Radiative transfer with SimpleX

Photon transport on irregular grids

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Context

Radiation hydrodynamics to understand:

- Interacting stellar wind zones
- Re-ionization
- LBV eruptions

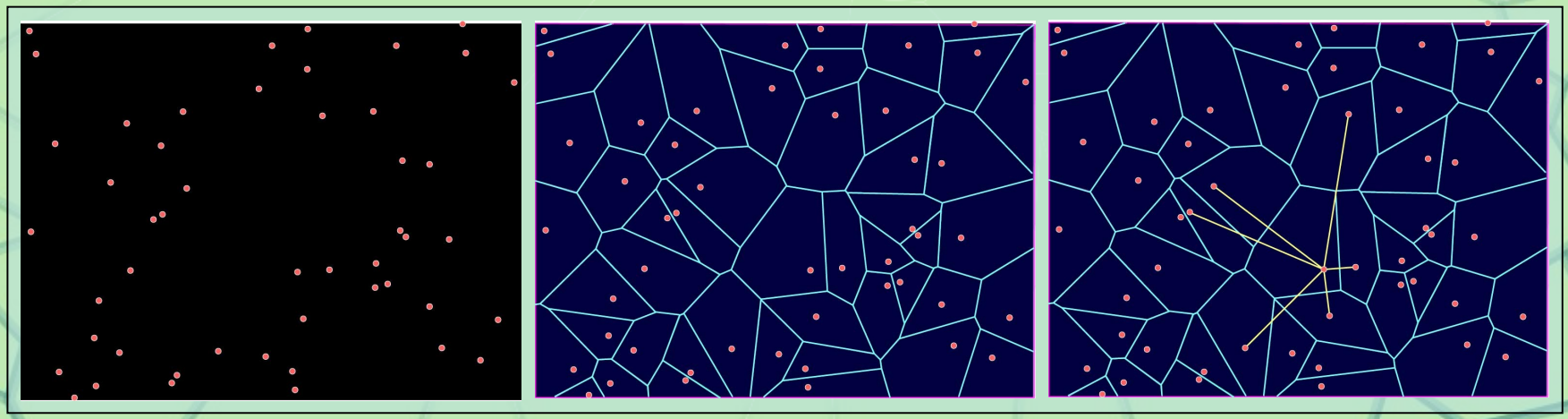
Radiative transfer is the computational bottleneck in almost all cases.

Requirements

- Should not scale with the number of sources
- Should include diffuse (re-emitted) photons
- Must be combined with AMR and SPH hydro codes
- Must perform well in both the optically thick and optically thin regime
- Must run in parallel

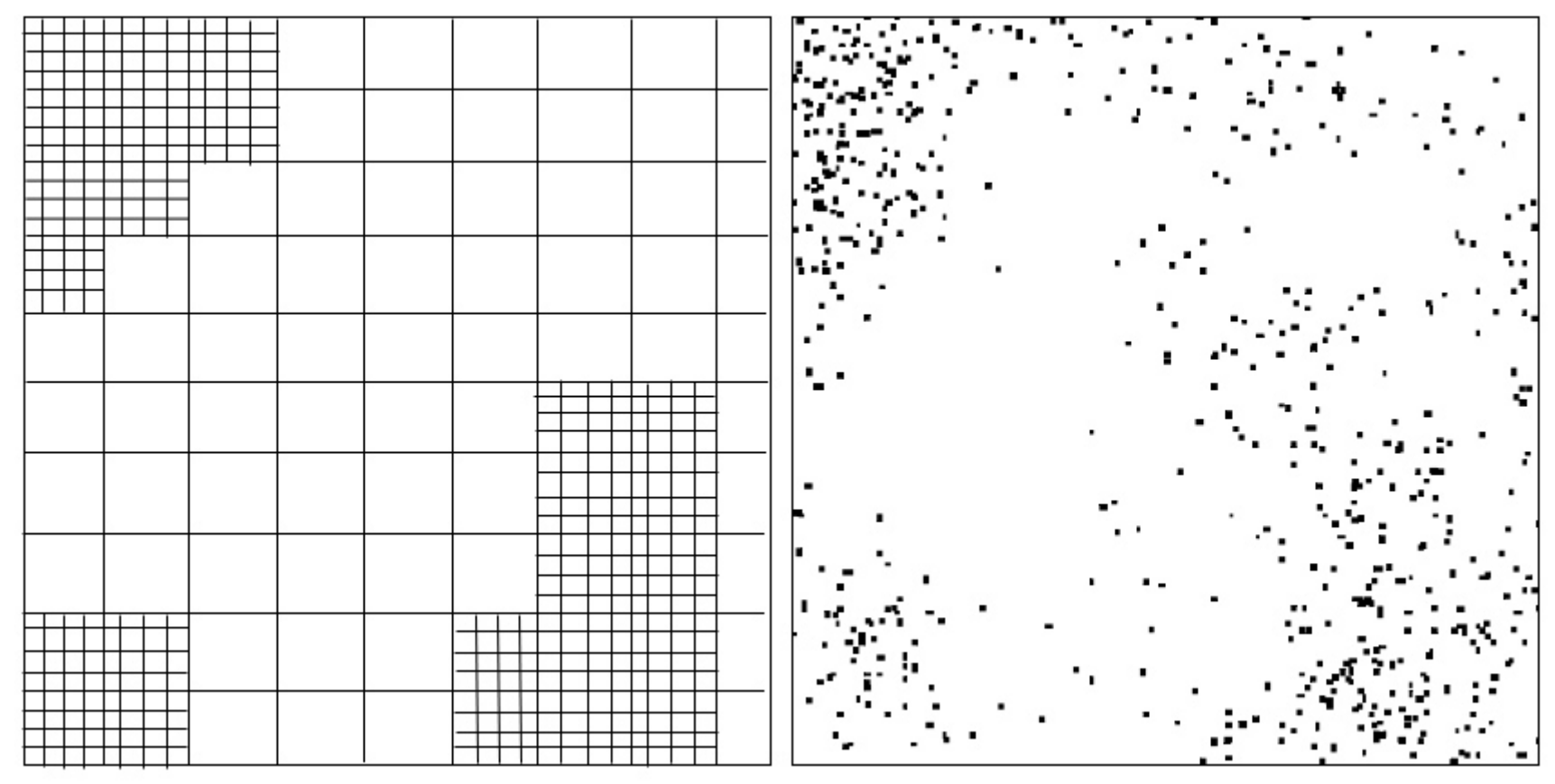
The SimpleX method

- Irregular grid: random nuclei (Poisson process)
- Space is tessellated using Voronoi recipe
- Delaunay triangulation to connect nuclei



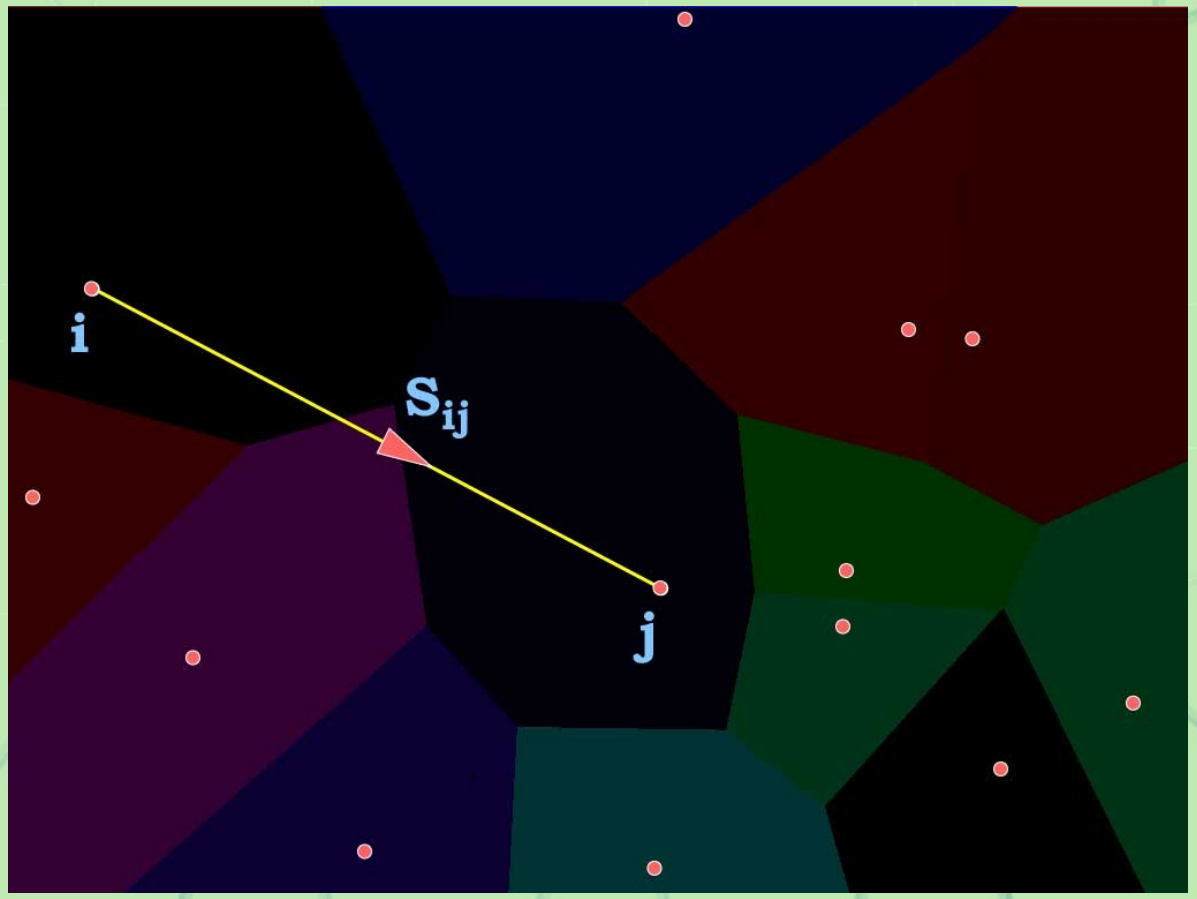
J. Ritzerveld & V. Icke 2006

AMR versus SimpleX

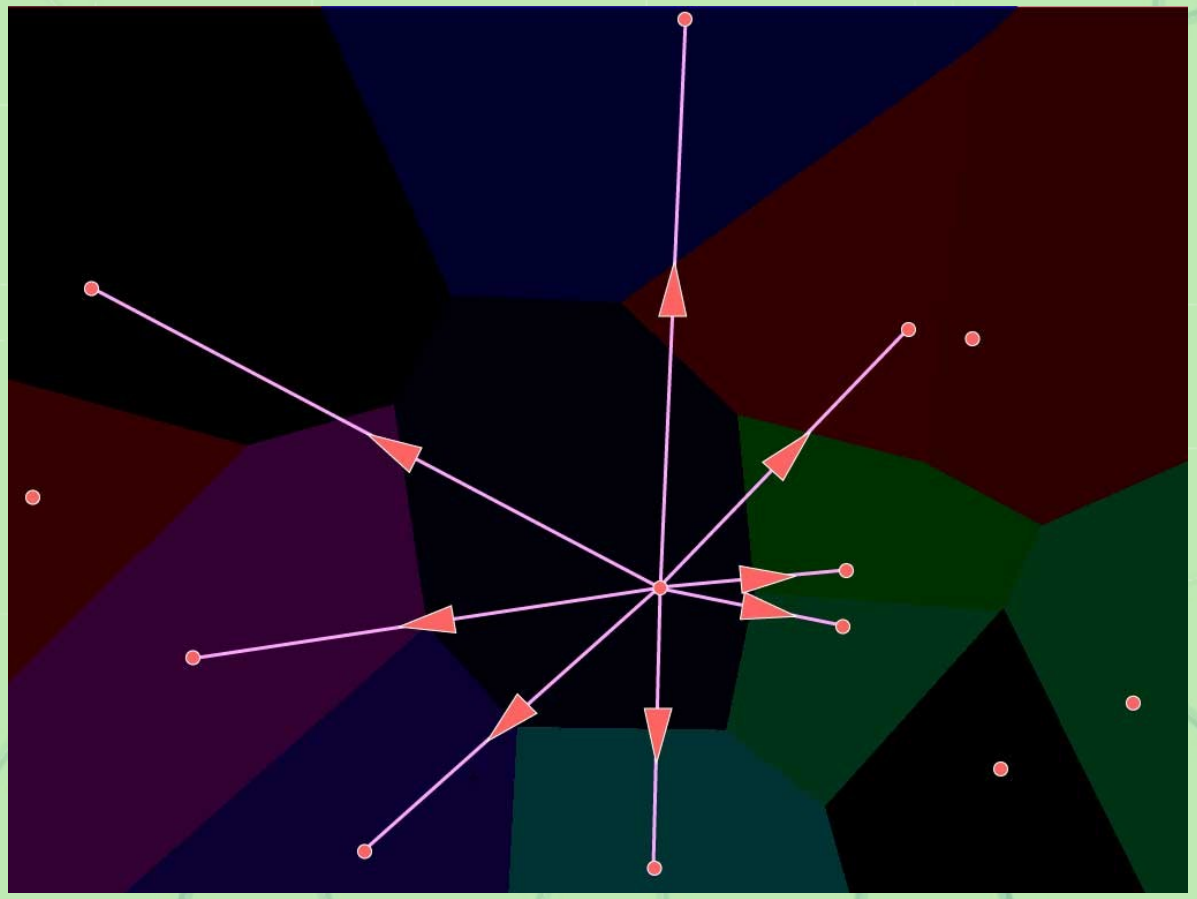


- Transport is reduced to a random walk over a Delaunay graph.
- Interactions happen at nuclei (typically when a mean free path has been traversed)
- Does not scale with the number of sources

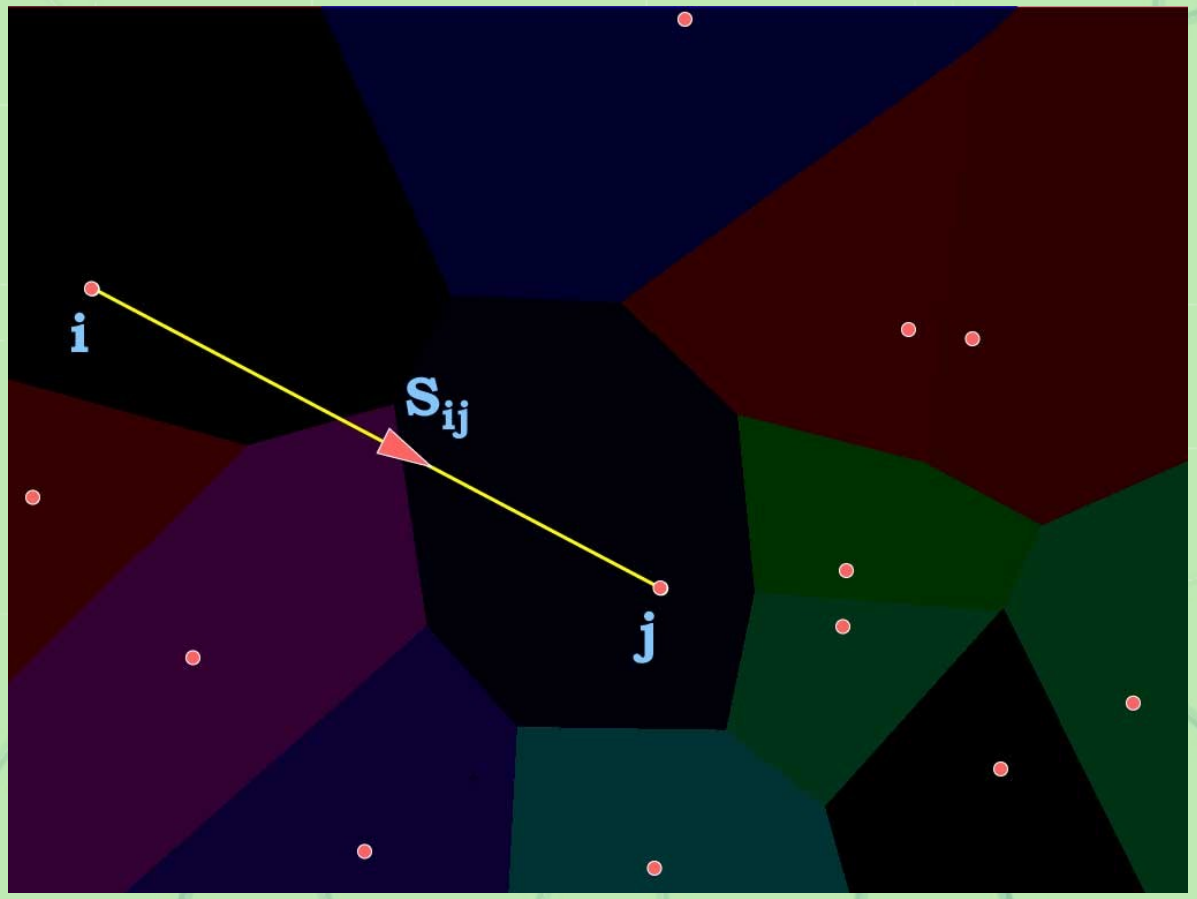
Diffuse transport



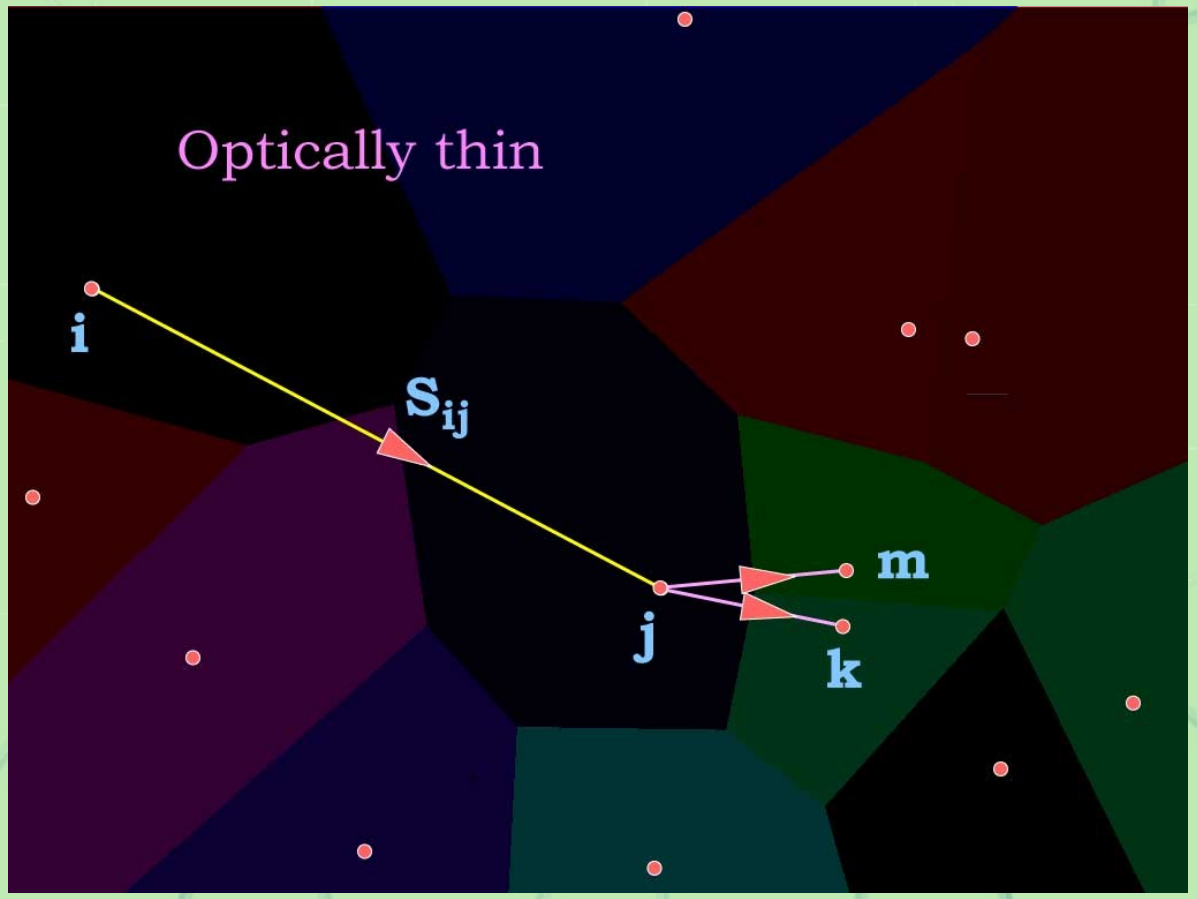
Diffuse transport



Ballistic transport



Ballistic transport

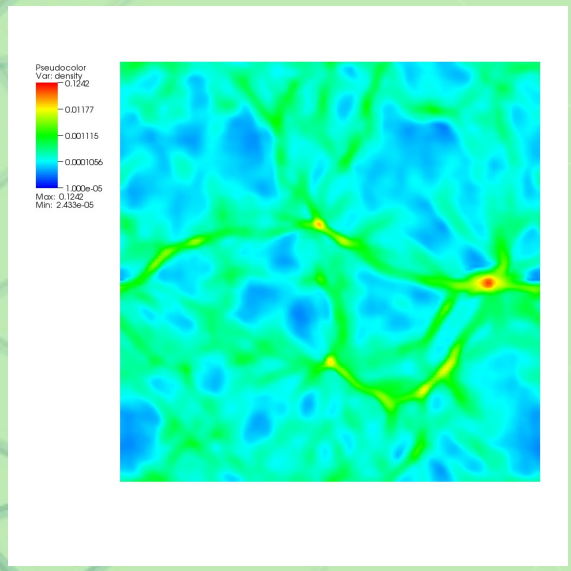


Sampling function

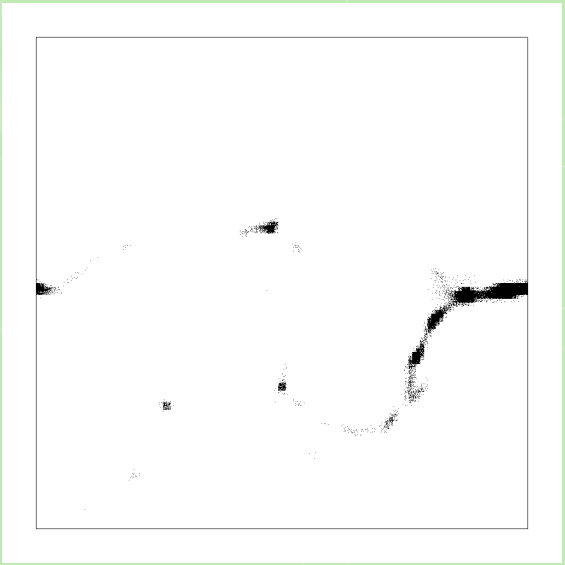
- Translating density to point density

$$n_p \propto \left(\frac{\rho}{\rho_0}\right)^3 + \left(\frac{\rho}{\rho_0}\right)^\alpha$$

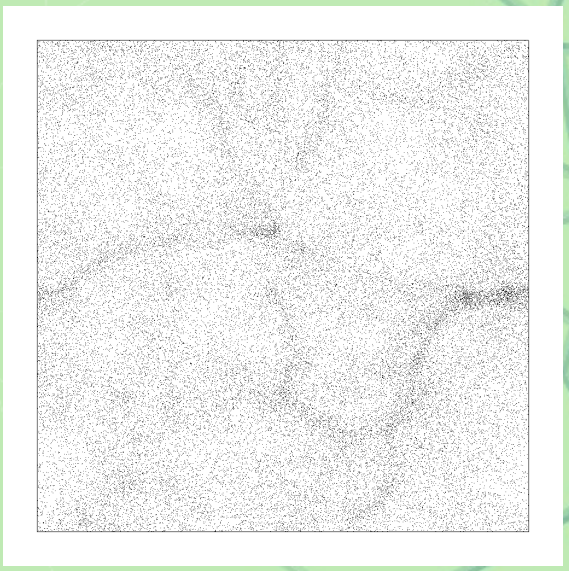
Cosmological density field



Density



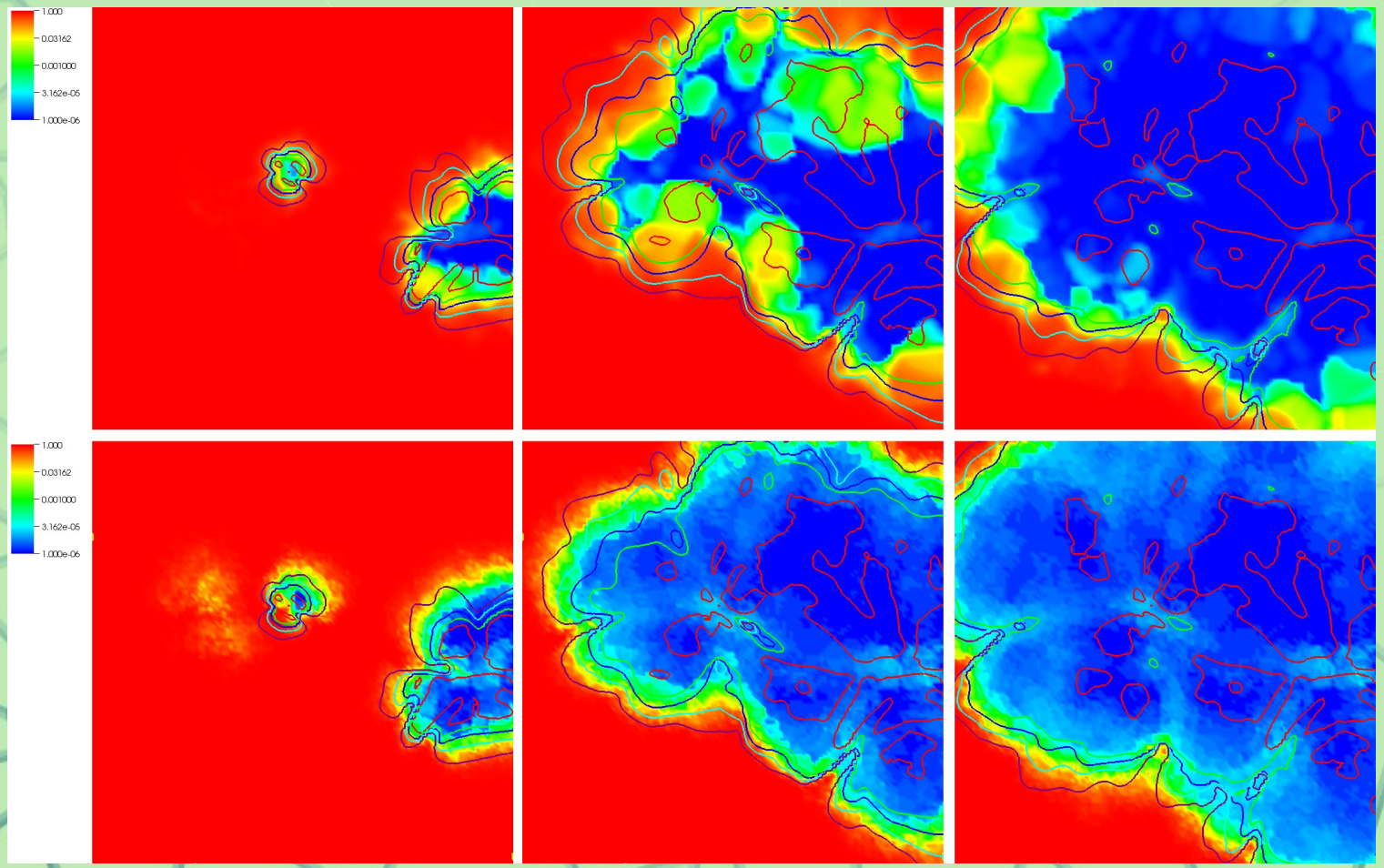
Third power



hybrid

Density field from Iliev et al 2006

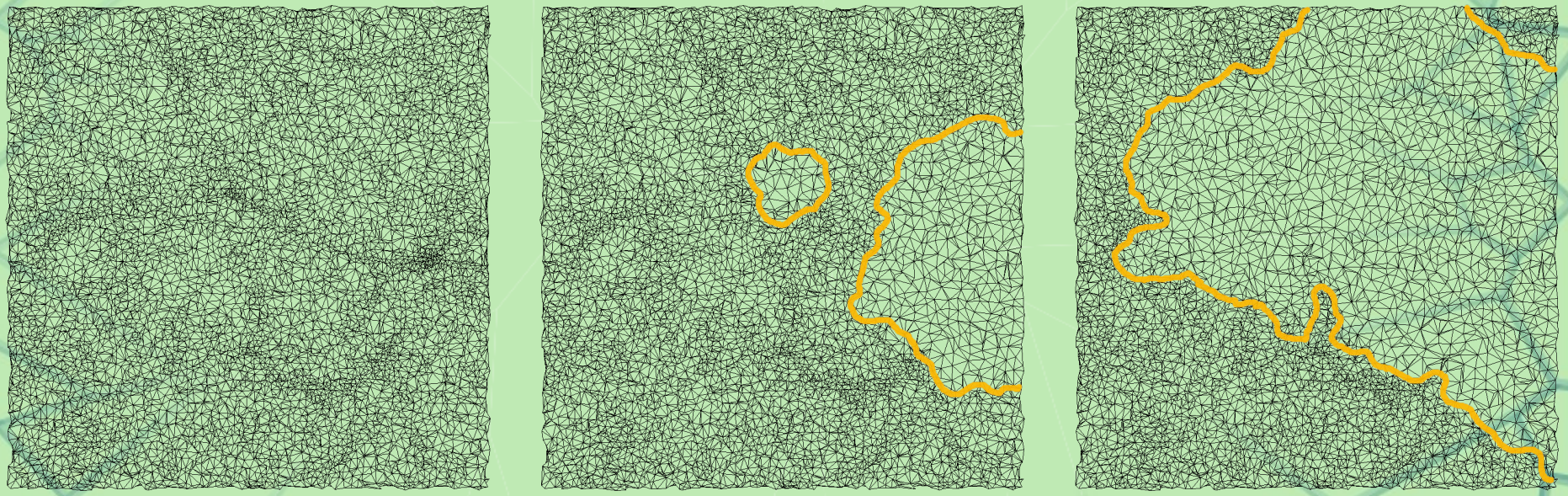
Results



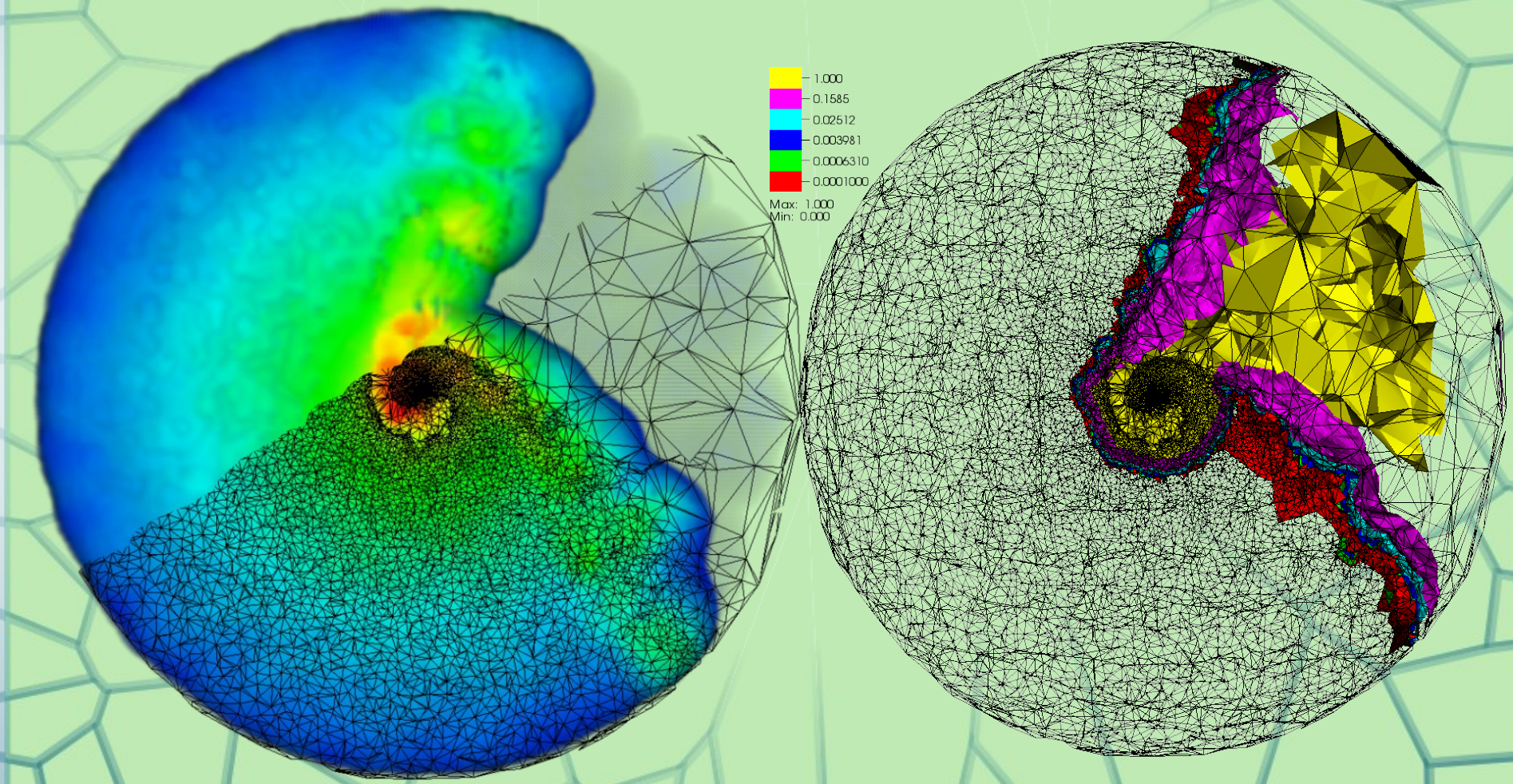
sqrt

hybrid

Dynamical grids

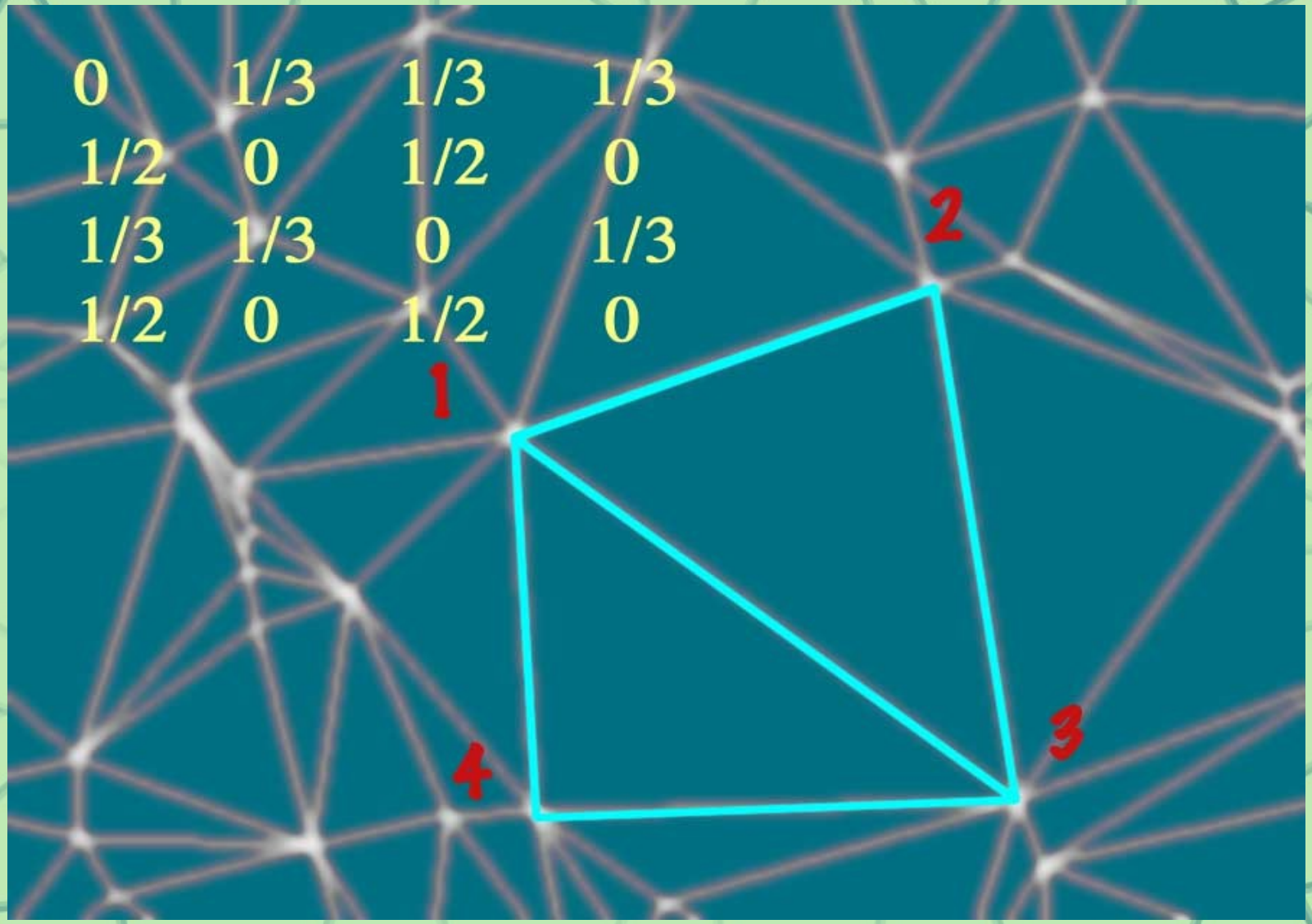


Interacting wind regions



Mathematical properties

- SimpleX transport can be described by a Markov chain.
- The stationary solution is represented by the eigenvector corresponding to eigenvalue 1 of the associated stochastic matrix.


0 1/3 1/3 1/3
1/2 0 1/2 0
1/3 1/3 0 1/3
1/2 0 1/2 0
1
2
3
4

Outlook

- Multi-frequency transport
- Fully coupled RHD
- Non-Delaunay grids