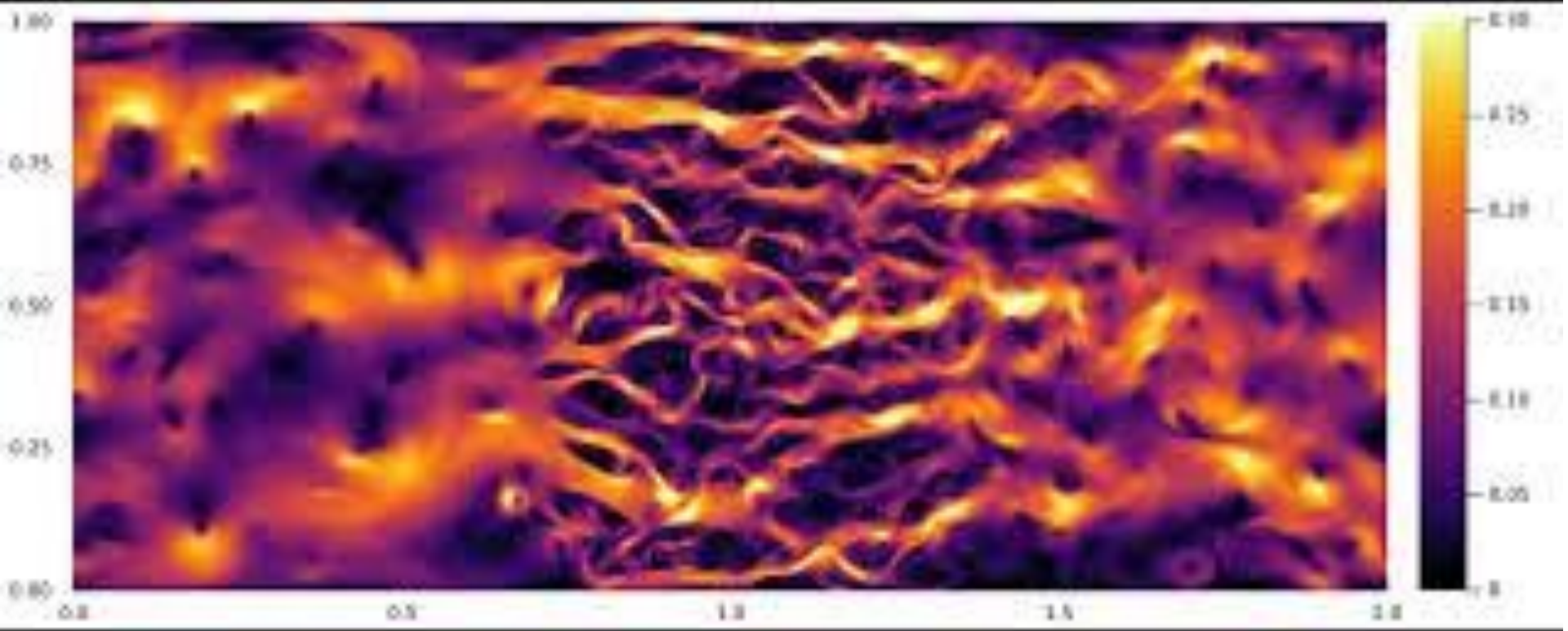
GPU Lattice Boltzmann Method for Heat Transport

The 0rganizers

Key Ideas

- Lattice-Boltzmann method
- 2D Instationary Flow with two-layer Heat transport model
- Fully explicit -> great parallelization on GPUs
- Use simplex noise contours as fins
- Use Julia to get 80% of the performance in 20% of the time

Results


1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
0.20
0.15
0.10
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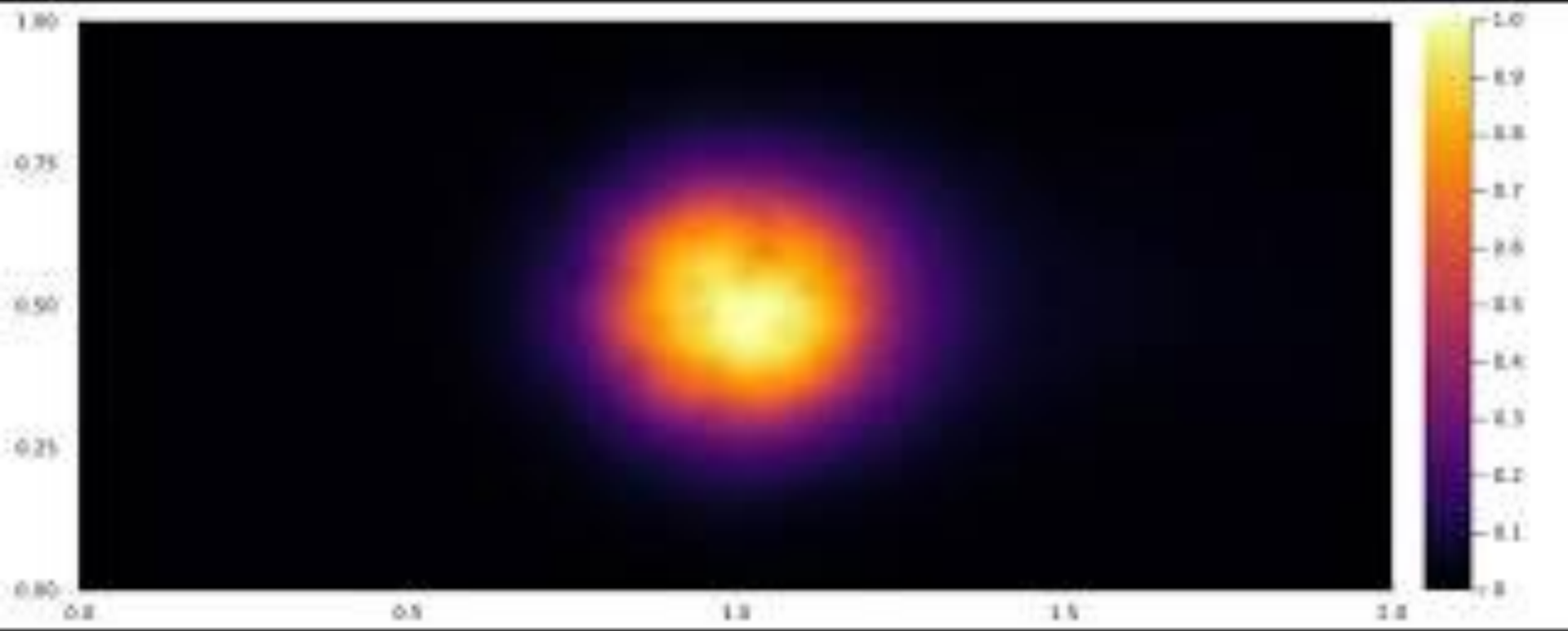
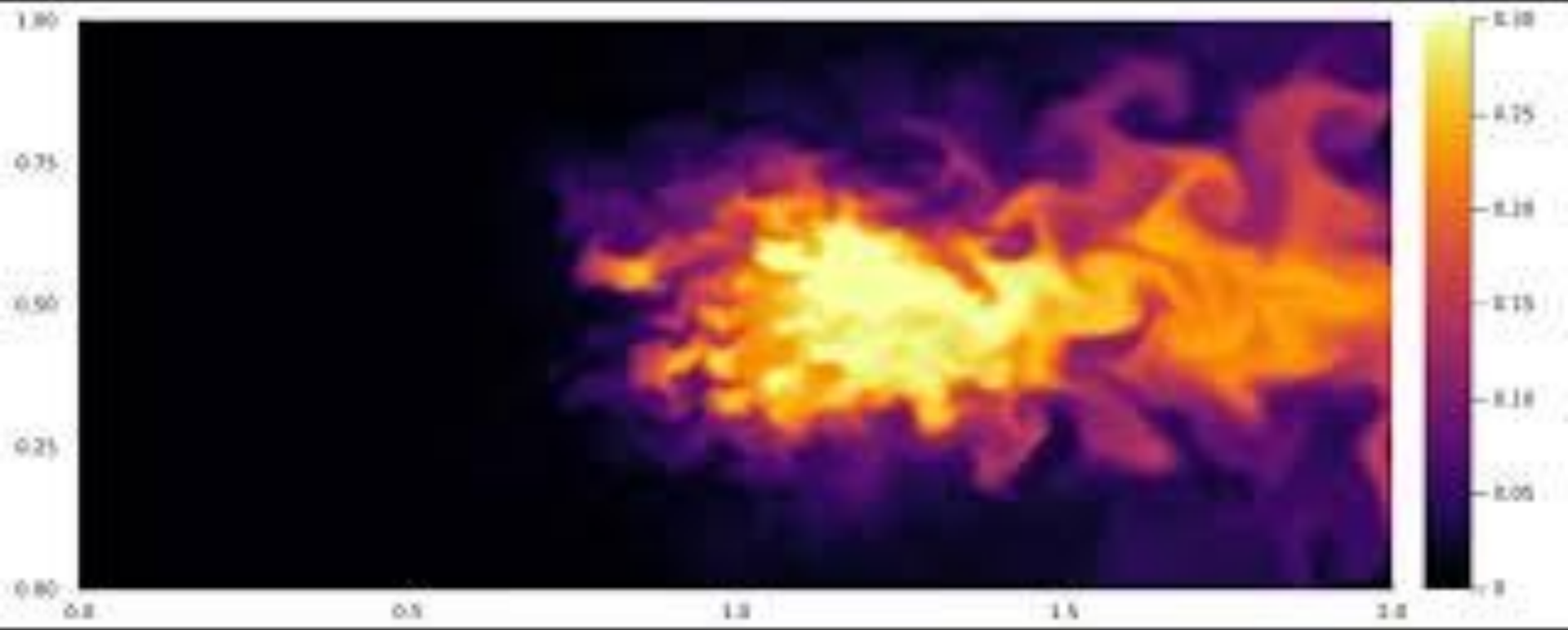
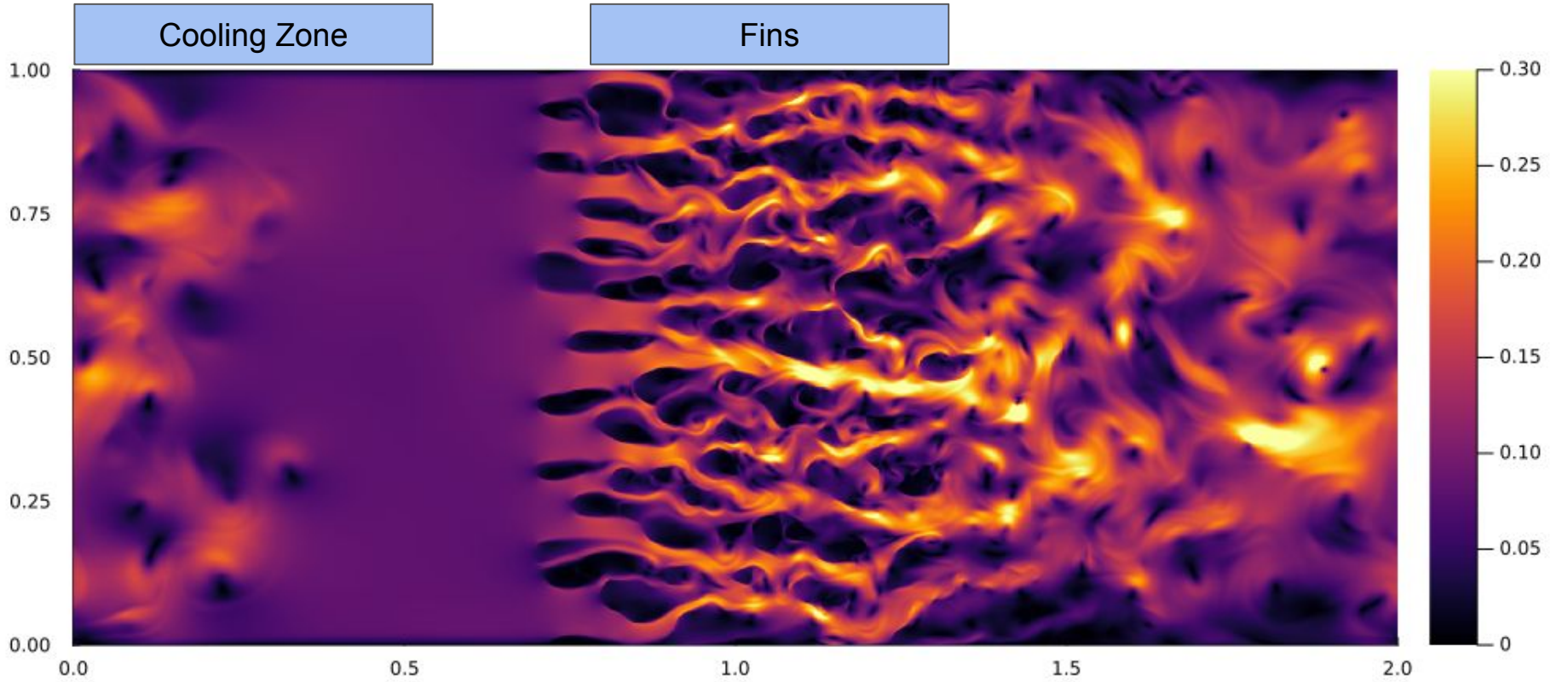

1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0


1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
0.30
0.25
0.20
0.15
0.10
0.05
0

Setup


Cooling Zone
Fins
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
0.30
0.25
0.20
0.15
0.10
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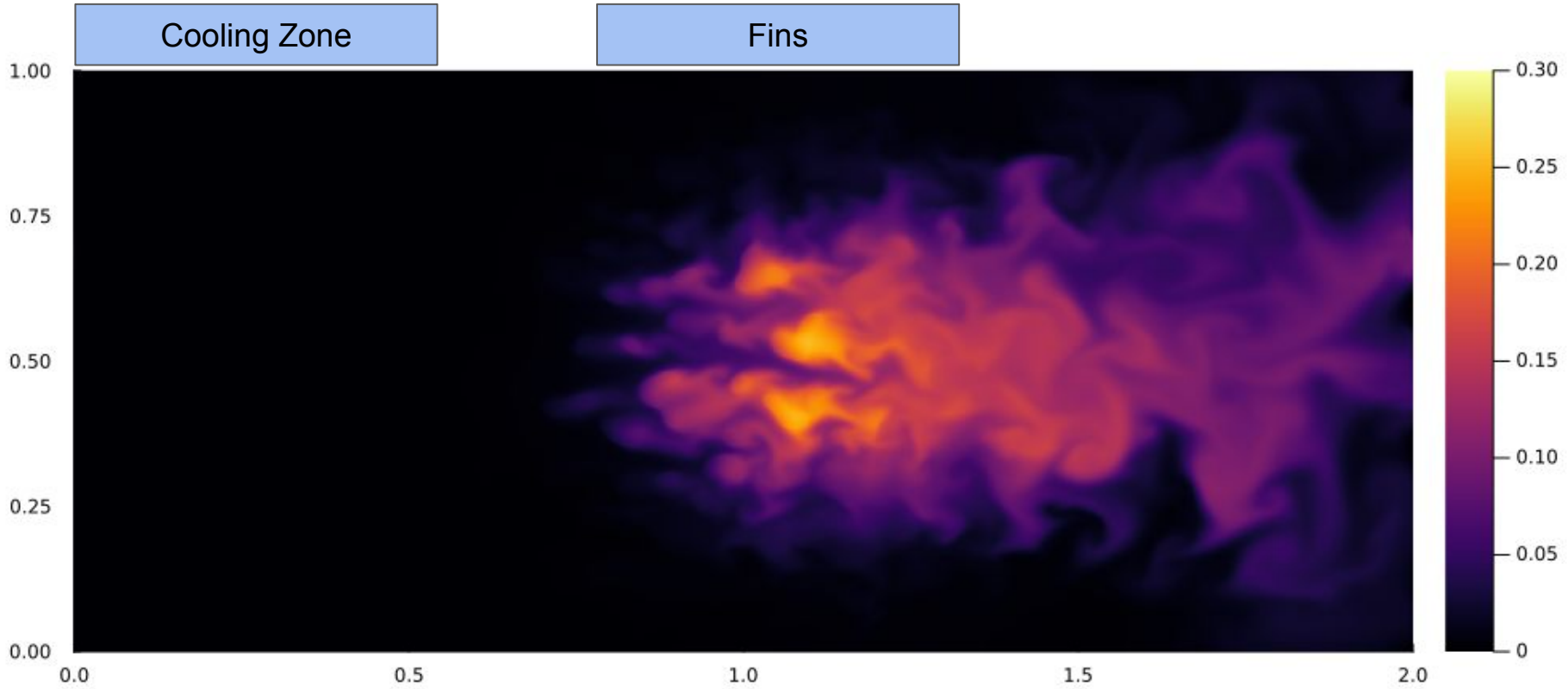
Setup


Cooling Zone
Fins
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
0.30
0.25
0.20
0.15
0.10
0.05
0

Lattice Boltzmann Algorithm

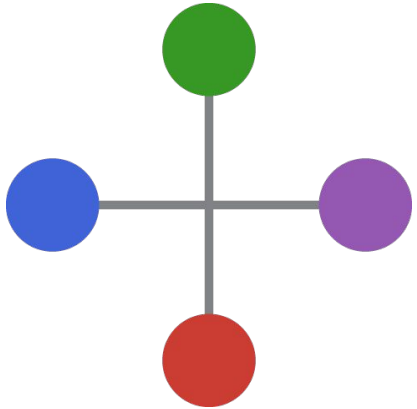
- Based on Tanabe et al. “Topology optimization using the lattice Boltzmann method for unsteady natural convection problems” and

$$\frac{\partial \boldsymbol{u}}{\partial t} + (\boldsymbol{u} \cdot \nabla)\boldsymbol{u} = -\nabla p + \nu \nabla^2 \boldsymbol{u} - \alpha_\gamma \boldsymbol{u} + \boldsymbol{e} g \beta \left(T - T_{\mathrm{ref}}\right).$$

Tech Stack

- Julia
  - Good support for autodiff
- Parallel Stencil
  - Theoretically good for xPU debugging
  - There is a course about it @ETH
    - Solving Partial Differential Equations in Parralel on GPUs

https://arxiv.org/abs/2211.15634



ParallelStencil.jl

Julia Language

GPU Speedup

1000x2000 Cells

- Nvidia RTX 4090: ~3 ms/iter

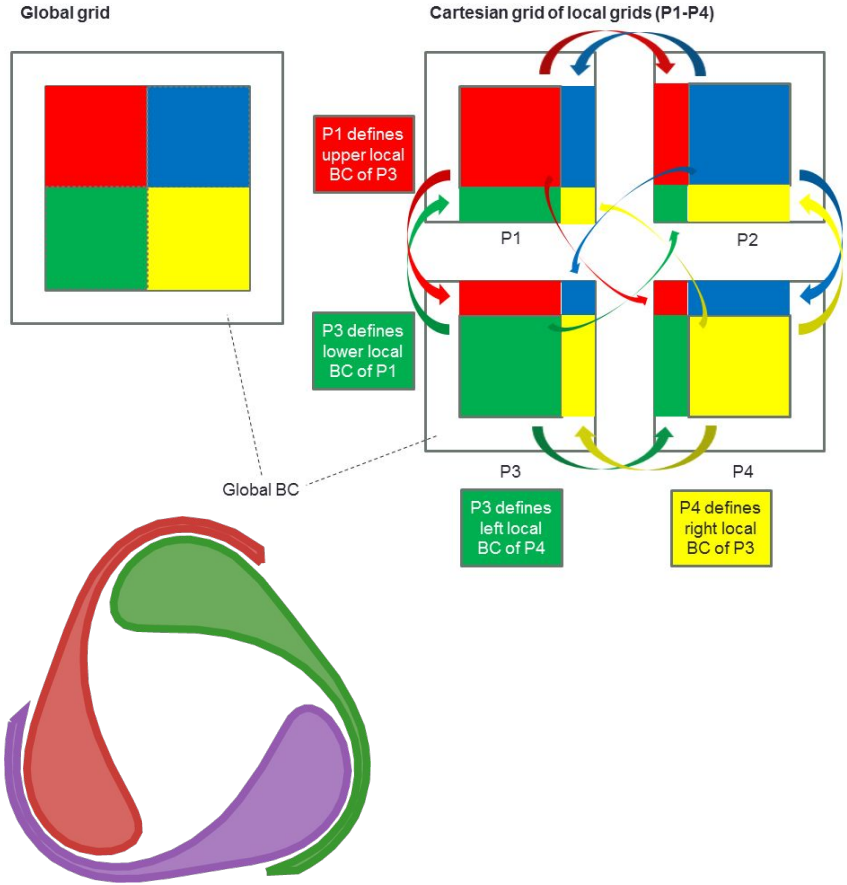
```
0.003892 seconds
0.003861 seconds
0.003820 seconds
0.003819 seconds
0.003852 seconds
0.003822 seconds
0.003898 seconds
```

- 16-core CPU: ~150 ms/iter

```
0.158382 seconds
0.182829 seconds
0.131559 seconds
0.170540 seconds
0.182400 seconds
0.139783 seconds
0.177649 seconds
0.173386 seconds
```

Future Plans

- Parallel Stencil Interfaces well with Implicit Global Grid which allows multi xPU support
  - Hide communication
  - Allows to push towards very high resolution
- Generating the Adjoint with SciMLSensitivity.jl



Git Hub Repo