Introduction to Parallel Computing (CMSC498X / CMSC818X)

Lecture 3: Writing Parallel Programs

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Announcements

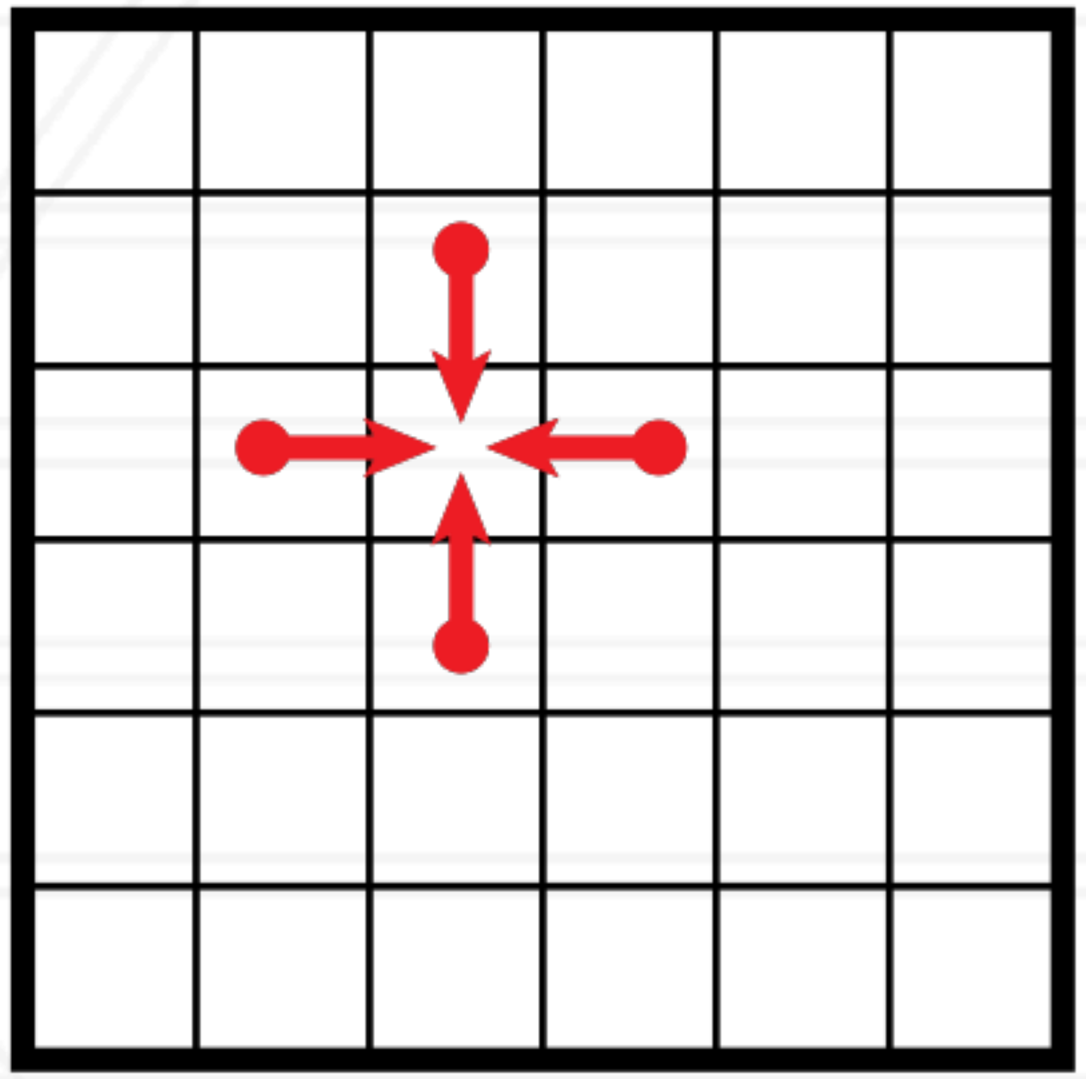
- Deepthought2 (dt2) accounts have been mailed to everyone
- If you want to use your own account, read the Piazza post and follow instructions

Writing parallel programs

- Decide the serial algorithm first
- Data: how to distribute data among threads/processes?
  - Data locality: assignment of data to specific processes to minimize data movement
- Computation: how to divide work among threads/processes?
- Figure out how often communication will be needed

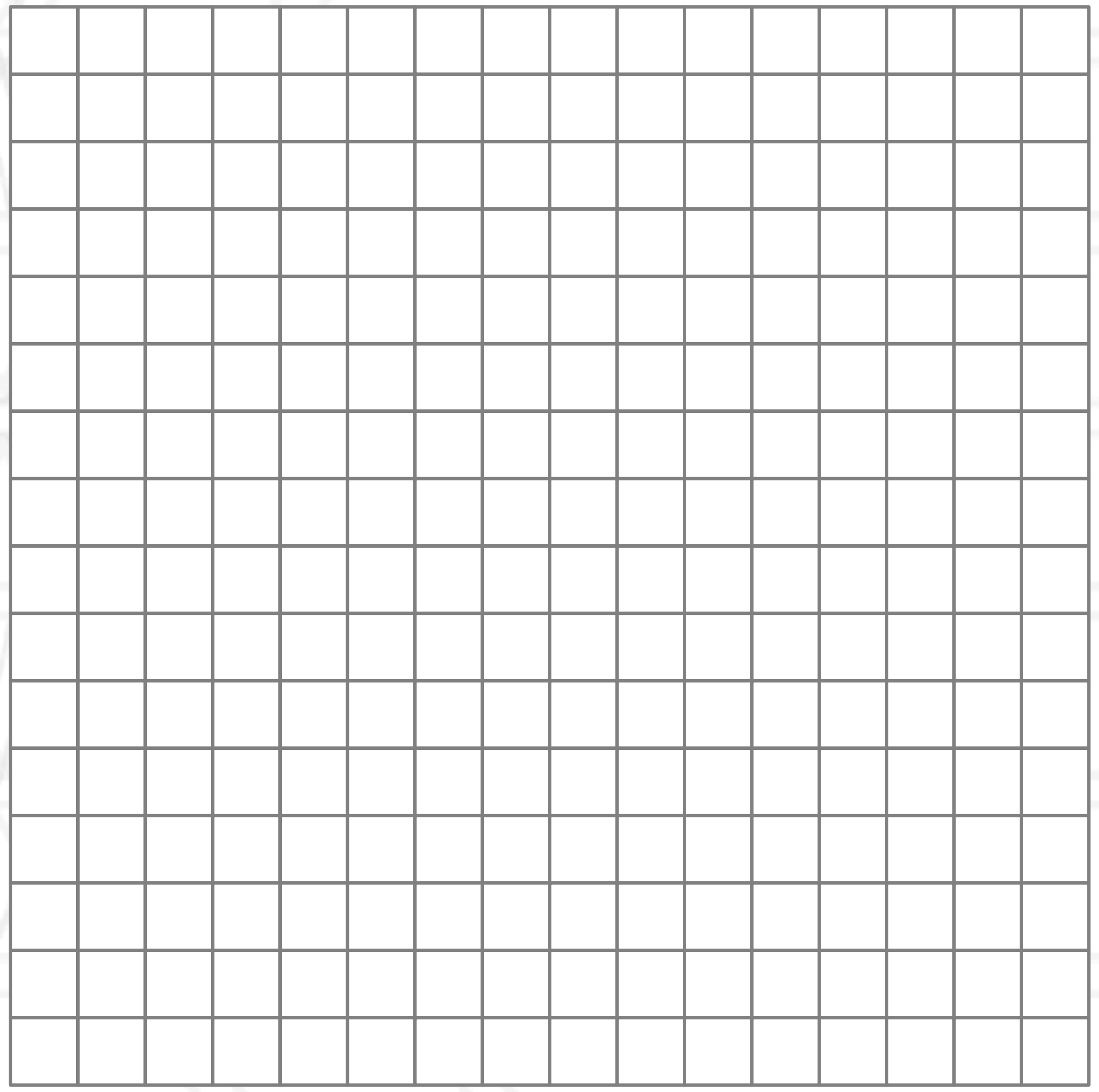
Two-dimensional stencil computation

- Commonly found kernel in computational codes
- Heat diffusion, Jacobi method, Gauss-Seidel method



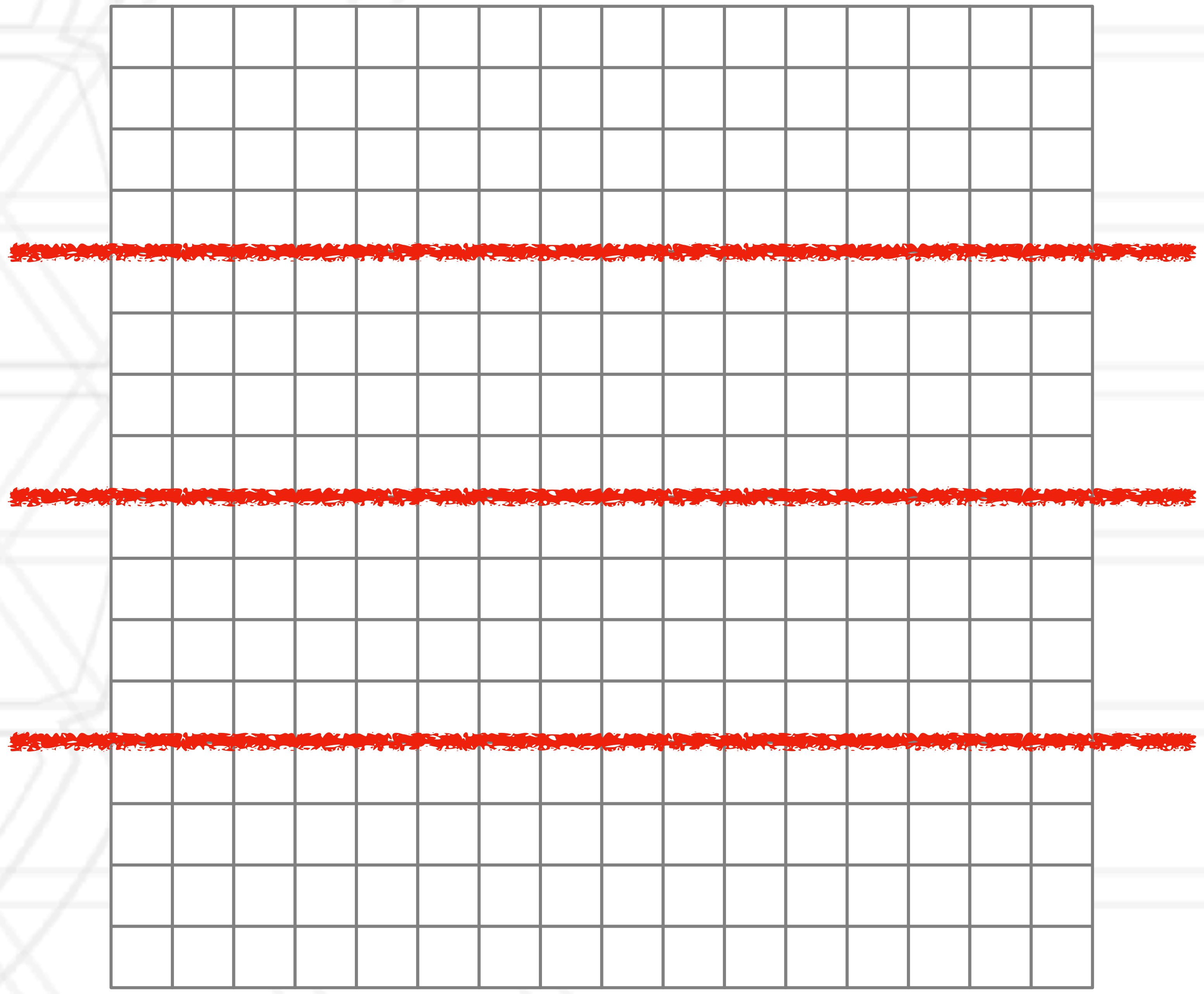
$$A[i,j] = \frac{A[i,j] + A[i-1,j] + A[i+1,j] + A[i,j-1] + A[i,j+1]}{5}$$

2D stencil iteration in parallel



2D stencil iteration in parallel

- 1D decomposition
  - Divide rows (or columns) among processes



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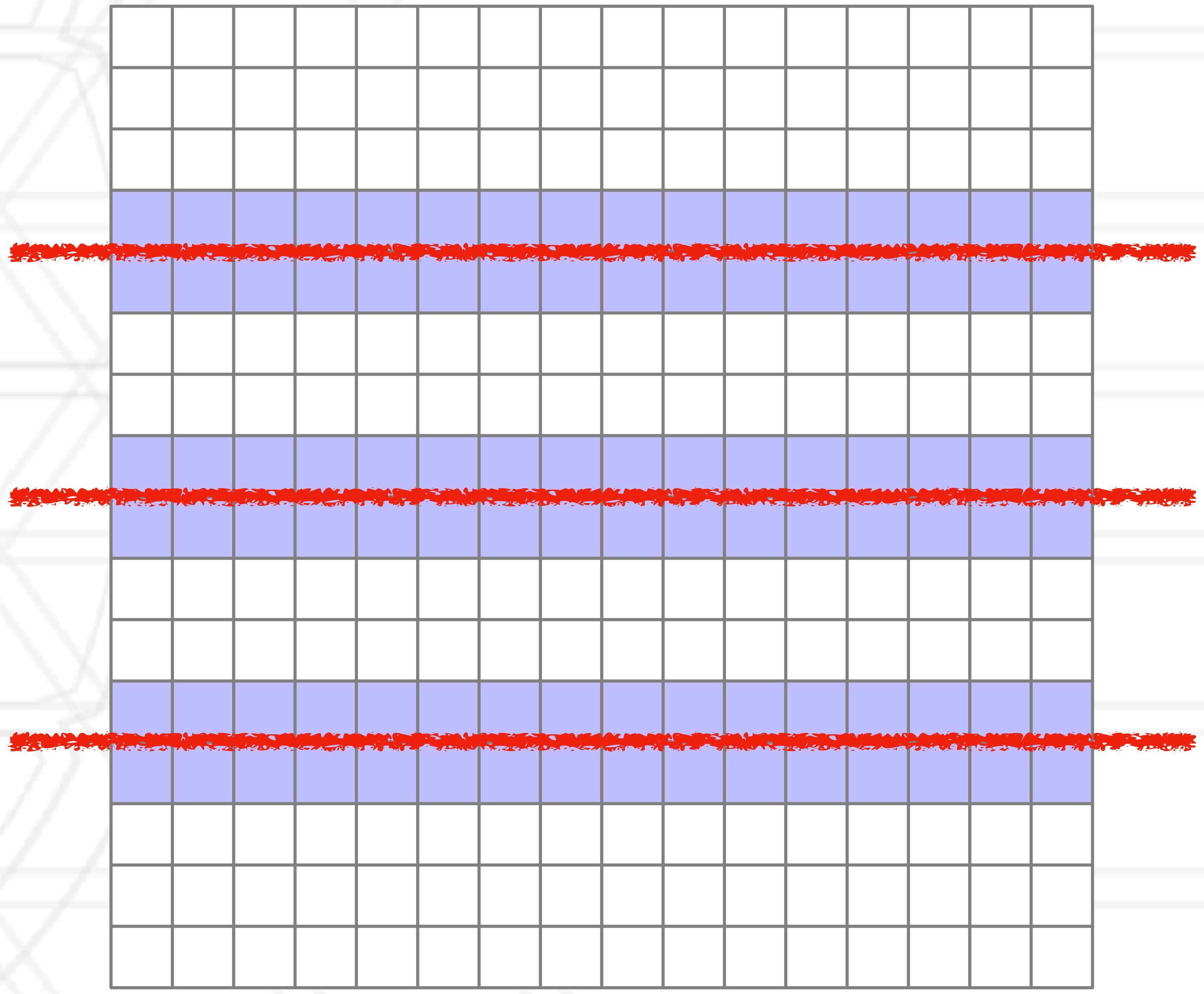

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- 1D decomposition
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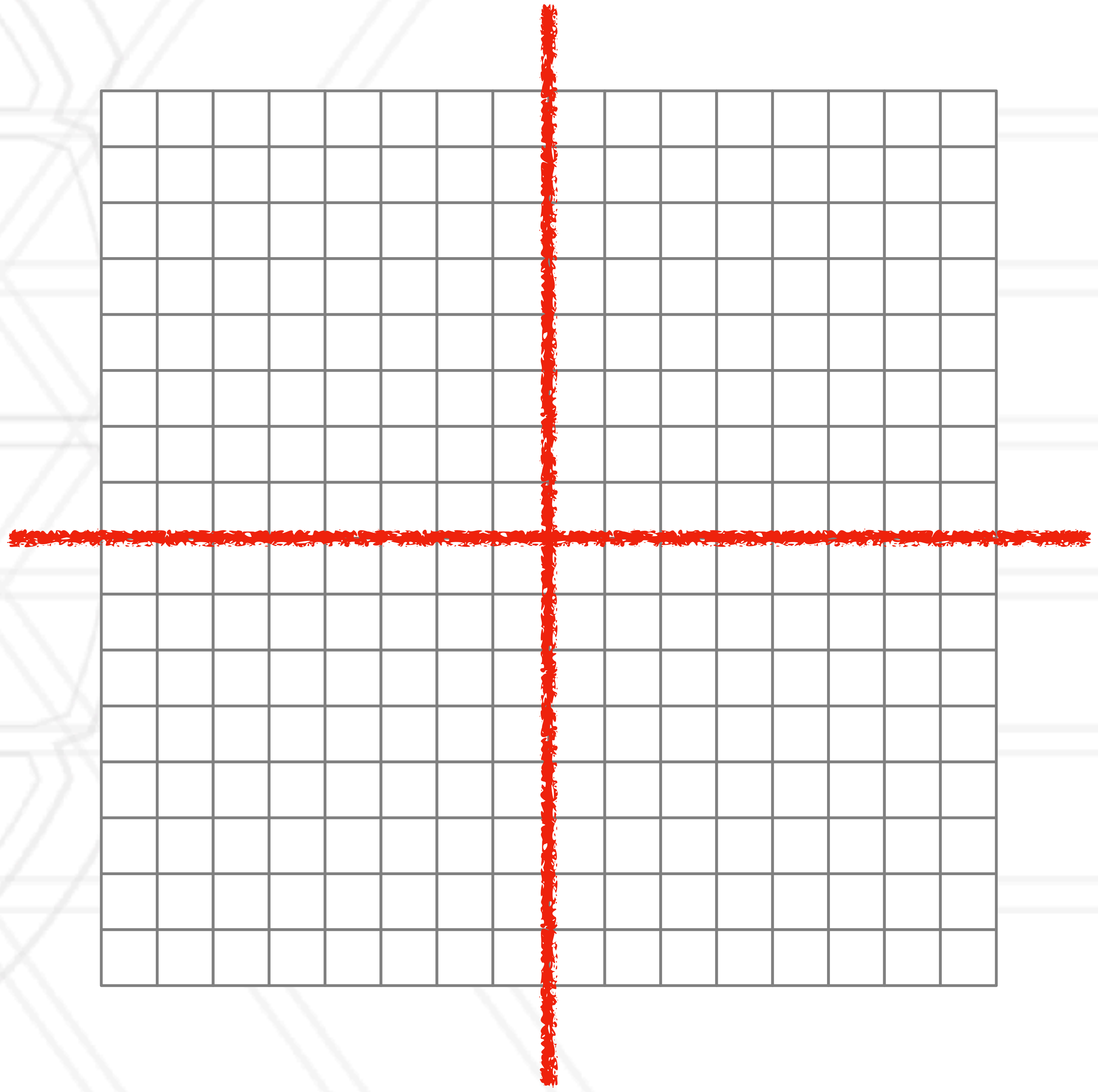
- 2D decomposition
  - Divide both rows and columns (2d blocks) among processes



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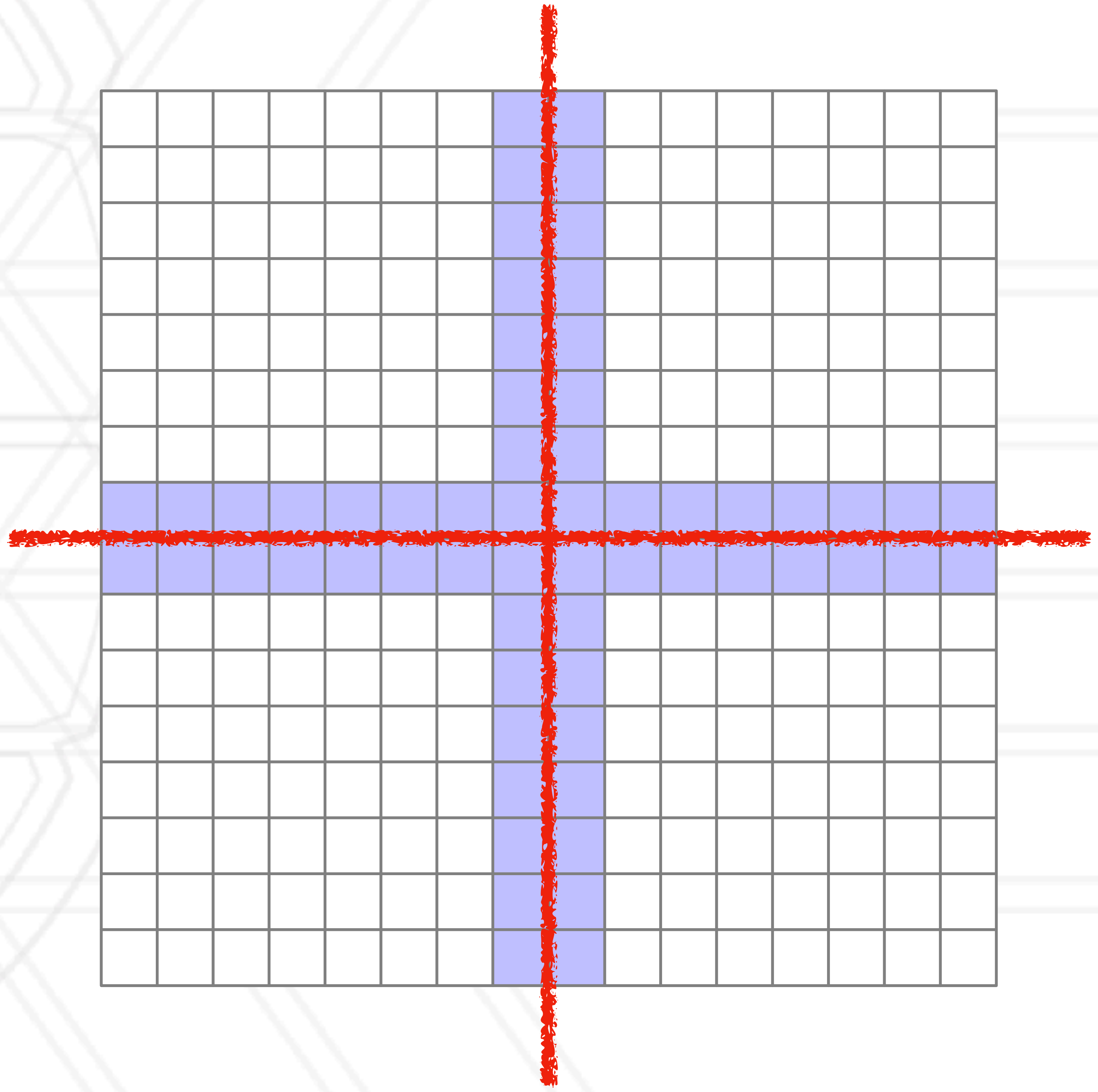
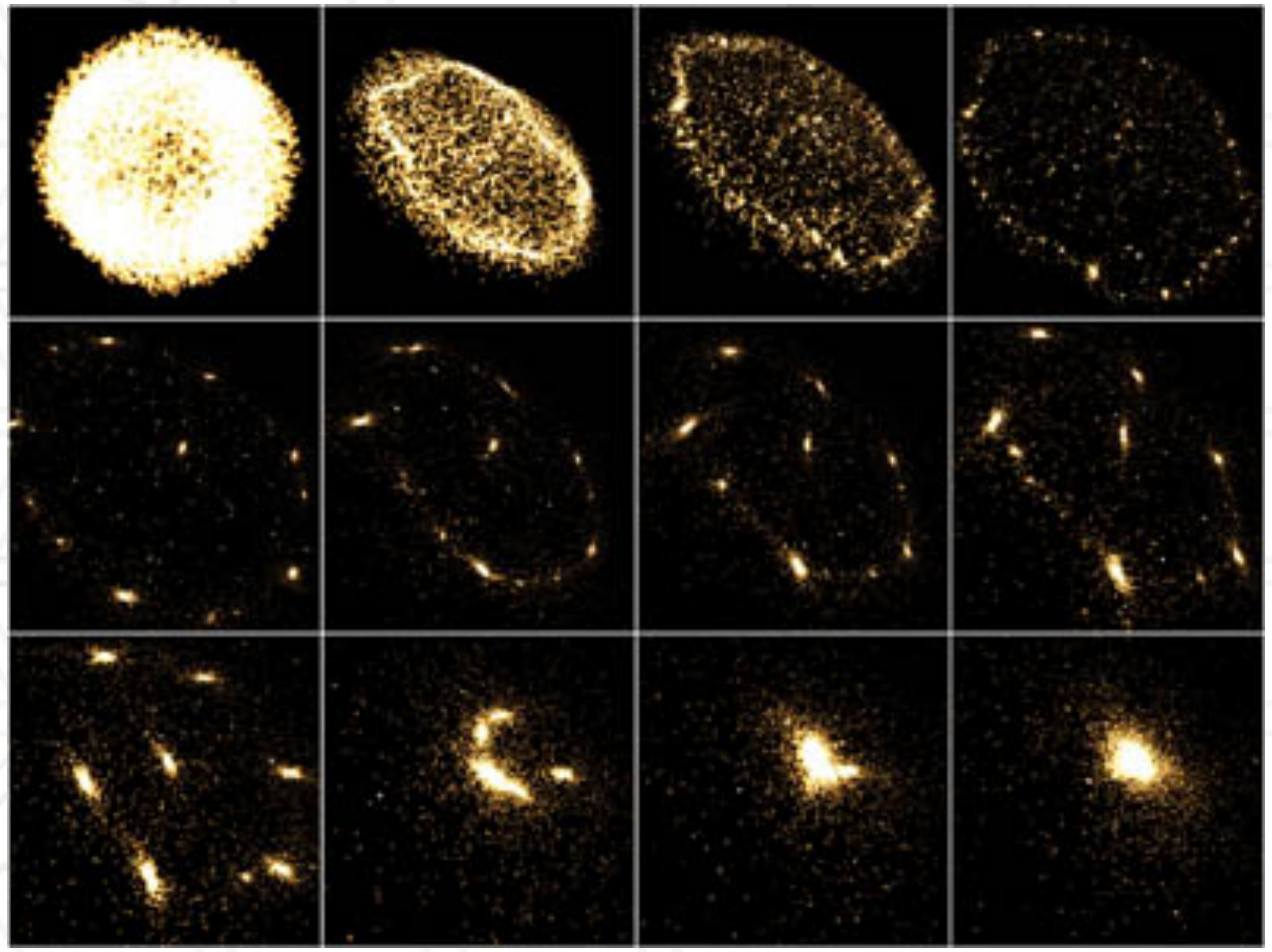


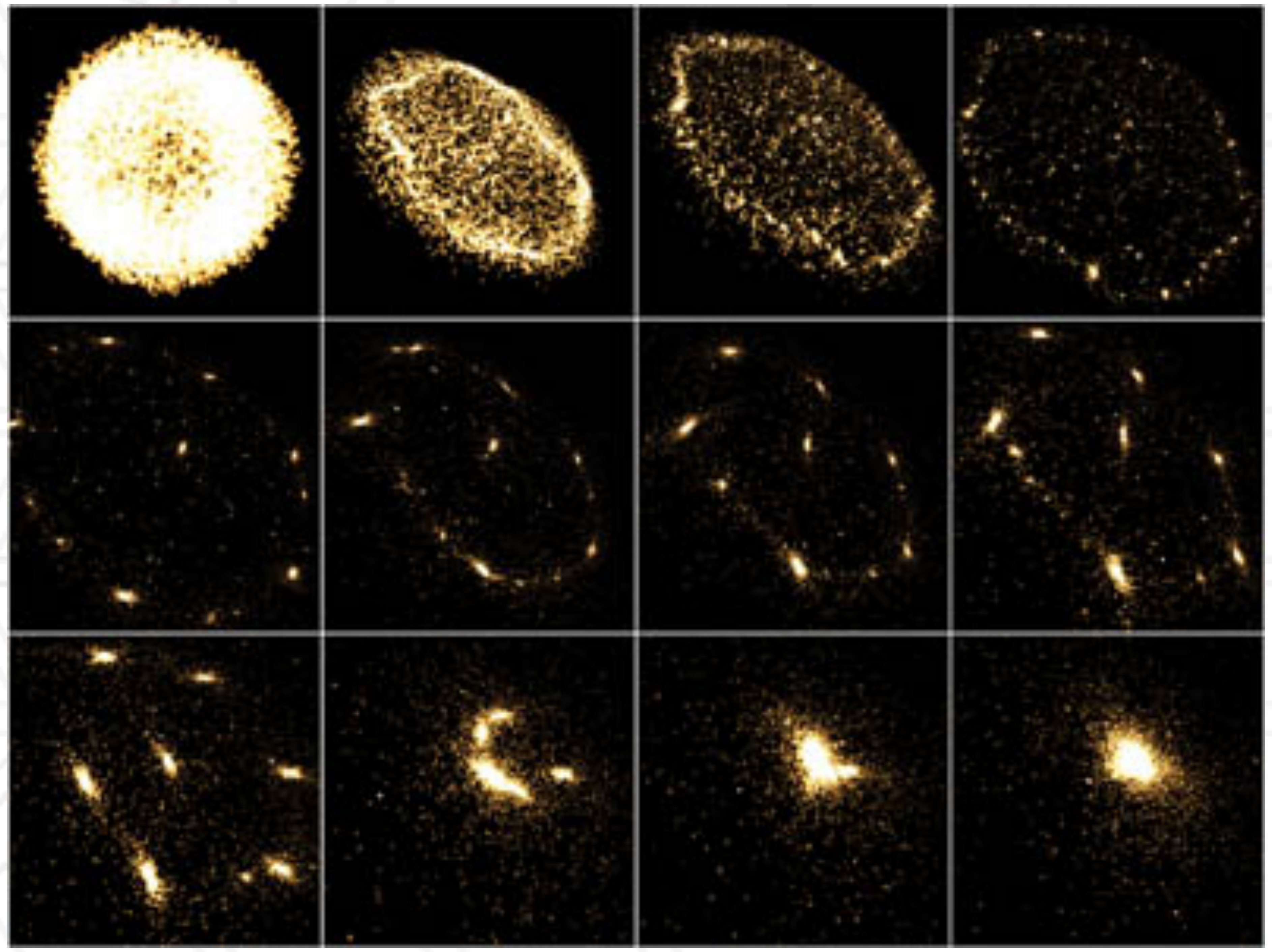
N-body problem



https://developer.nvidia.com/gpugems/gpugems3/part-v-physics-simulation/chapter-31-fast-n-body-simulation-cuda

N-body problem

- Simulating the movement of N-bodies under gravitational forces



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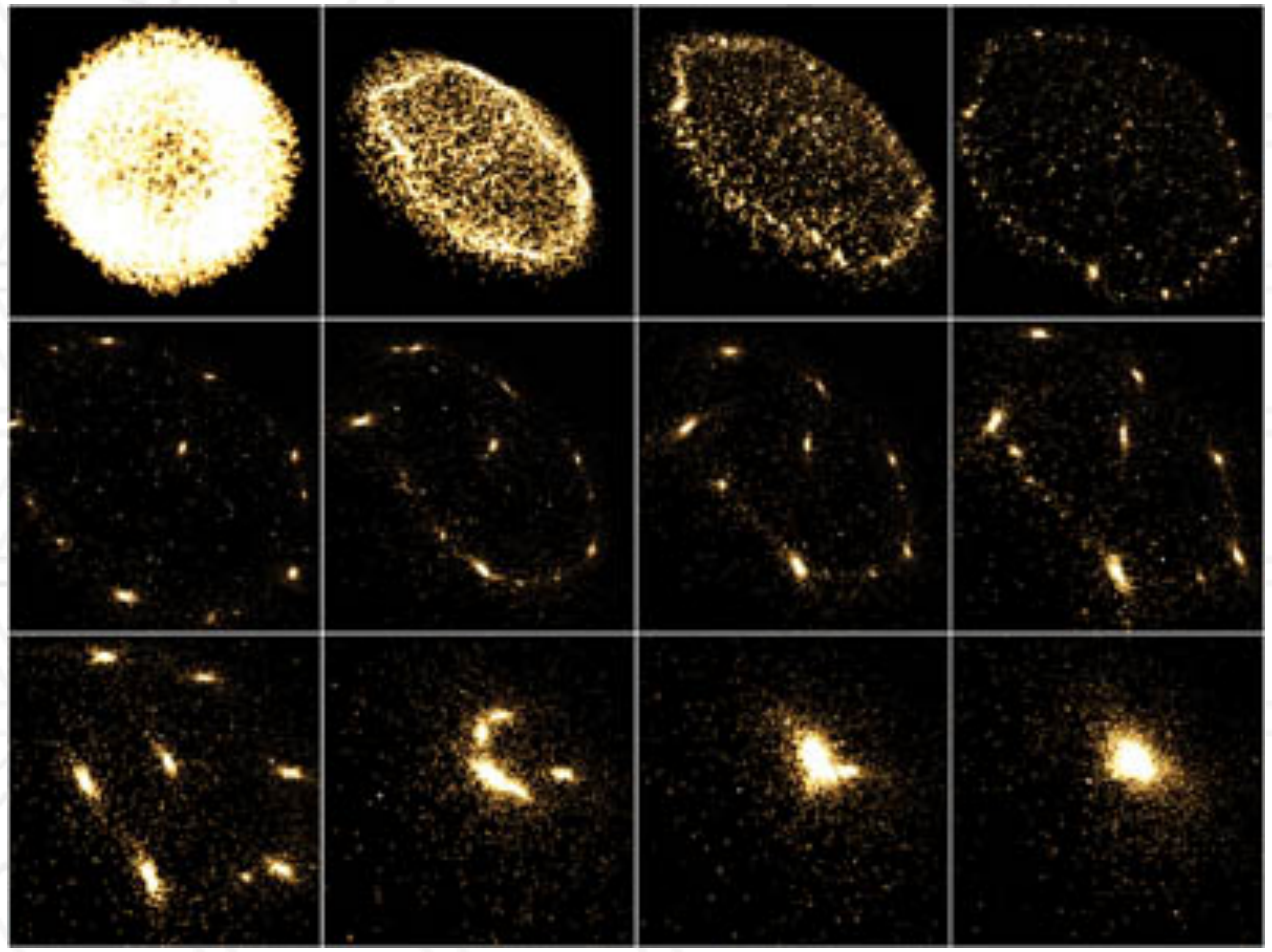
N-body problem

- Simulating the movement of N-bodies under gravitational forces
- Naive algorithm: O(n^2)
  - Every body calculates forces pair-wise with every other body (particle)



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Data distribution in N-body problems

- Naive approach: Assign n/k particles to each process
- Other approaches?

http://datagenetics.com/blog/march22013/

https://en.wikipedia.org/wiki/Z-order_curve

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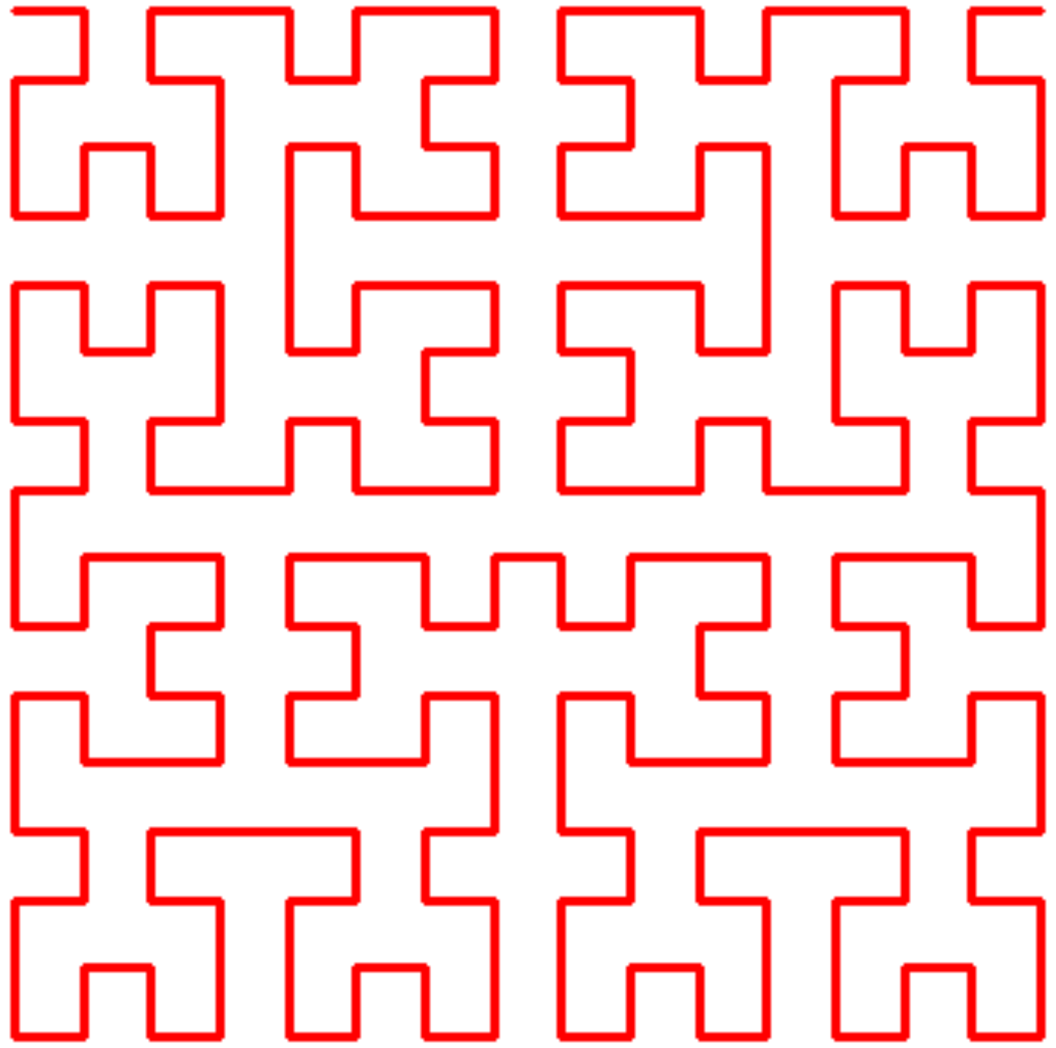

Space-filling curves

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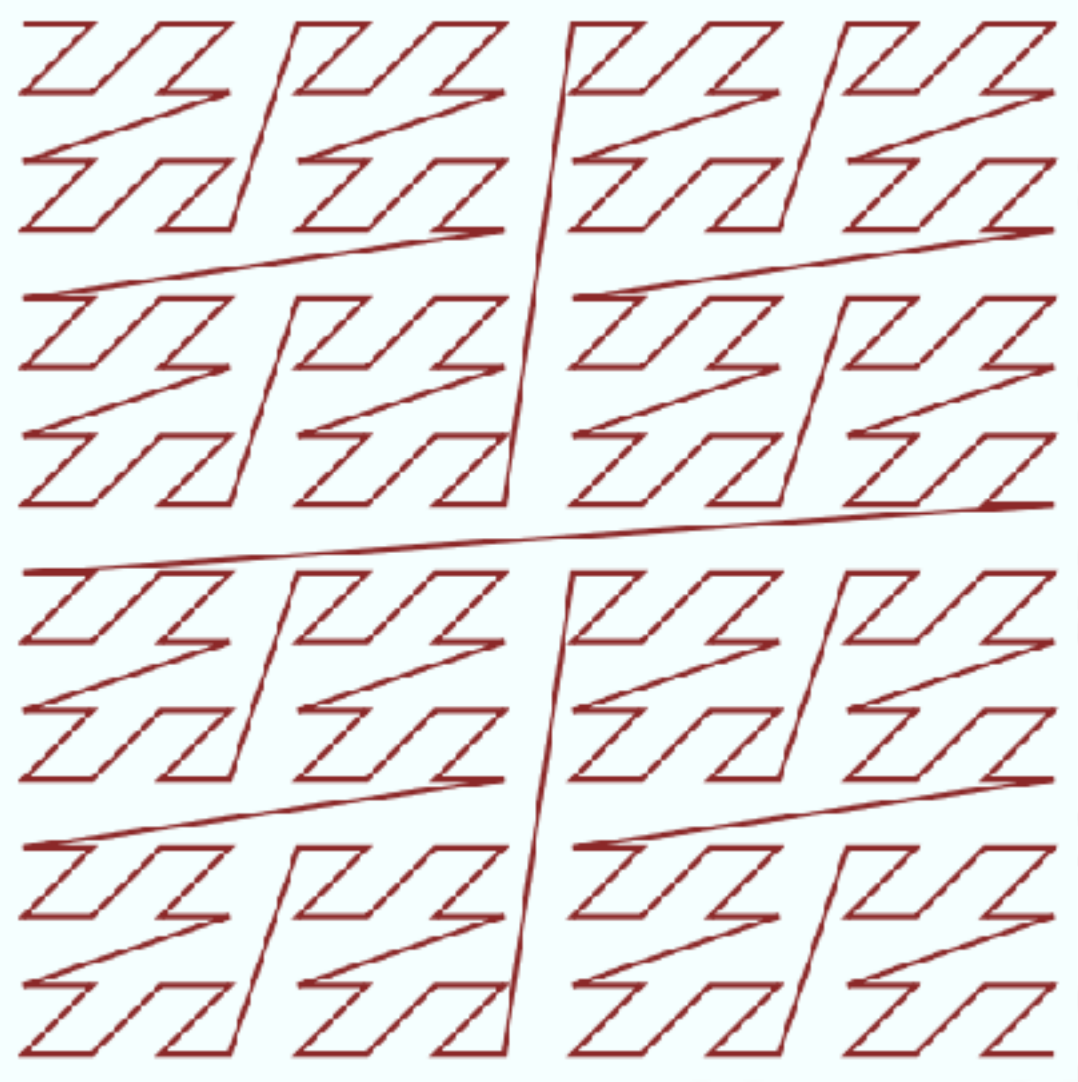

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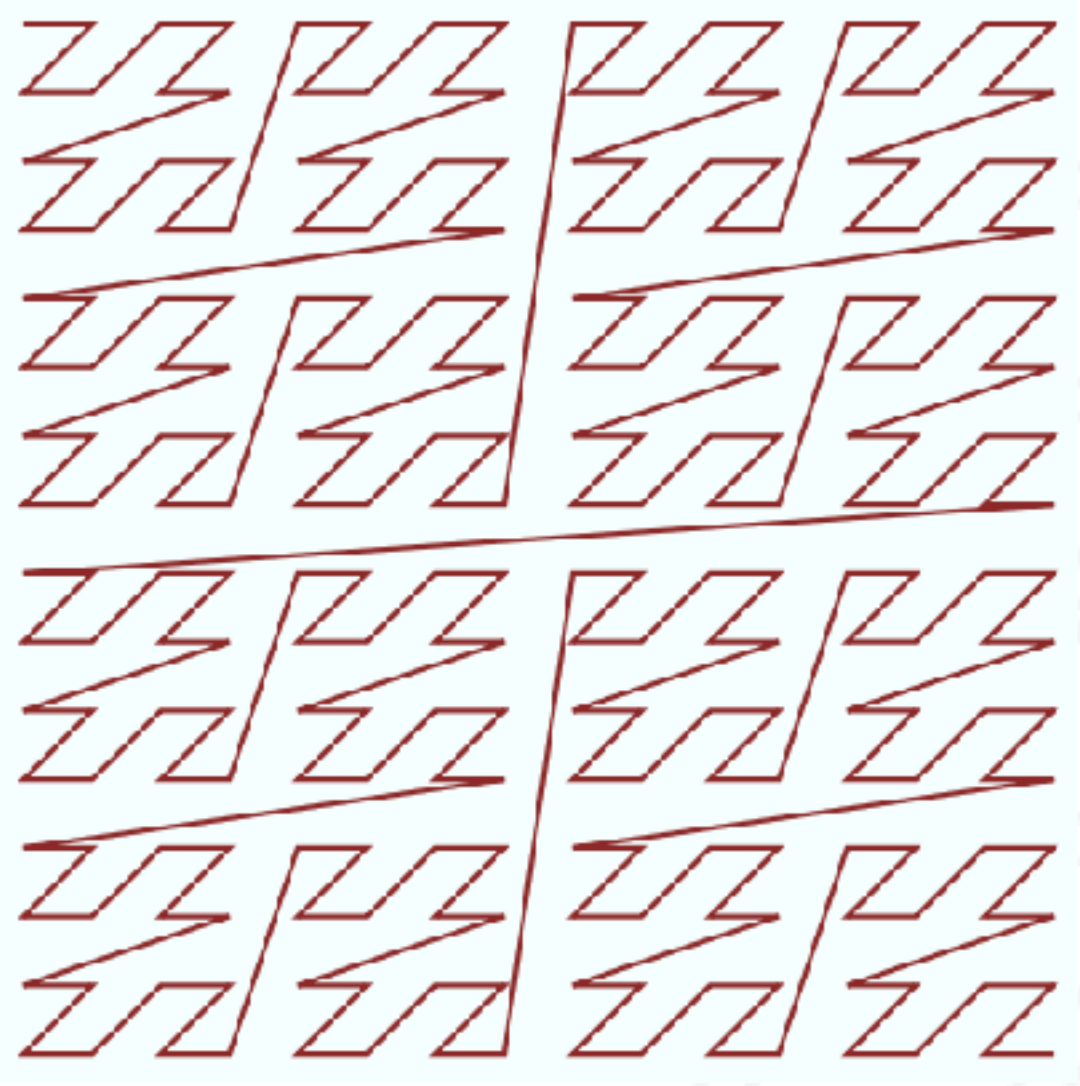

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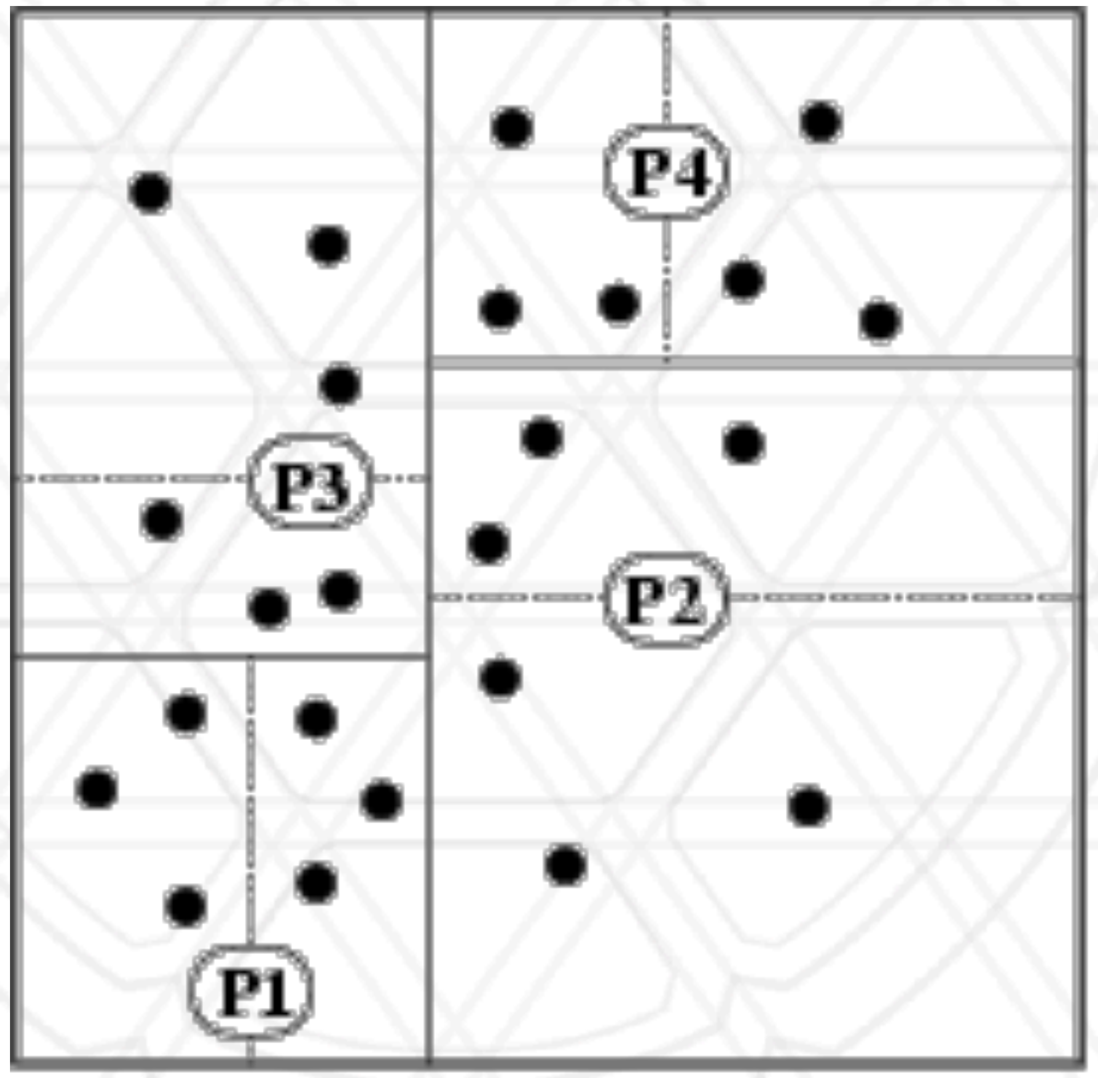
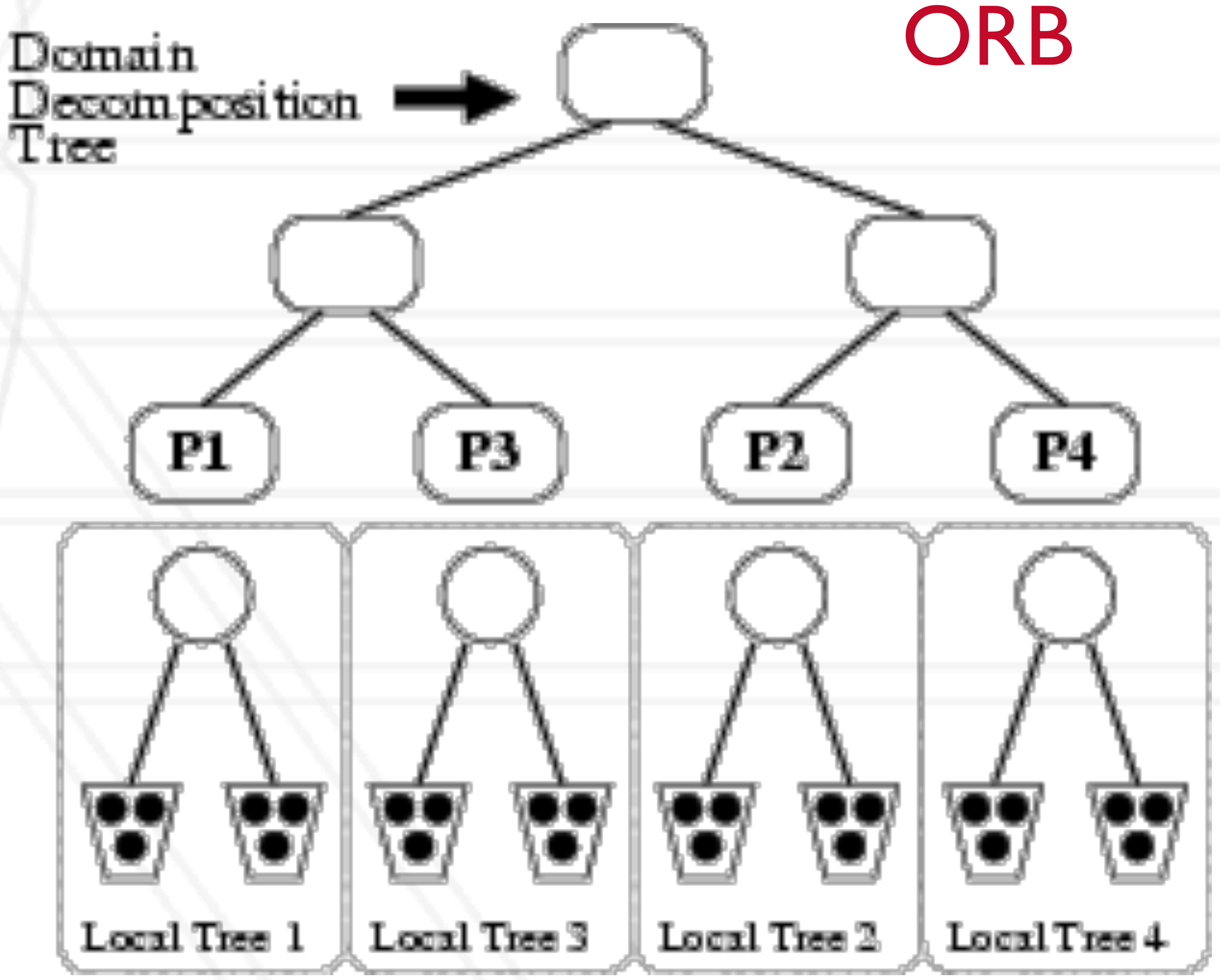


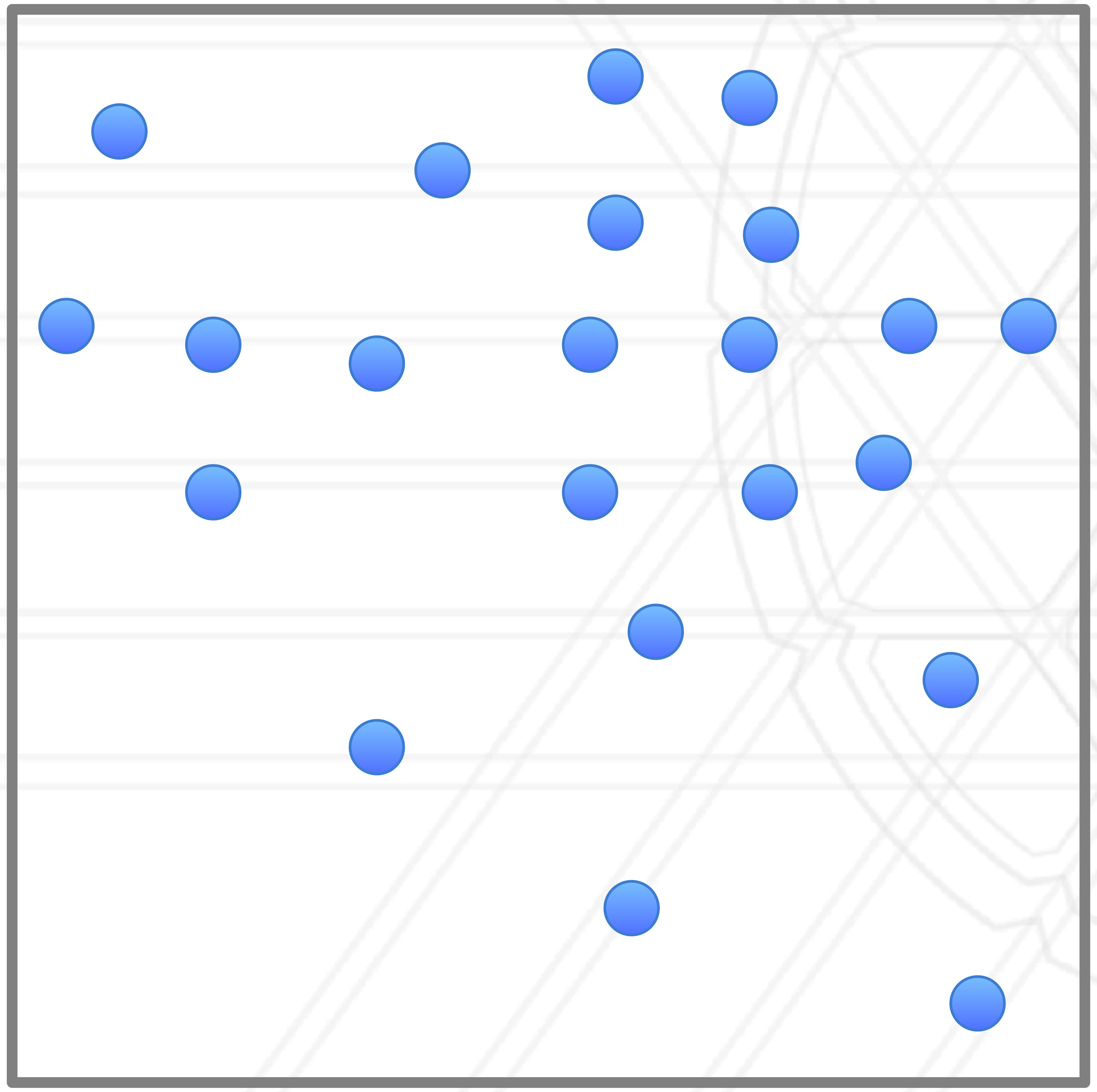


ORB

http://charm.cs.uiuc.edu/workshops/charmWorkshop2011/slides/CharmWorkshop2011_apps_ChaNGa.pdf

Data distribution in N-body problems

- Let us consider a two-dimensional space with bodies/particles in it



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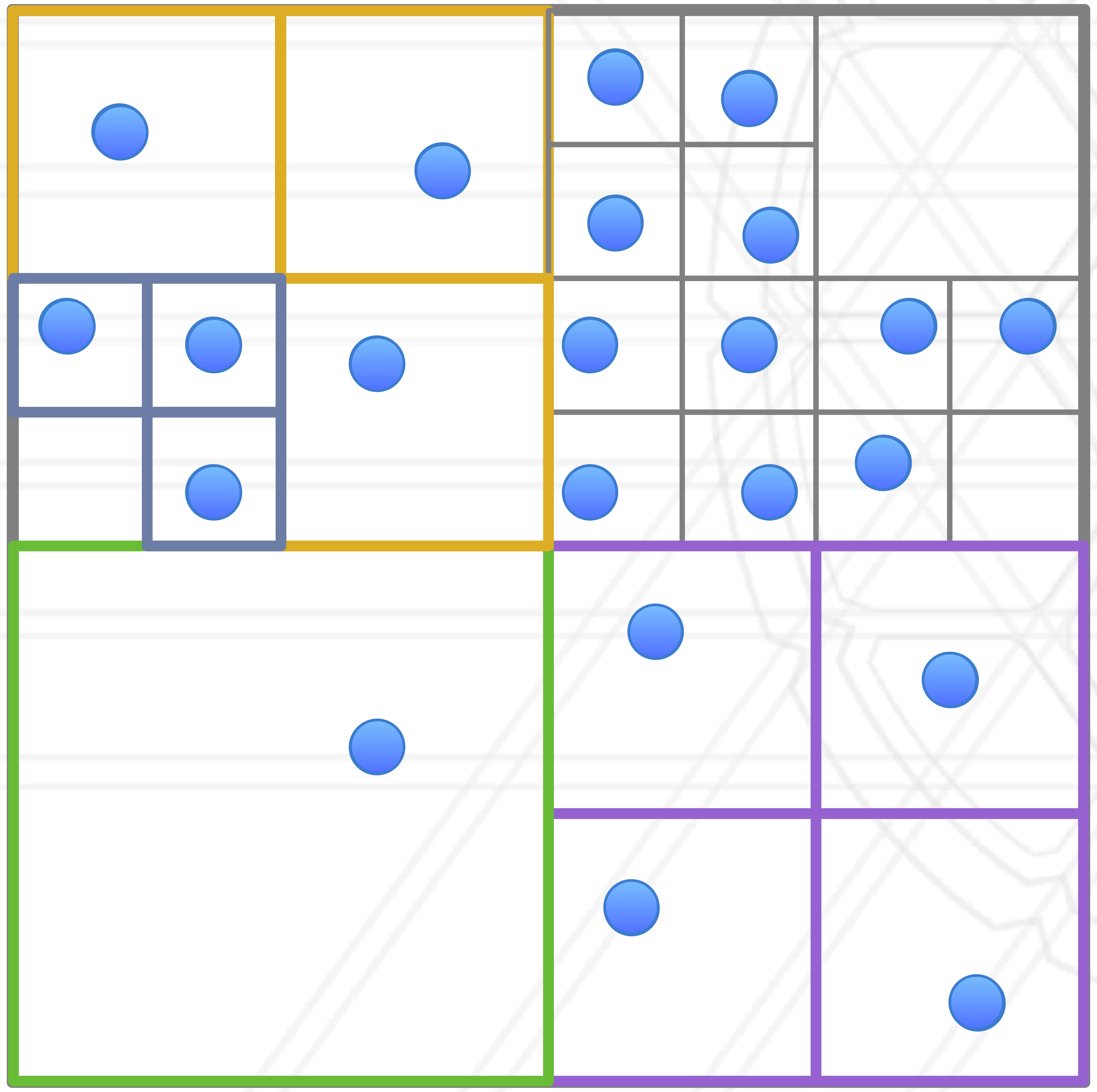

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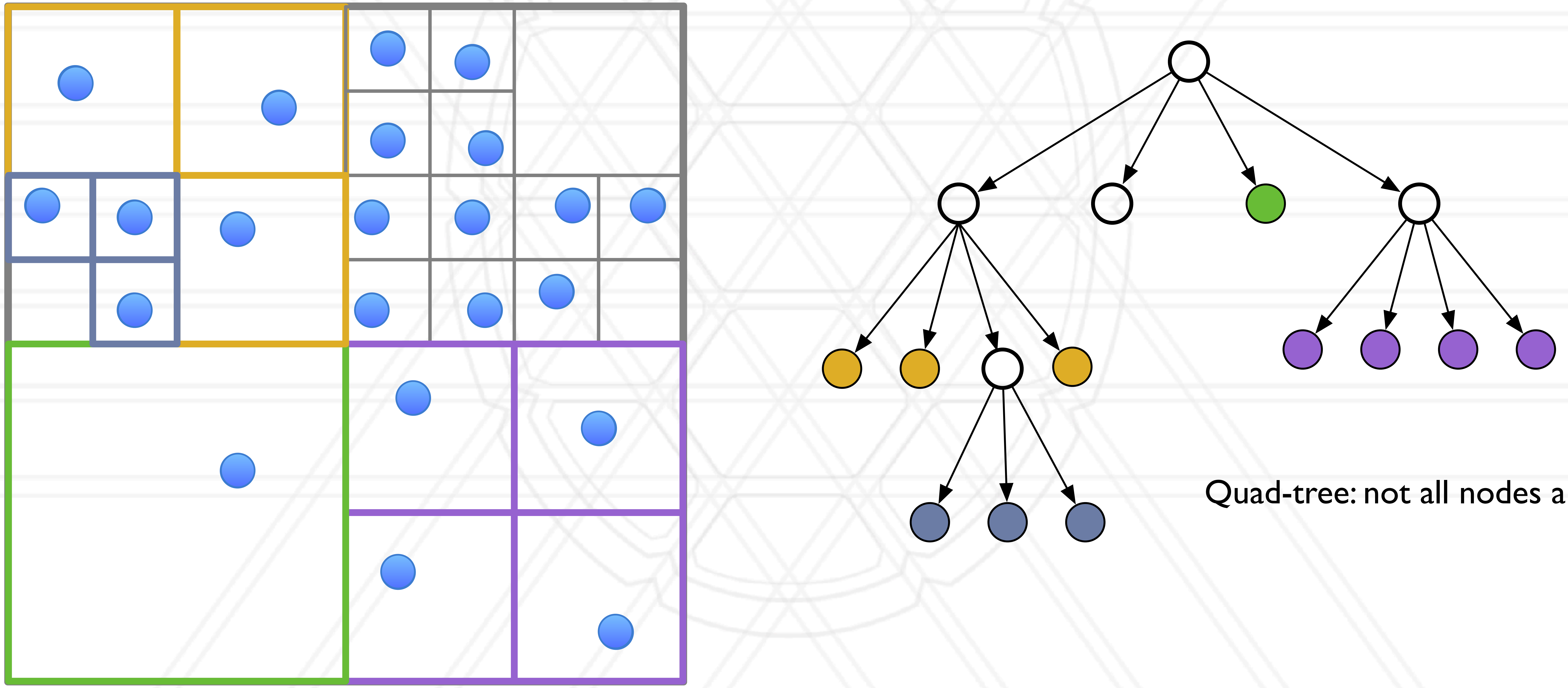

Quad-tree: not all nodes are shown

Load balance and grain size

- Load balance: try to balance the amount of work (computation) assigned to different threads/ processes
  - Bring ratio of maximum to average load as close to 1 as possible
  - Secondary consideration: also load balance amount of communication
- Grain size: ratio of computation-to-communication
  - Coarse-grained (more computation) vs. fine-grained (more communication)

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