need distribution?



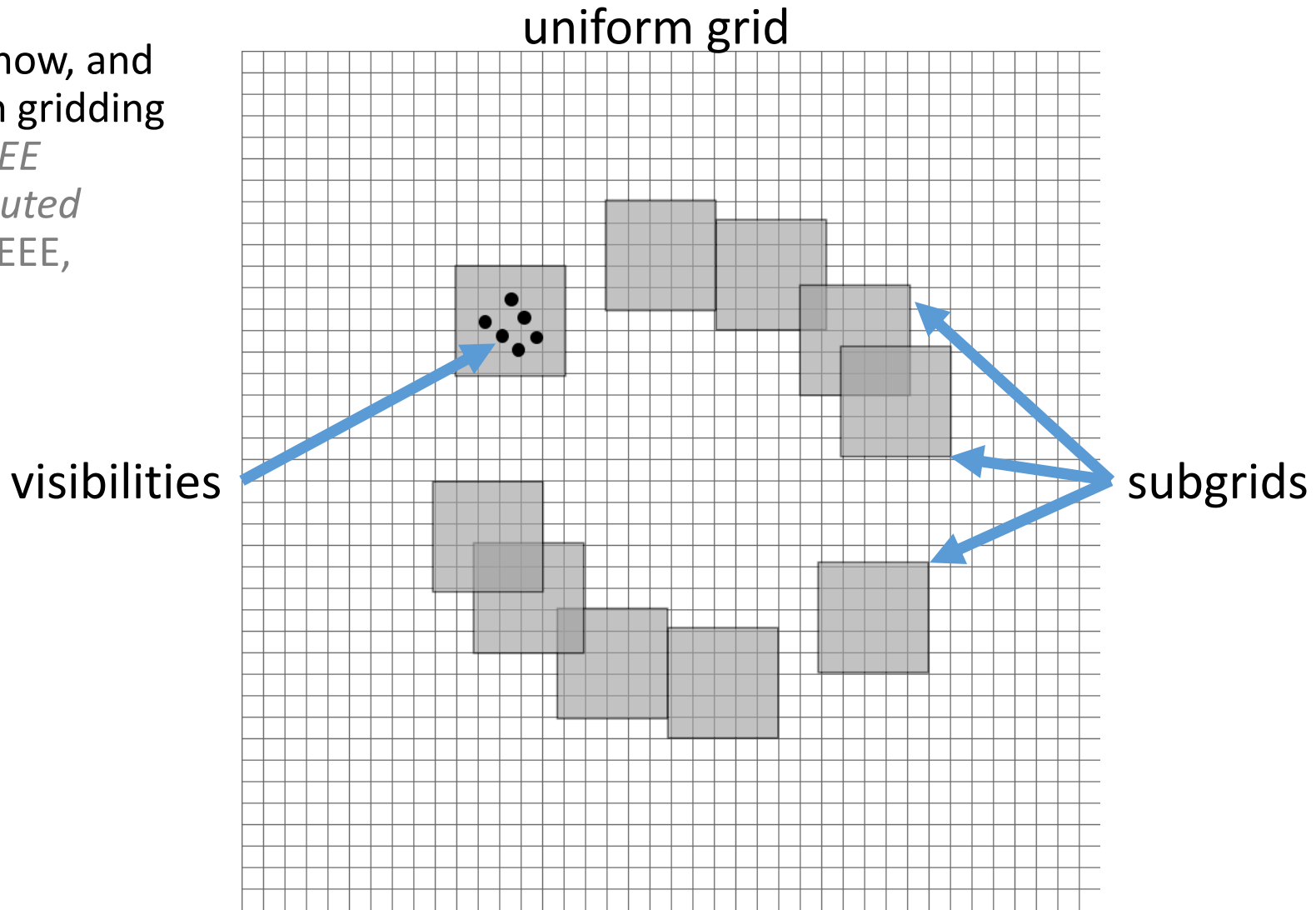
Distributed gridding and deconvolution

- Implementation: .netcore (C#)
- MPI for node communication
- Hardware: 4 Linux nodes, 1 CPU each
- Speedup on 1GB LMC MeerKAT observation

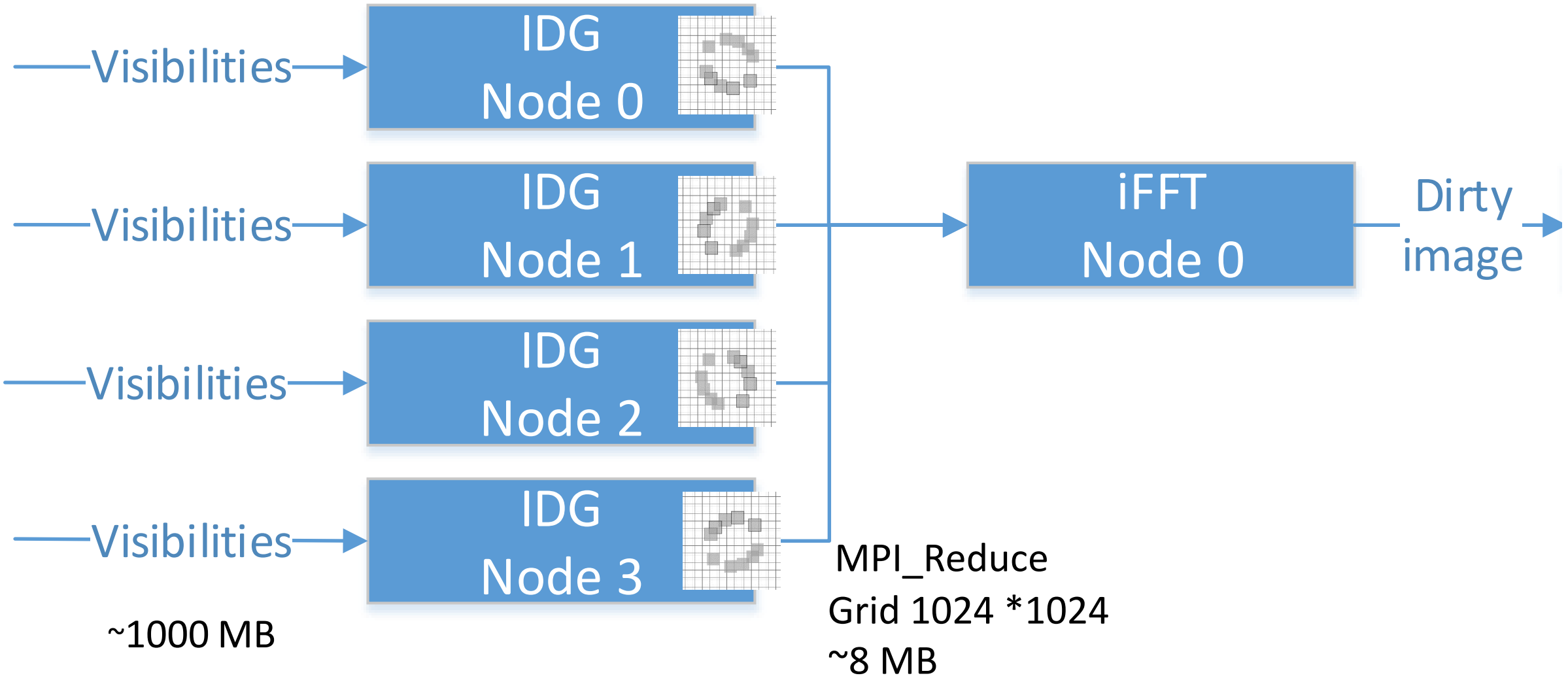
Preliminary results and algorithms

Image Domain Gridding (IDG)

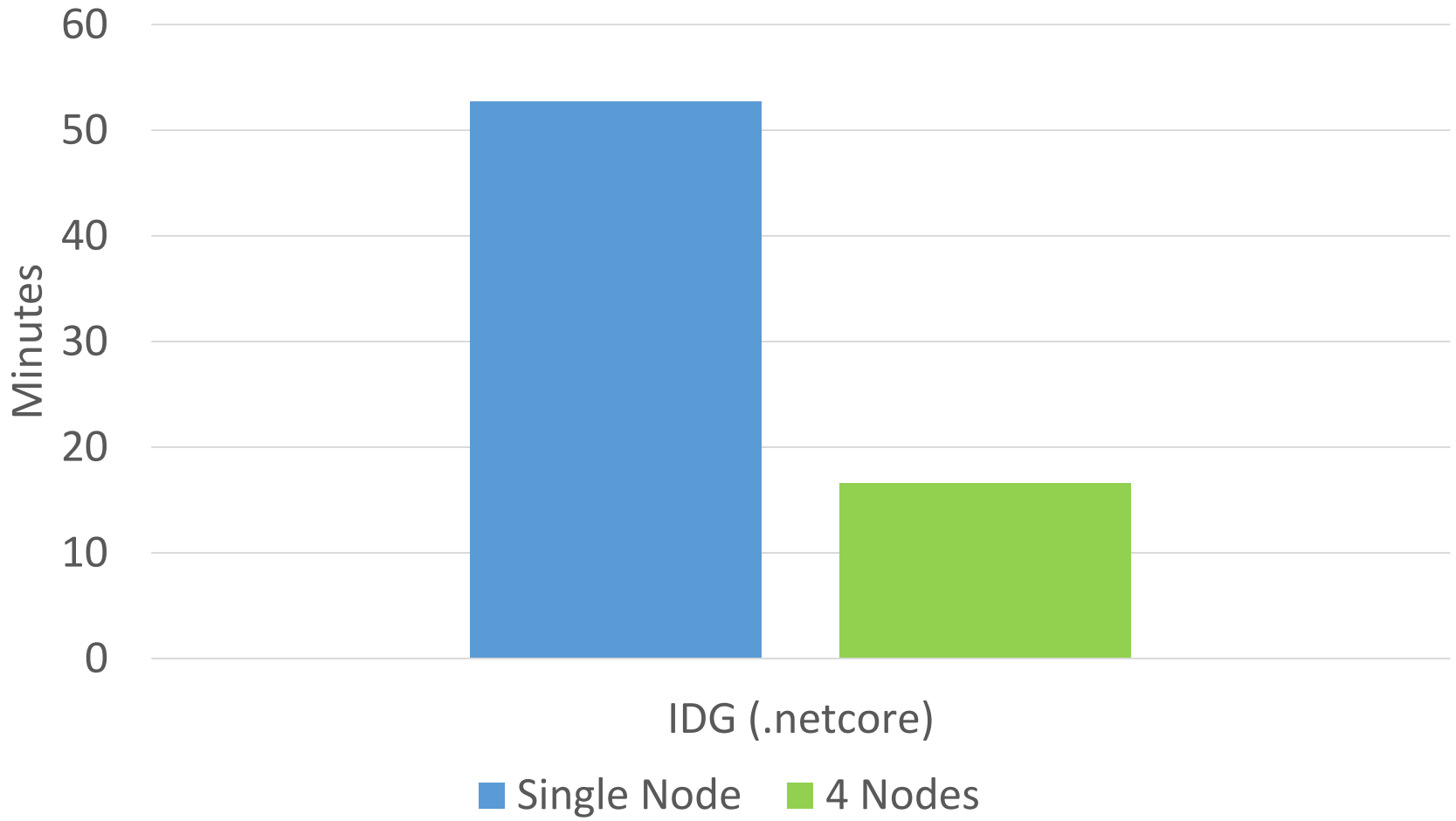
Veenboer, Bram, Matthias Petschow, and John W. Romein. "Image-Domain gridding on graphics processors." *2017 IEEE International Parallel and Distributed Processing Symposium (IPDPS)*. IEEE, 2017.



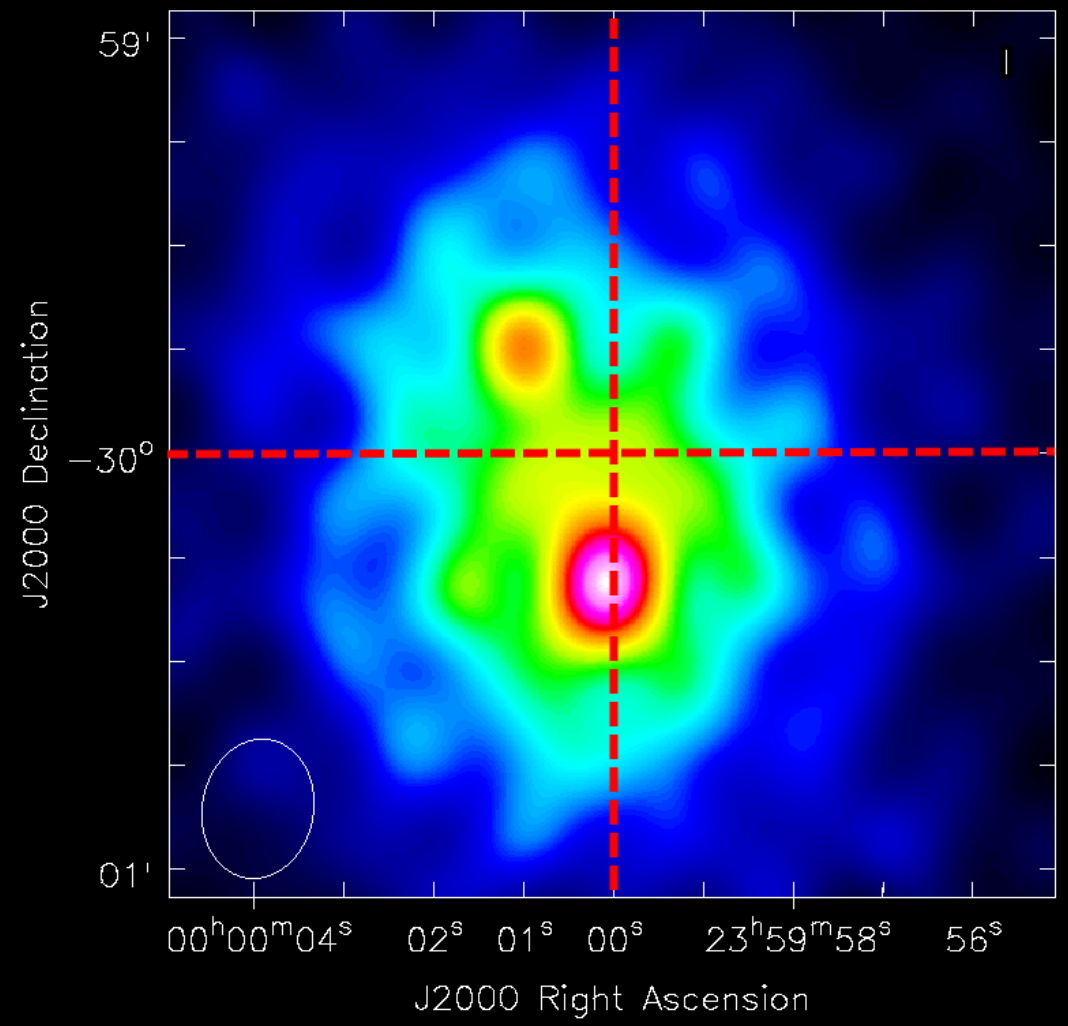
Distributed gridding

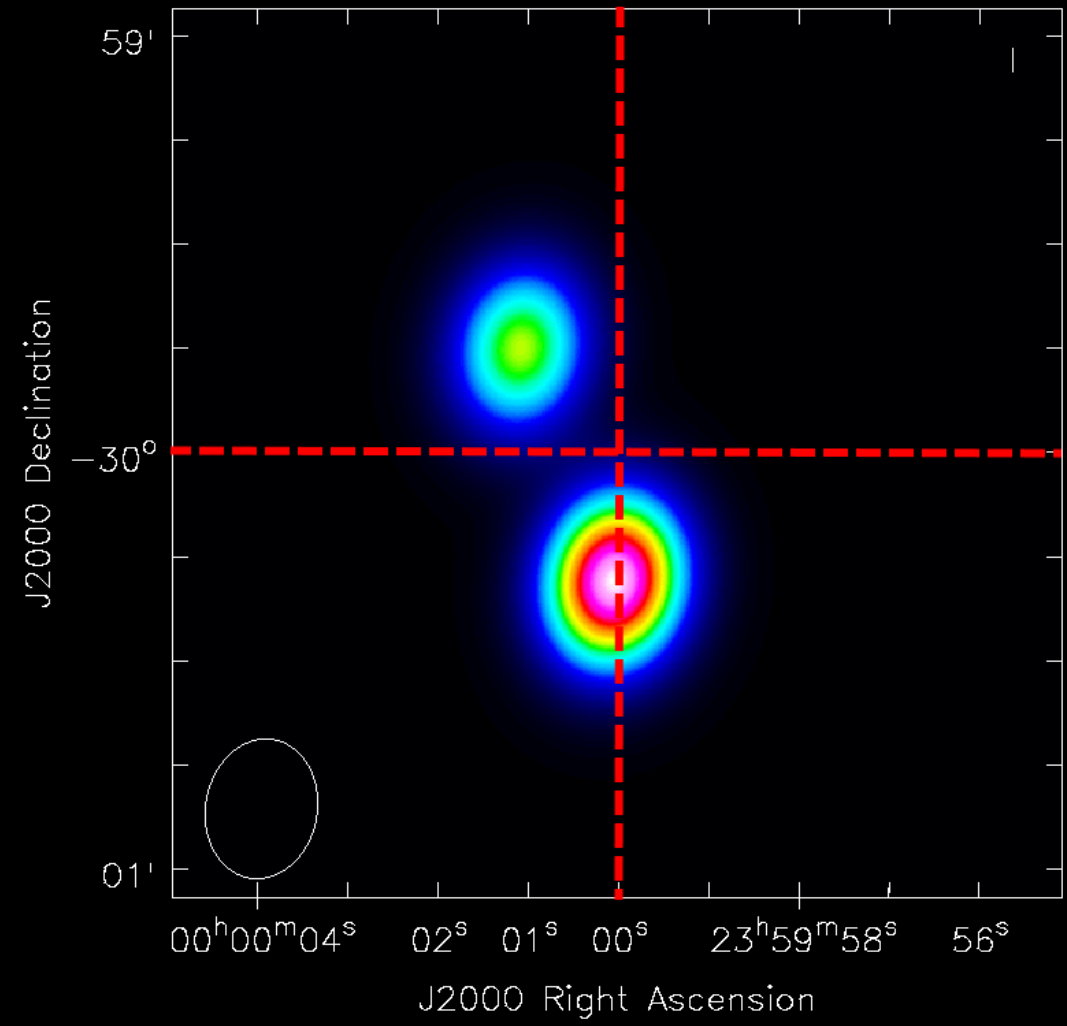


Distributed gridding



Distributed deconvolution





Methods for distributed deconvolution

- ADMM methods in Radio Astronomy
  - Ferrari, André, et al. "Distributed image reconstruction for very large arrays in radio astronomy." *2014 IEEE 8th Sensor Array and Multichannel Signal Processing Workshop (SAM)*. IEEE, 2014.
  - Carrillo, Rafael E., Jason D. McEwen, and Yves Wiaux. "PURIFY: a new approach to radio-interferometric imaging." *Monthly Notices of the Royal Astronomical Society* 439.4 (2014): 3591-3604.
  - …

- Coordinate Descent methods in Signal Processing
  - Fercoq, Olivier, et al. "Fast distributed coordinate descent for non-strongly convex losses." *2014 IEEE International Workshop on Machine Learning for Signal Processing (MLSP)*. IEEE, 2014.
  - Felix, Simon, Roman Bolzern, and Marina Battaglia. "A compressed sensing-based image reconstruction algorithm for solar flare X-ray observations." *The Astrophysical Journal*849.1 (2017): 10.
  - …

Coordinate Descent deconvolution

$$residuals = dirty\ image$$

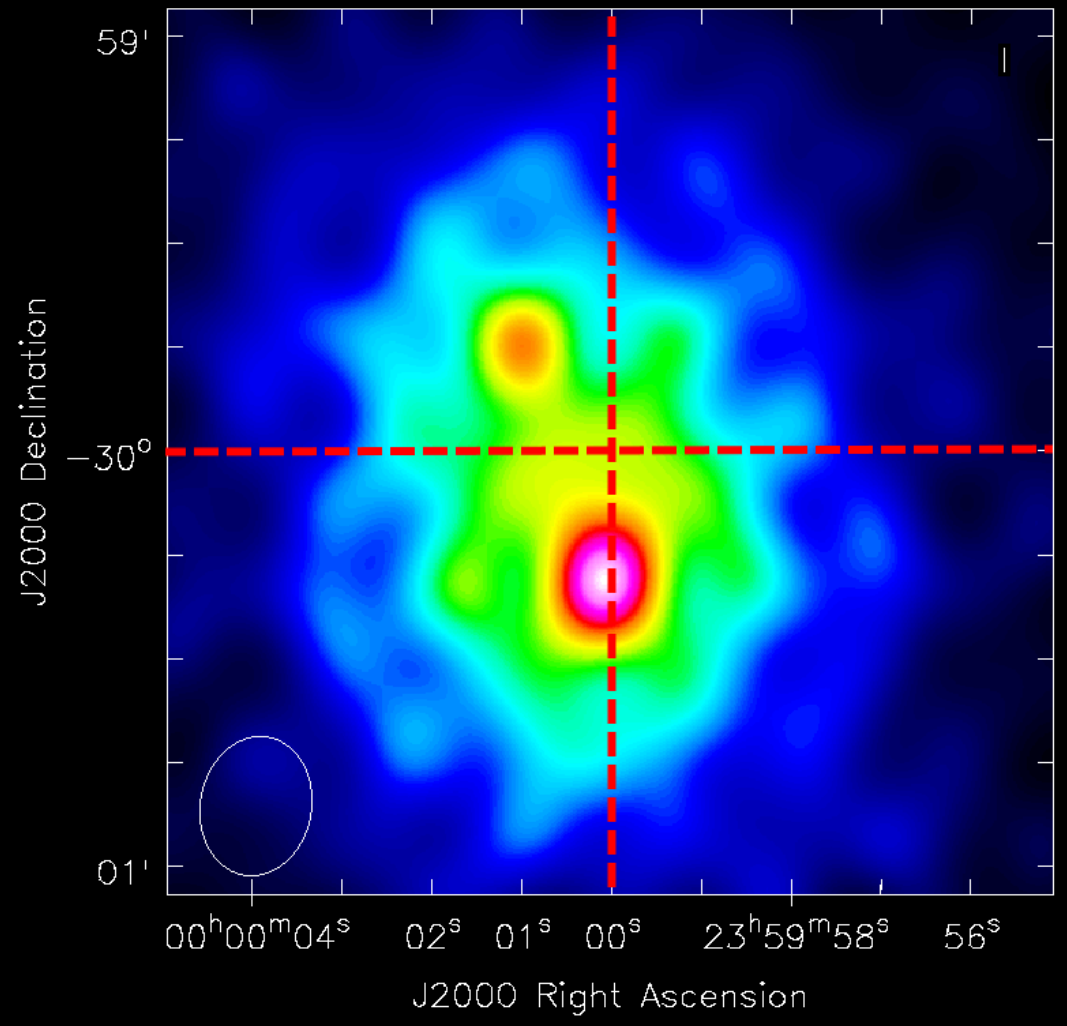
1. Search pixel with the value that can be modified the most (optimum of a parabola)
2. Optimize maximum pixel
3. Update *residuals*
4. Repeat until *residuals* are small

More sophisticated CD methods, but that is the core algorithm

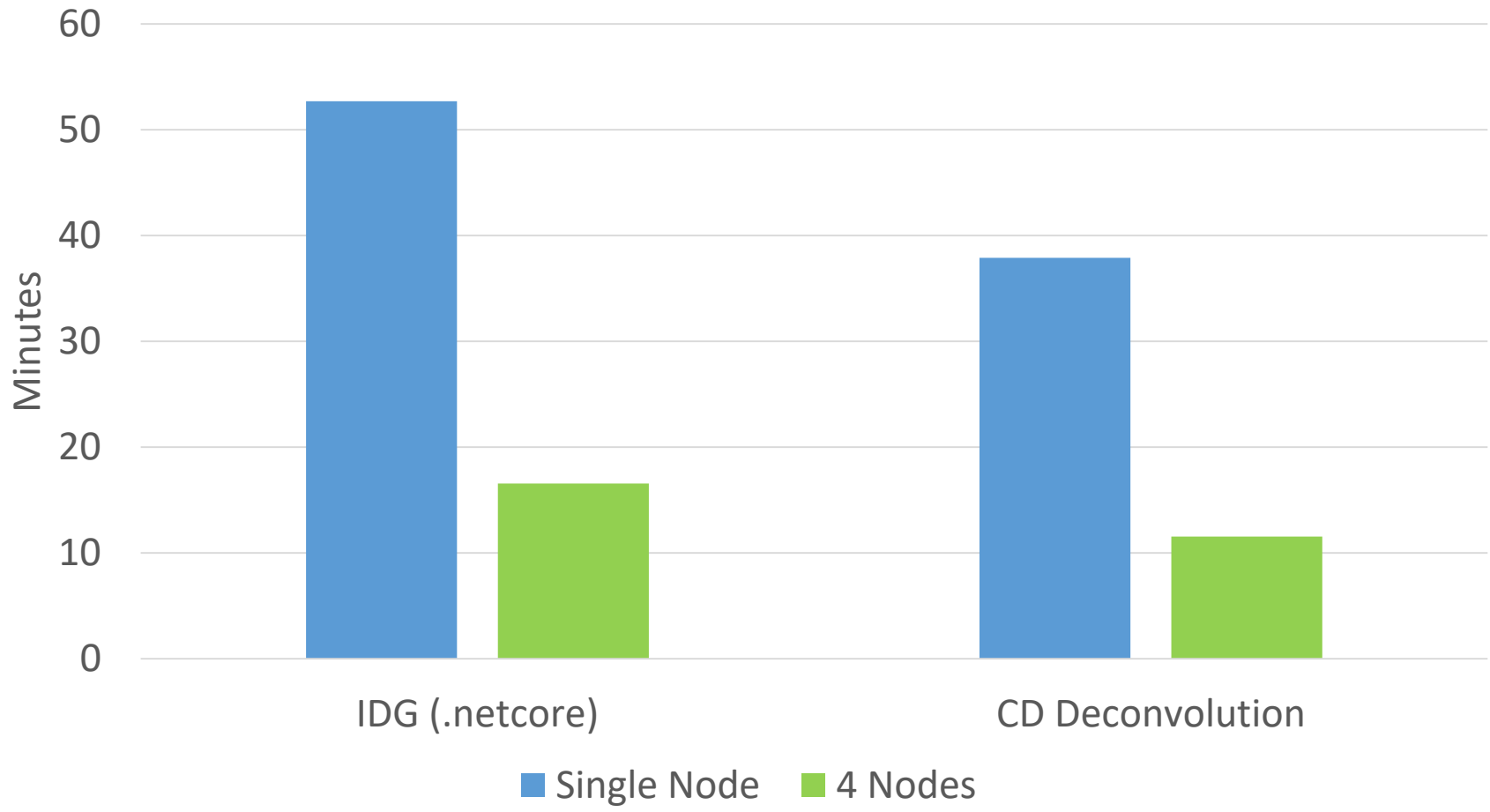
Distributed Coordinate Descent deconvolution

Distributed CD:

1. Search local pixel with the value that can be modified the most
2. Find best global pixel (MPI_ReduceAll)
3. Update local residuals
4. Repeat



Distributed Coordinate Descent



Baseline distributed gridding + deconvolution

- Distributed gridding: More effective with a lot of input data
- Distributed deconvolution:
  - We have more communication efficient CD methods to explore:
    - Shotgun
    - PCDM
    - Hydra
    - …
  - CD on the GPU: McGaffin, Madison Gray, and Jeffrey A. Fessler. "Edge-preserving image denoising via group coordinate descent on the GPU." *IEEE Transactions on Image Processing* 24.4 (2015): 1273-1281.

Questions