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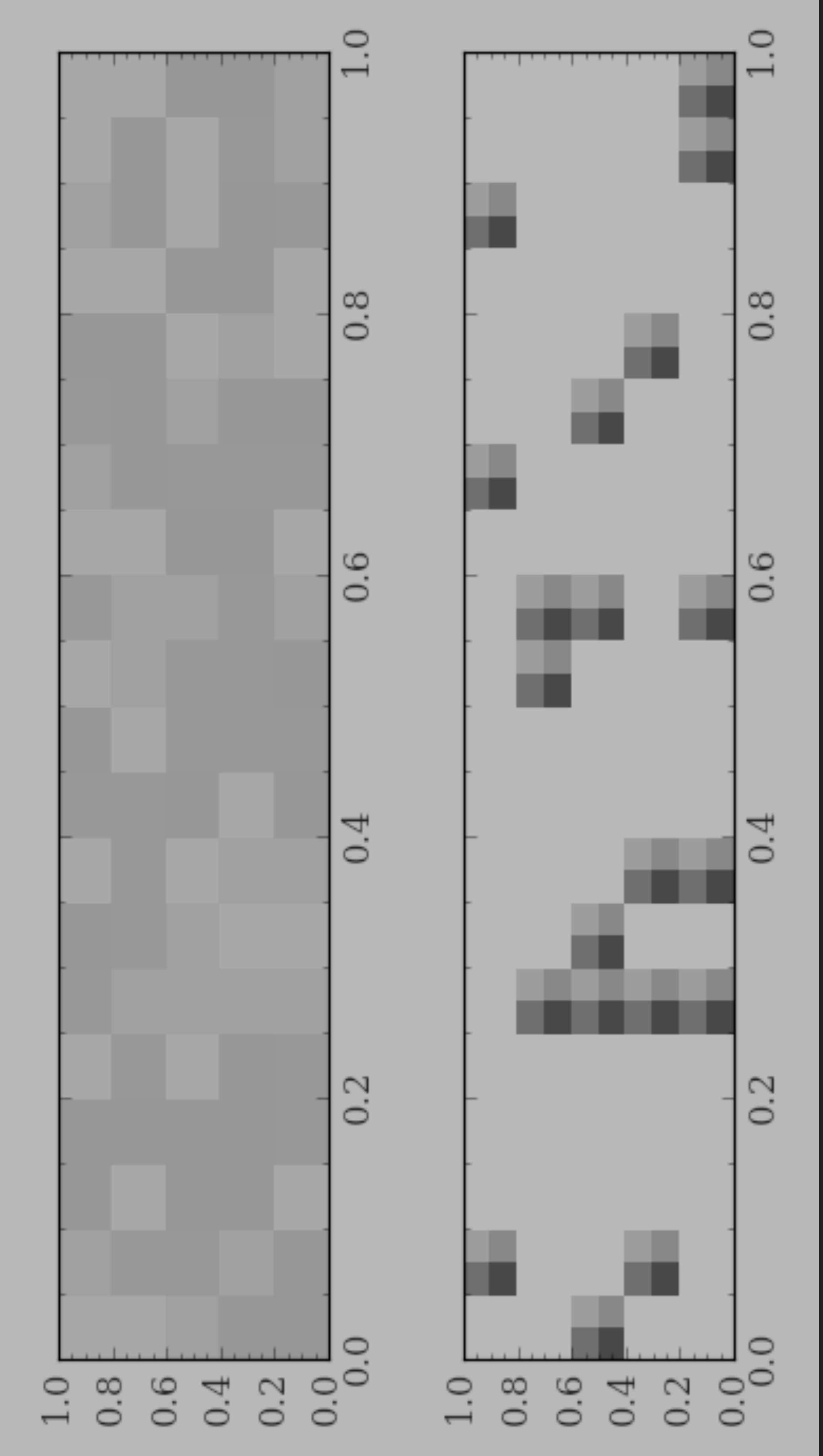
RADIATIVE VLASOV SIMULATIONS

PATH TO RADIATIVE RELATIVISTIC BOLTZMANN SIMULATIONS



TOWARDS EXASCALE

TOOLS

EXASCALE ERA

- Exascale = 100 million cores
  - We need to rethink parallellization
  - Minimize communication
  - Dynamic grids / meshes

LOAD BALANCING

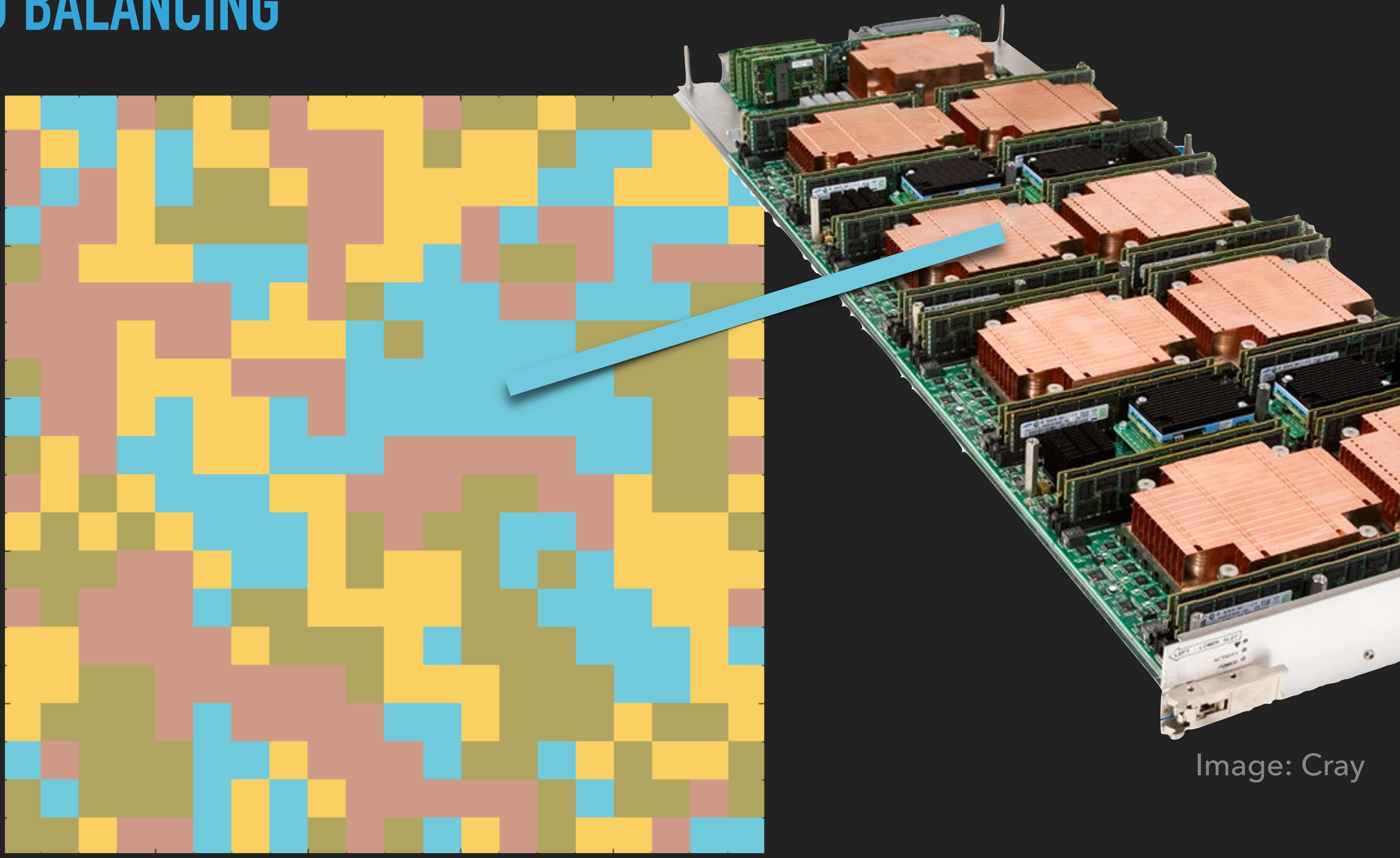
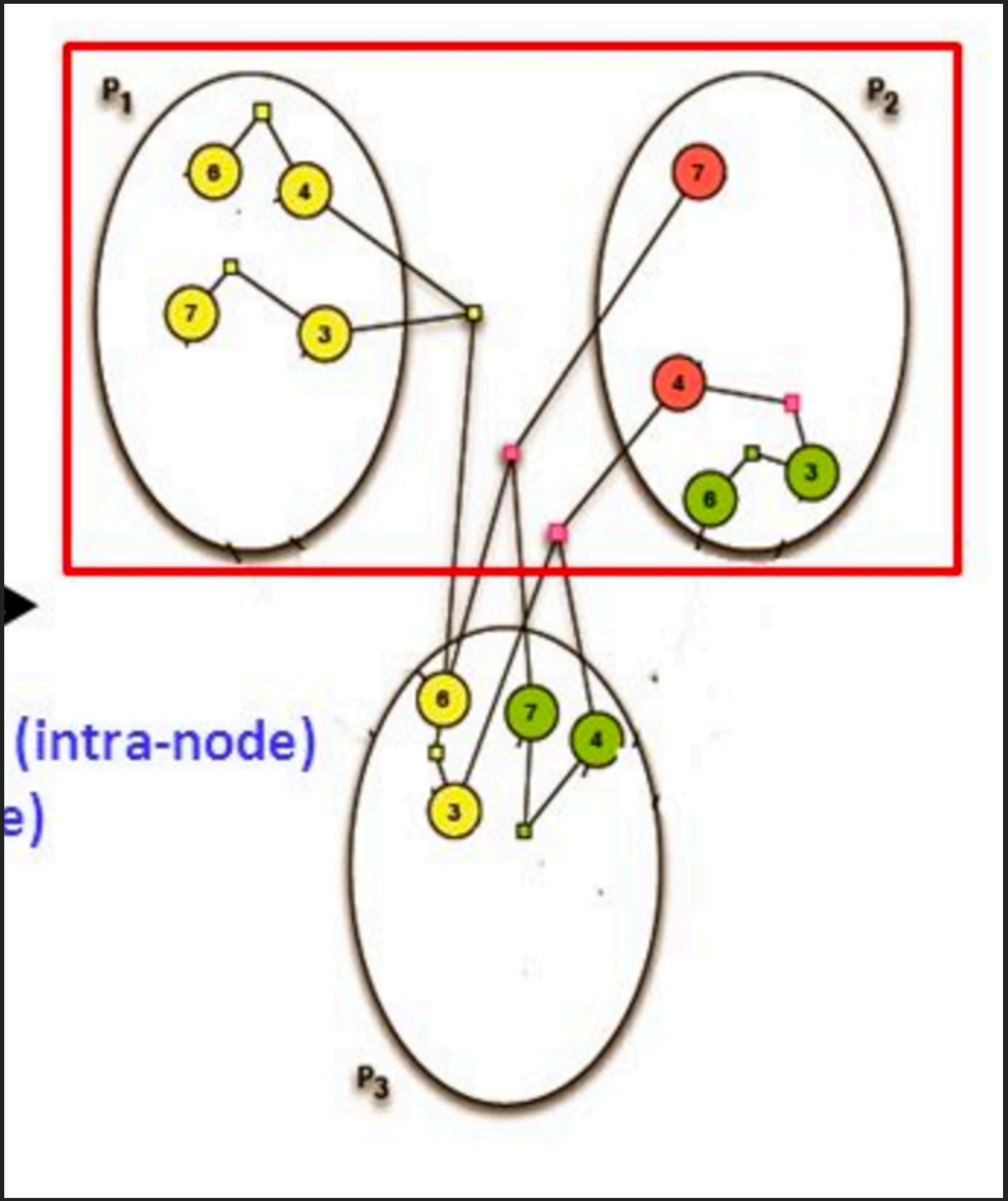
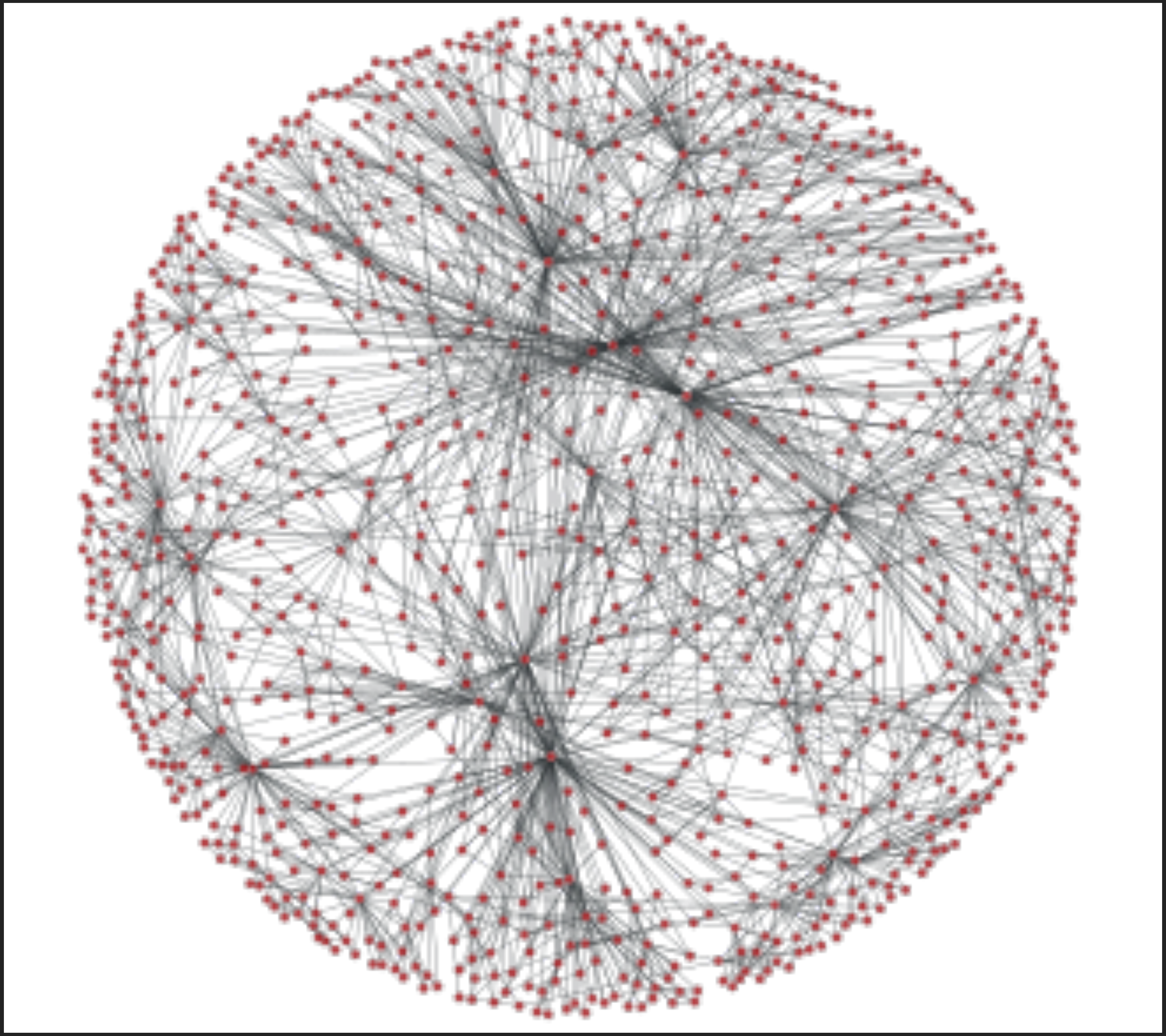


Image: Cray

(HYPER)GRAPH SLICING



(HYPER)GRAPH SLICING: THE PROBLEM



graph-tool

LOAD BALANCING

- Cellular Automata rules

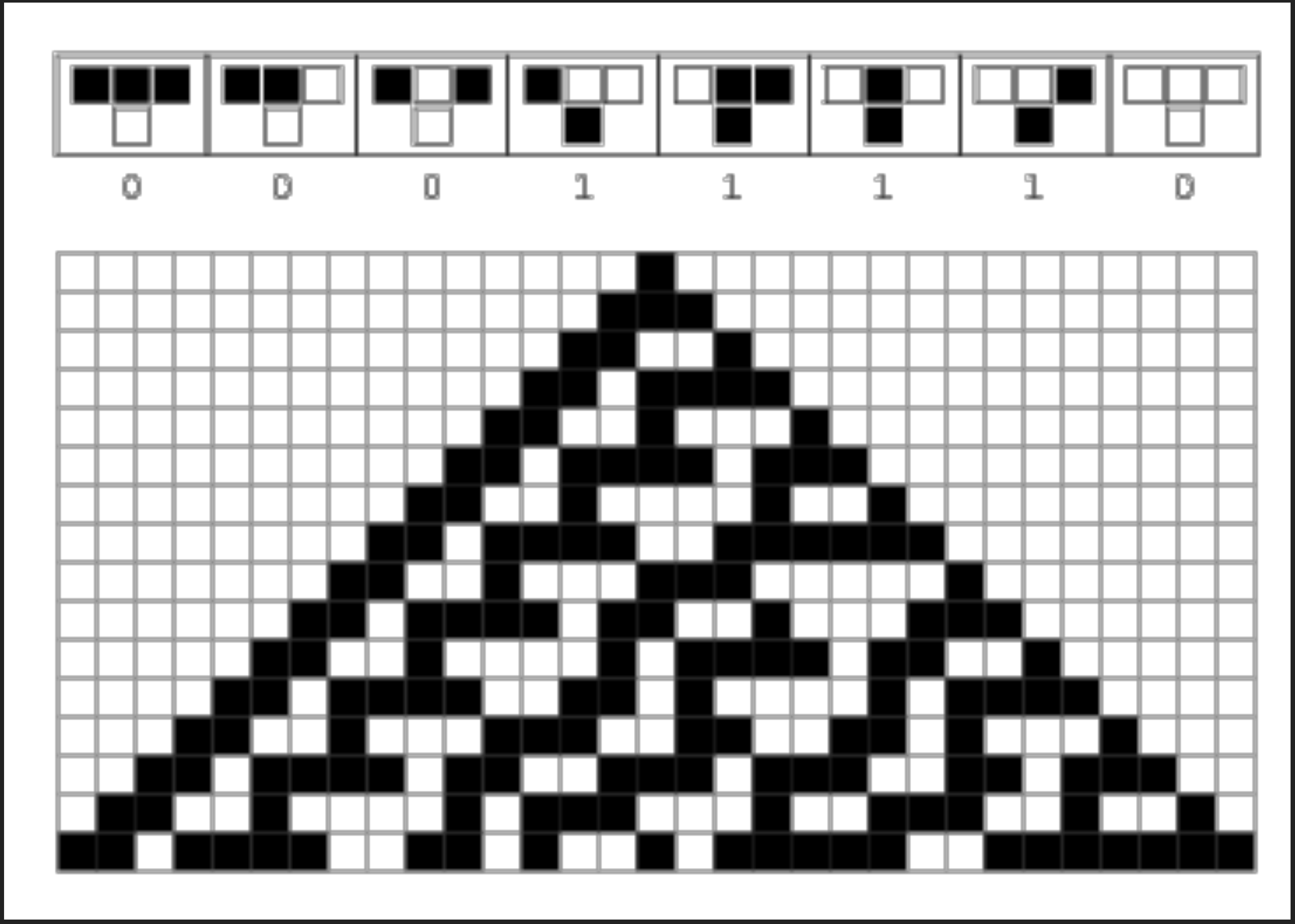
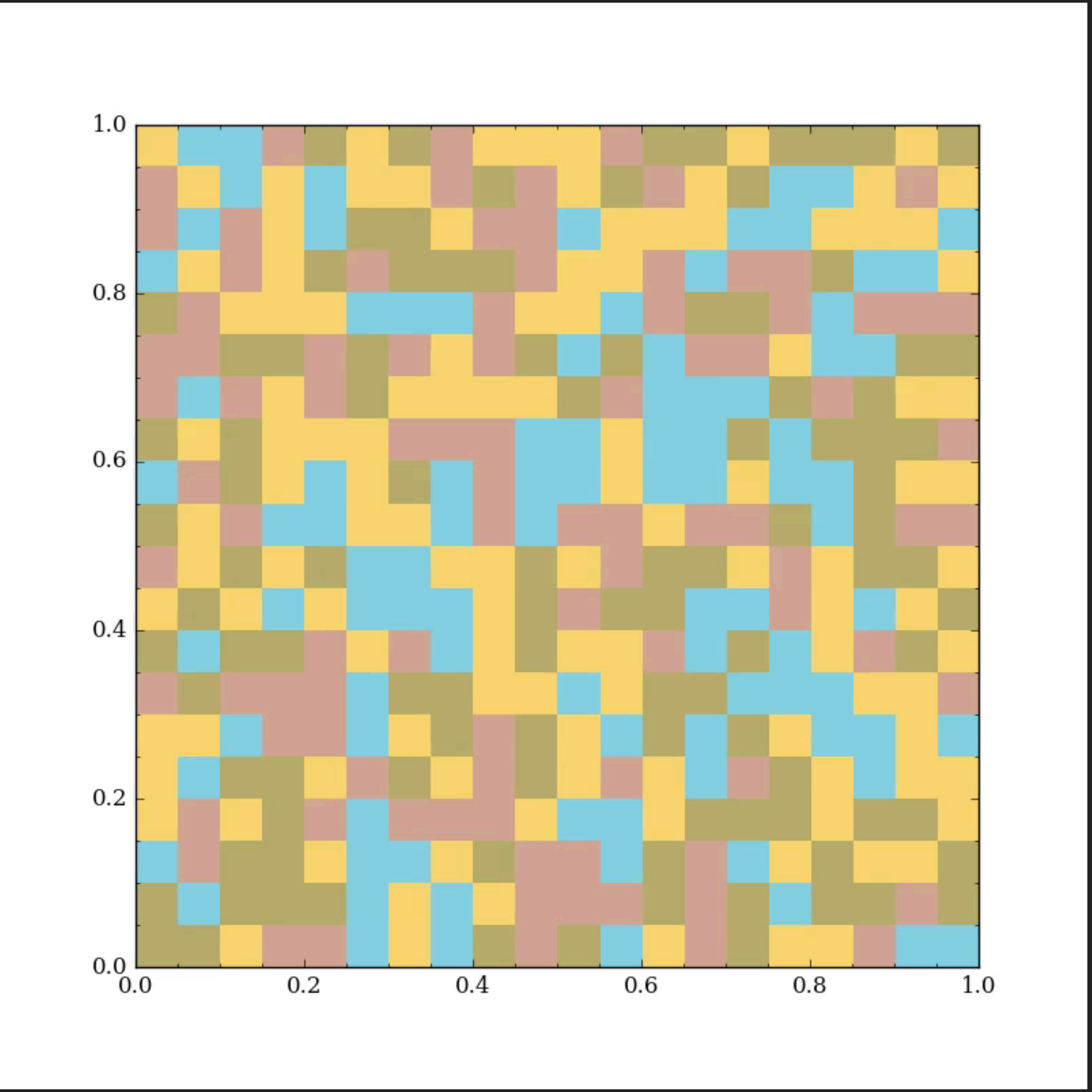


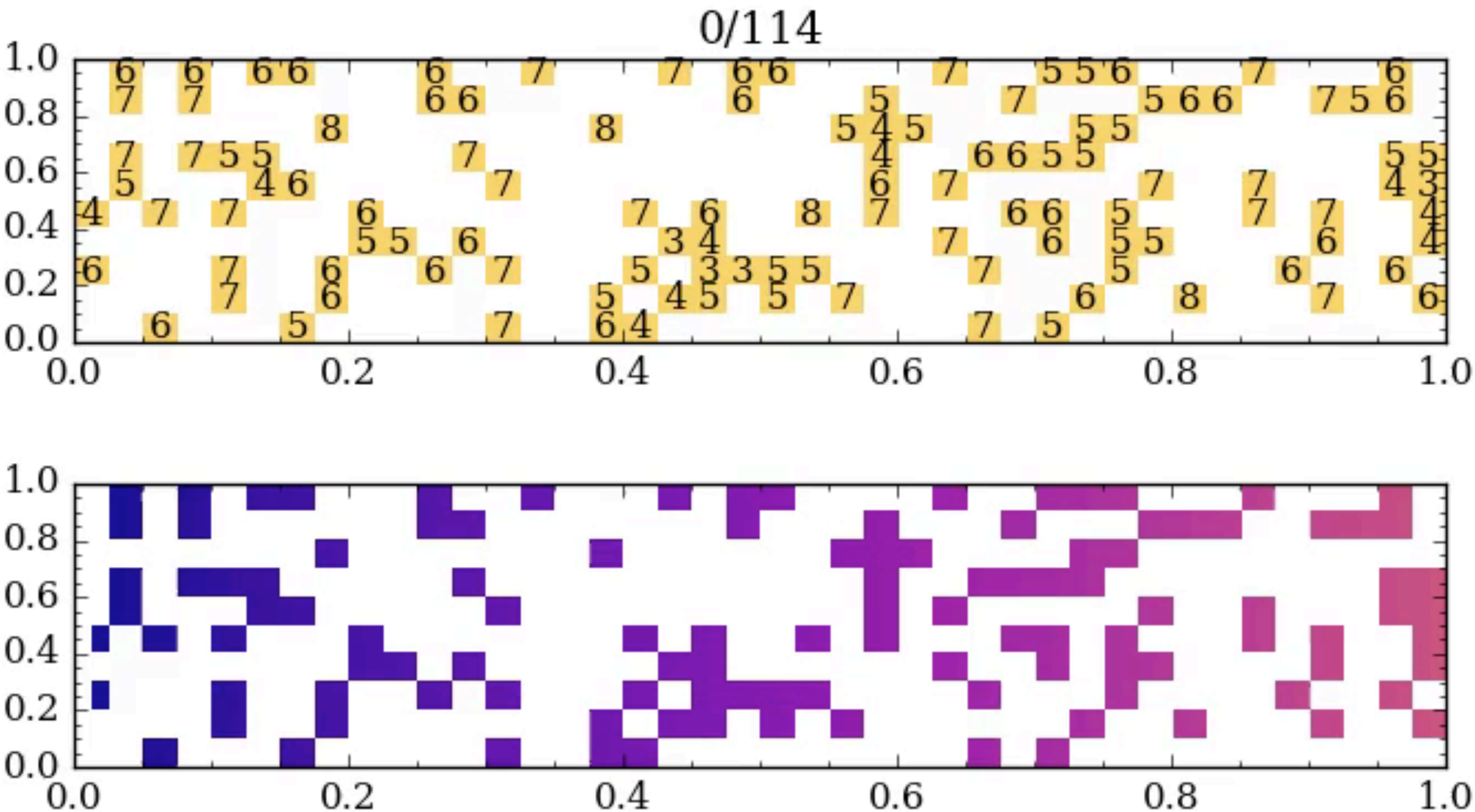
Image: http://mathworld.wolfram.com/CellularAutomaton.html

LOAD BALANCING

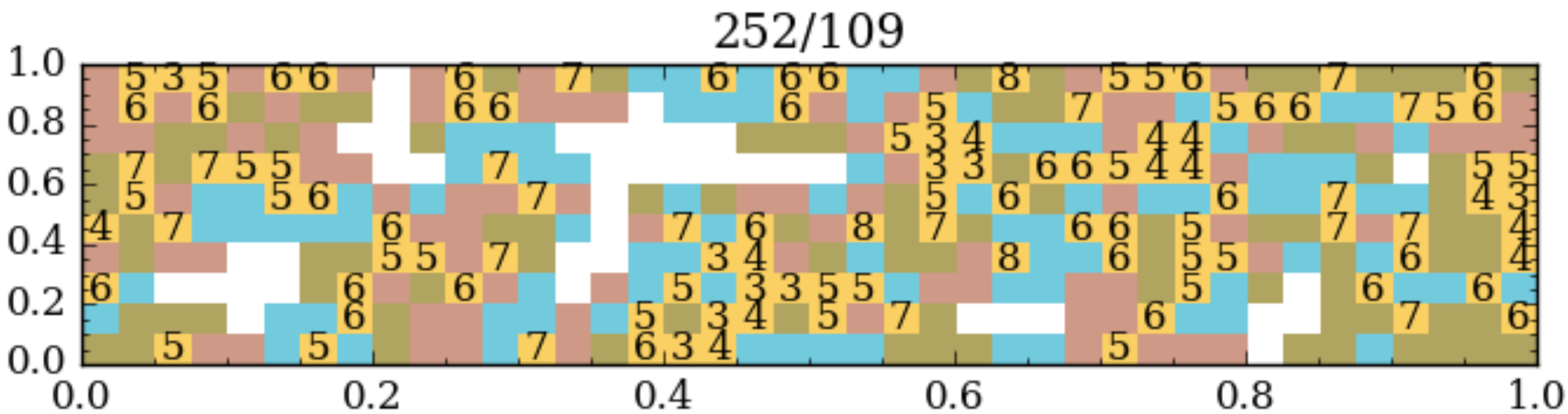
- Rules:
  - Kidnap worst cells
  - Compete against others

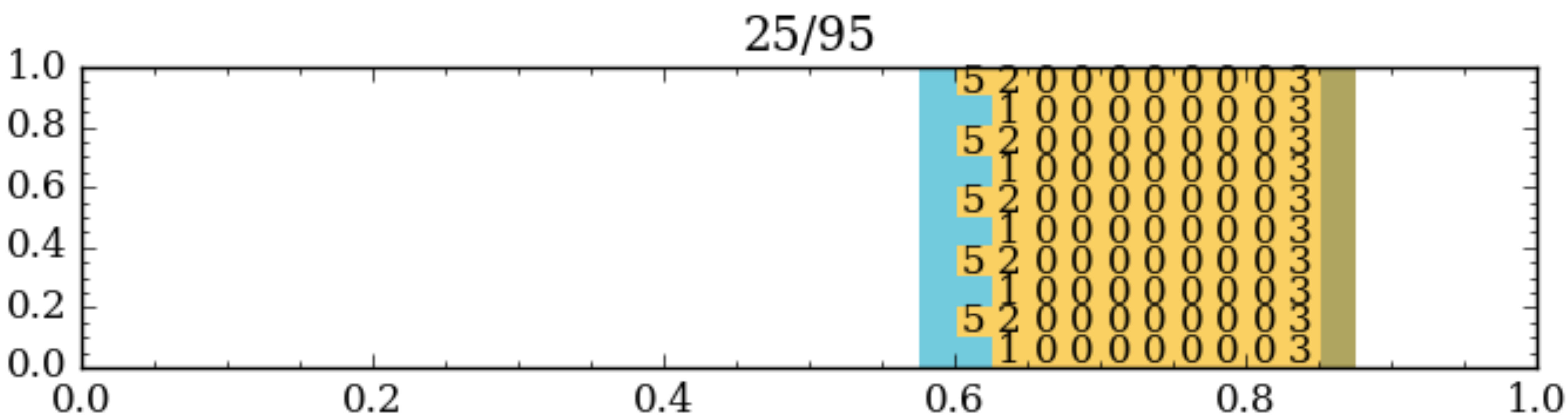


LOAD BALANCING



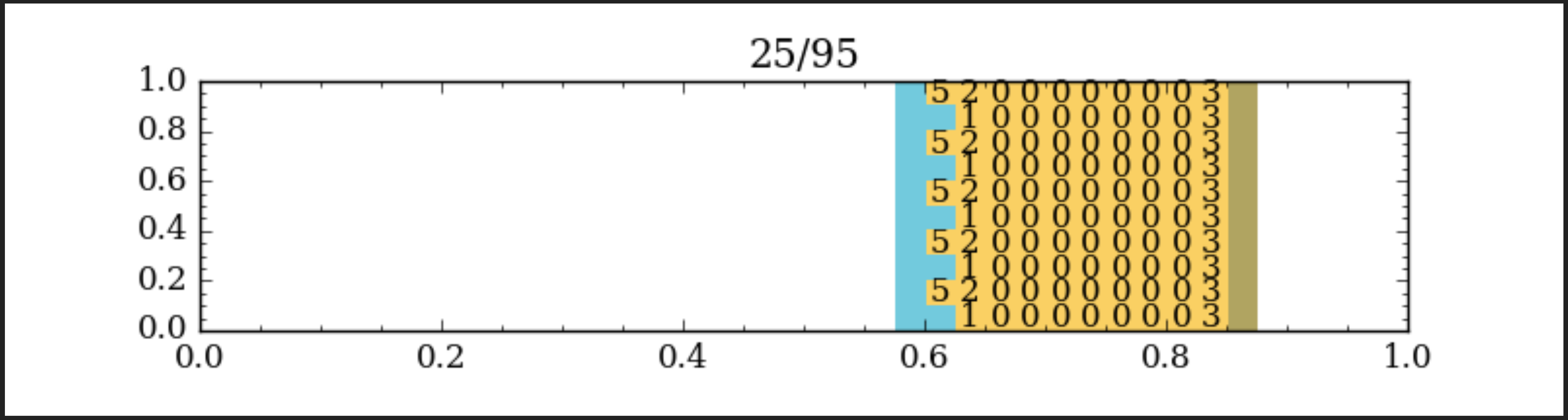
LOAD BALANCING

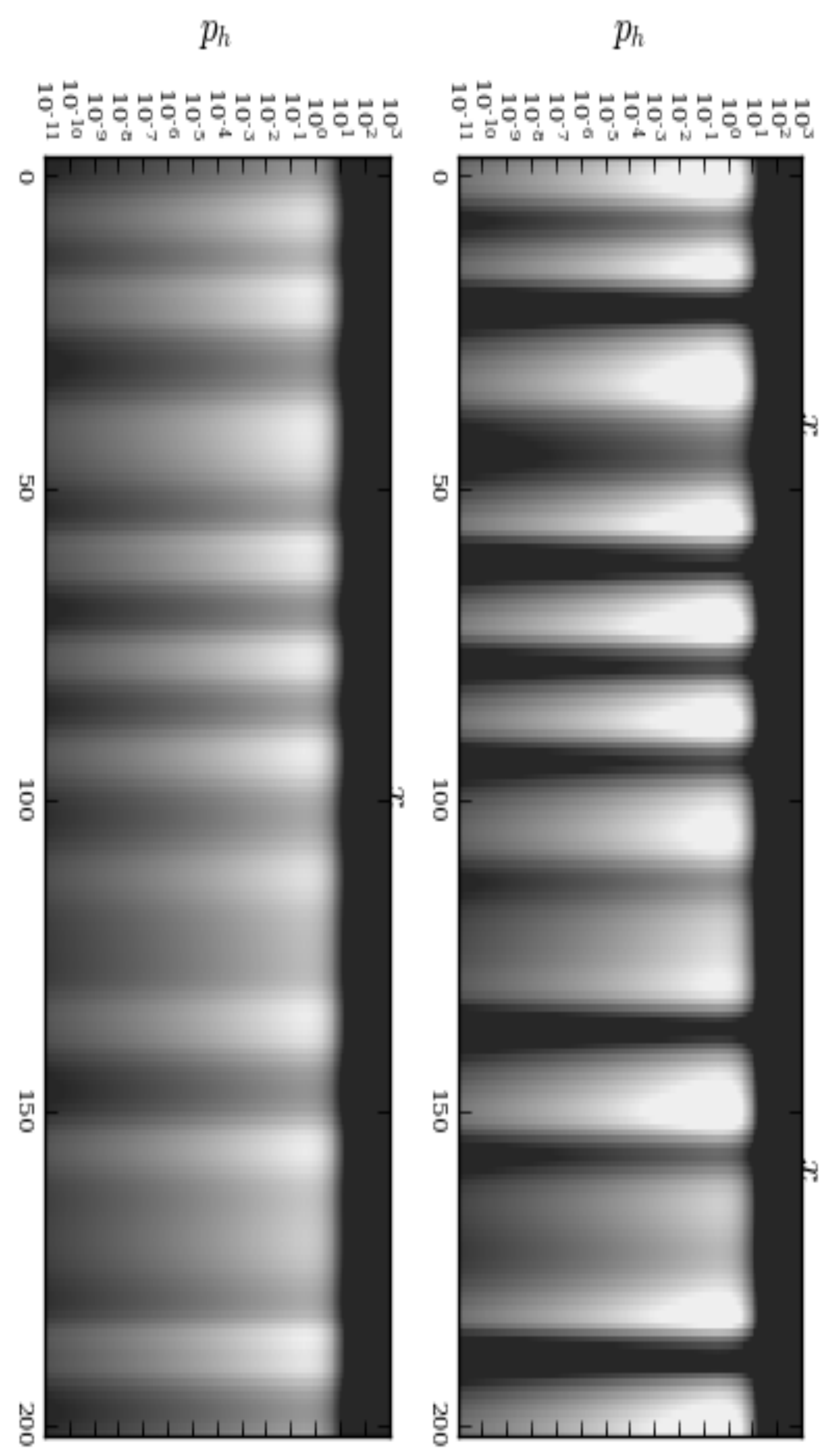




NATURAL PARALLELLIZATION

- MPI across “colors” i.e., nodes
- Task-based openMP inside node over each cell/block
- Vectorization inside block





RADIATIVE VLASOV

SIMULATIONS

SOLVING RELATIVISTIC VLASOV-MAXWELL EQUATIONS

$$\frac{\partial f_\mathrm{s}}{\partial t} + \nabla_{\boldsymbol{x}} \cdot (\boldsymbol{v} f_\mathrm{s}) + \nabla_{\boldsymbol{u}} \cdot (\boldsymbol{a}_\mathrm{s} f_\mathrm{s}) = C,$$

where $C := \partial_t f_\mathrm{s} |_\mathrm{coll}$ is the collision operator.

$$\boldsymbol{a}_\mathrm{s} = d_t \boldsymbol{u} = (q_\mathrm{s}/m_\mathrm{s})(\boldsymbol{E} + \boldsymbol{v} \times \boldsymbol{B}),$$

$$\gamma^2 = 1 + (u/c)^2 = (1 - (v/c)^2)^{-1}$$

$$\boldsymbol{x} := (x, y, z) \qquad \boldsymbol{v} := d_t \boldsymbol{x} \qquad \boldsymbol{u} := d_\tau \boldsymbol{x} = \gamma \boldsymbol{v}.$$

RELATIVISTIC VLASOV-MAXWELL EQUATIONS

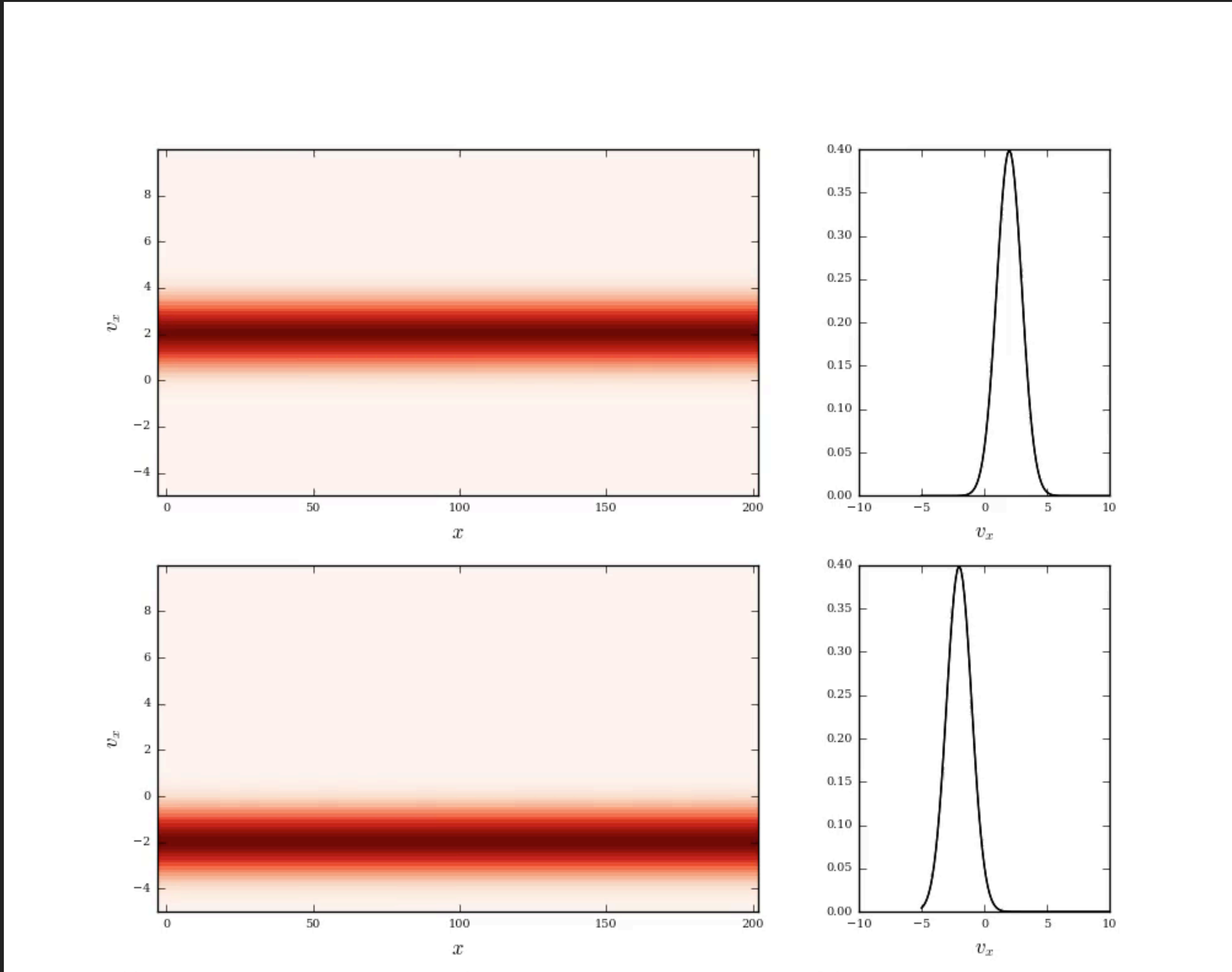
$$\frac{\partial f_s}{\partial t} + \nabla_{\boldsymbol{x}} \cdot (\boldsymbol{v} f_s) + \nabla_{\boldsymbol{u}} \cdot (\boldsymbol{a}_s f_s) = C,$$

where $C := \partial_t f_s |_{\text{coll}}$ is the collision operator.

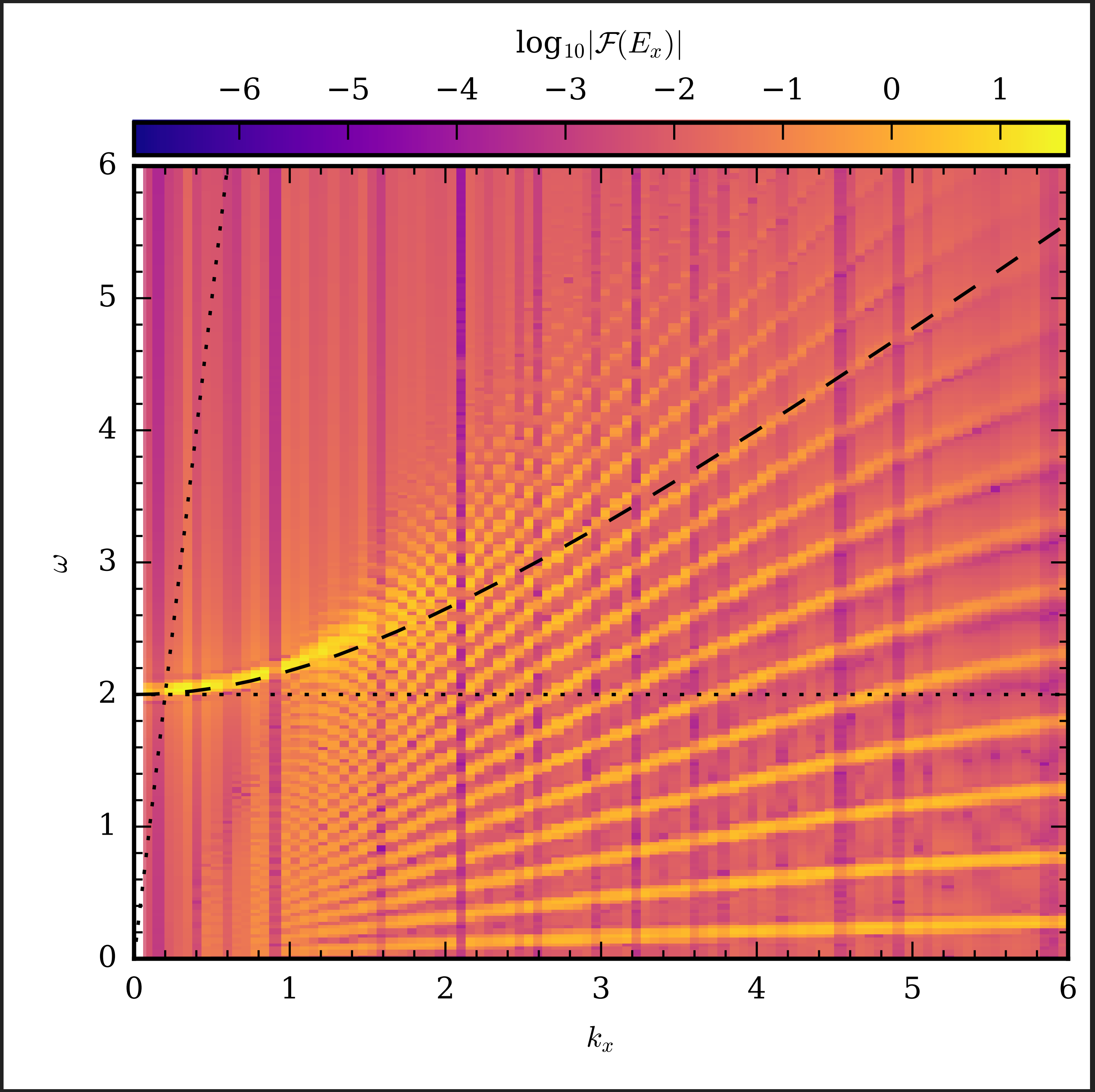
$$\frac{\partial f_s}{\partial t} + \nabla_{\boldsymbol{x}} \cdot (\boldsymbol{v} f_s) = 0$$

$$\frac{\partial f_s}{\partial t} + \frac{q_s}{m_s} \nabla_{\boldsymbol{a}} \cdot (\boldsymbol{E} + \boldsymbol{v} \times \boldsymbol{B}) f_s = 0$$

TWO-STREAM INSTABILITY



WARM PLASMA DISPERSION RELATION + MY NOISE!



RADIATIVE VLASOV

$$\frac{\partial f_s}{\partial t} + \nabla_{\boldsymbol{x}} \cdot (\boldsymbol{v} f_s) + \nabla_{\boldsymbol{u}} \cdot (\boldsymbol{a}_s f_s) = C,$$

where $C := \partial_t f_s |_{\mathrm{coll}}$ is the collision operator.

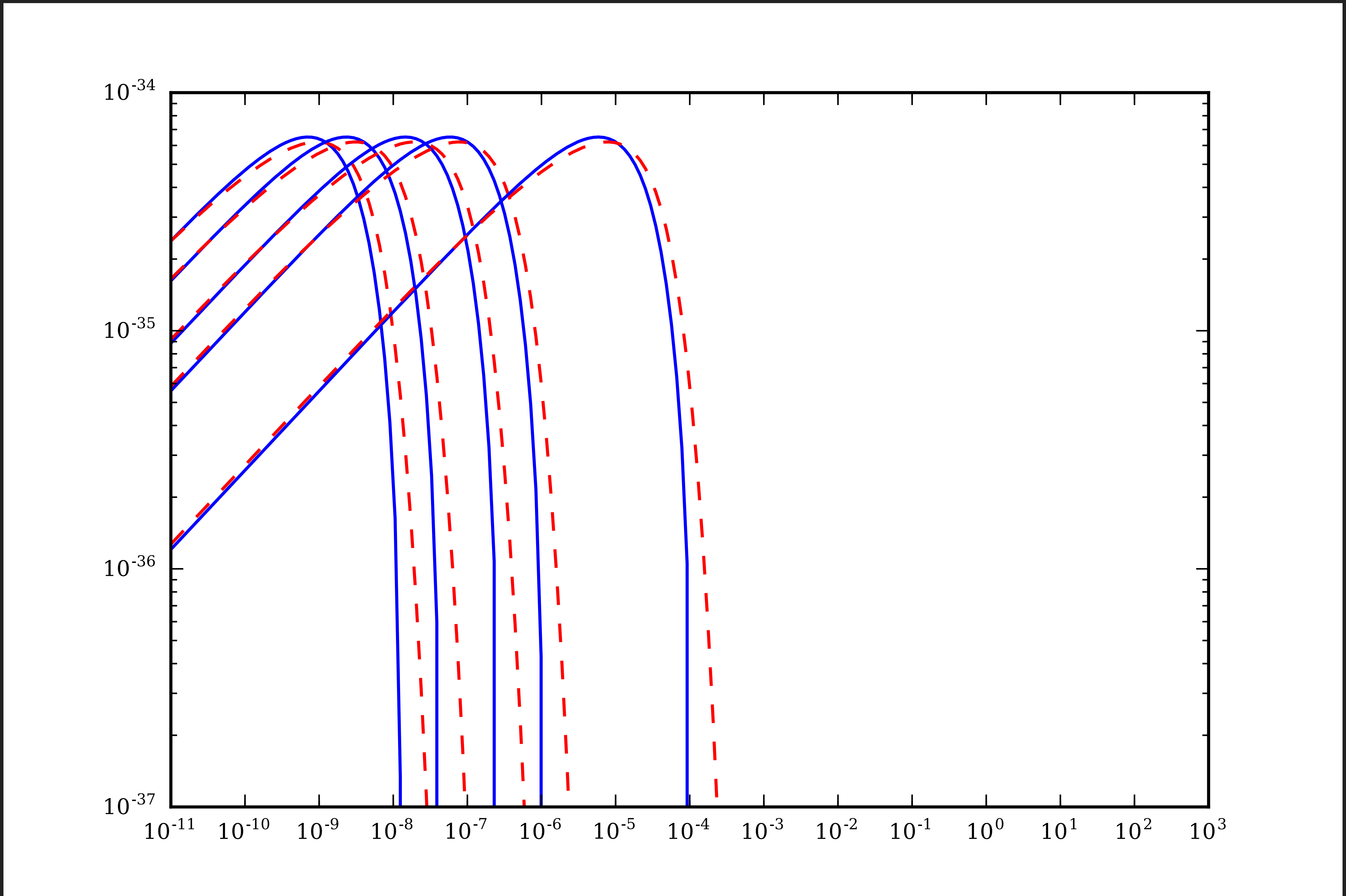
$$\frac{\partial f_s}{\partial t} + \nabla_{\boldsymbol{x}} \cdot (\boldsymbol{v} f_s) = 0$$

$$\frac{\partial f_s}{\partial t} + \frac{q_s}{m_s} \nabla_{\boldsymbol{a}} \cdot (\boldsymbol{E} + \boldsymbol{v} \times \boldsymbol{B}) f_s = 0$$

$$\frac{\partial f_s}{\partial t} = C$$

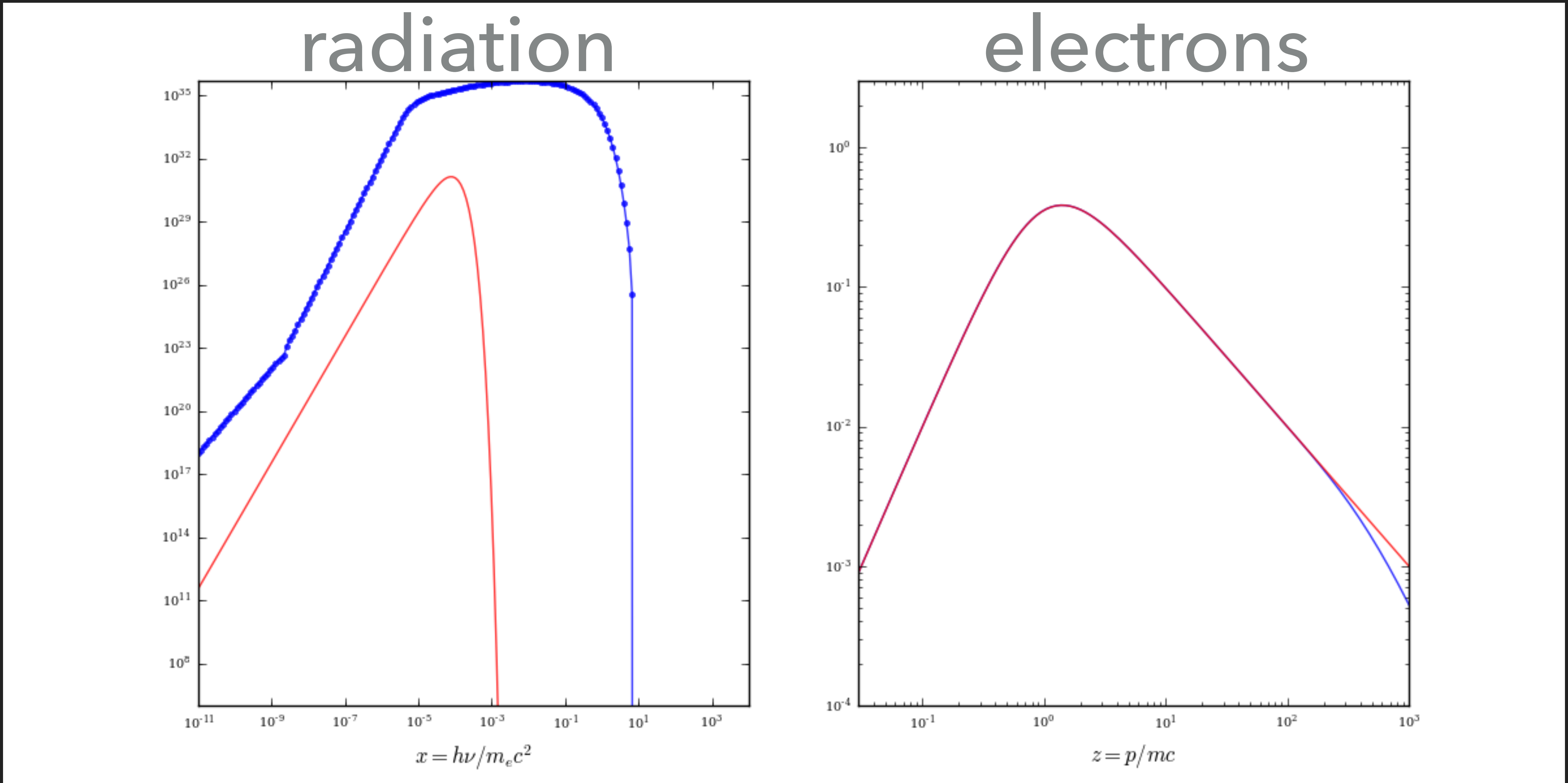
COUPLING COLLISION OPERATOR WITH RADIATION

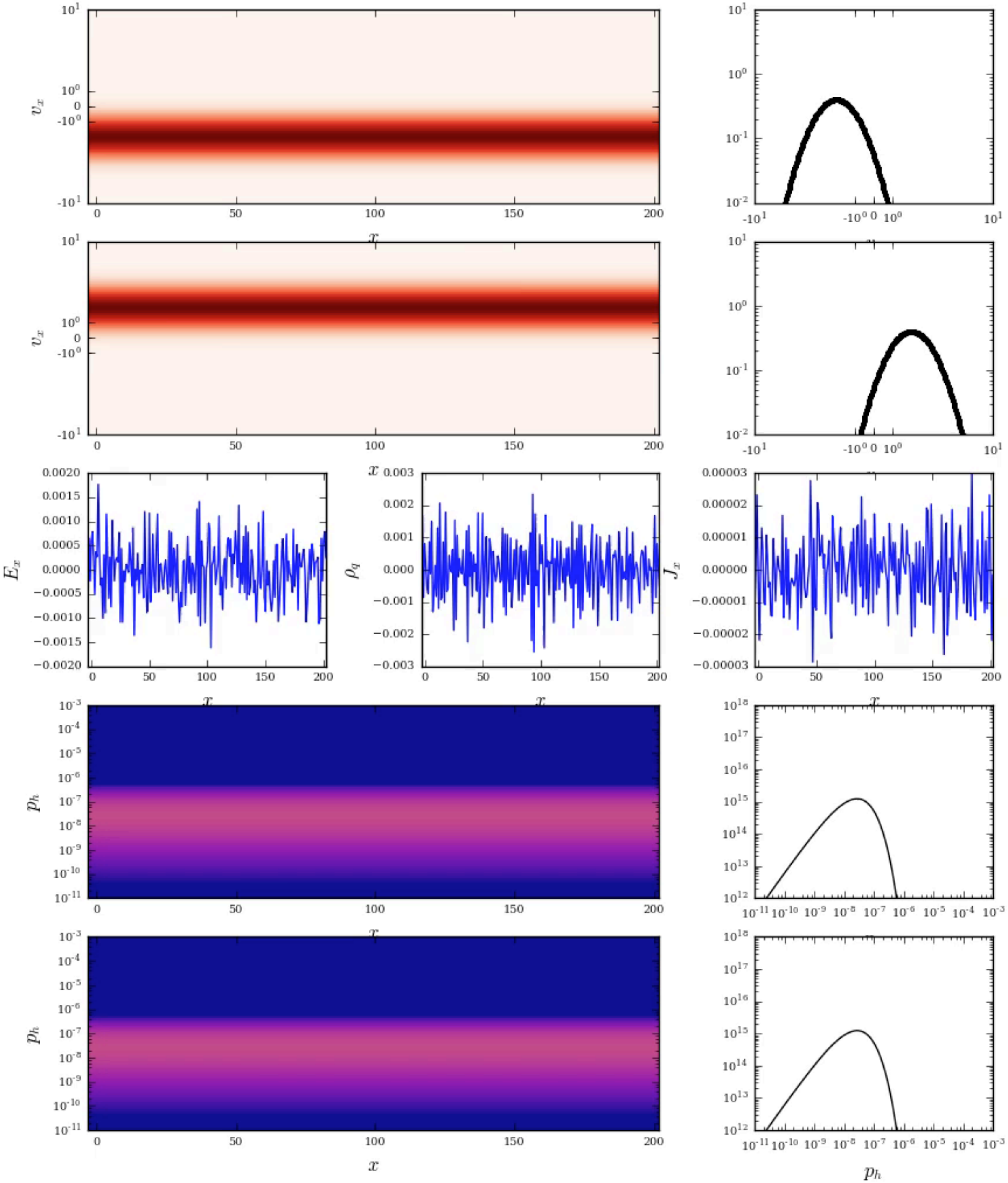
- Synchrotron response to delta-injection



COUPLING COLLISION OPERATOR WITH RADIATION

- Synchrotron response to powerlaw





v_x
x
E_x
ρ_q
J_x
p_h

SUMMARY

- We are moving to the exascale era, are we really ready?
  - Tools?
  - Simulations/Physics?
- What can we learn from the current rescale era?