University of Stuttgart
Institute for Combustion Technology (ITV)

Three-dimensional effects on the local and global structure of thermo-diffusive instabilities in premixed hydrogen flames

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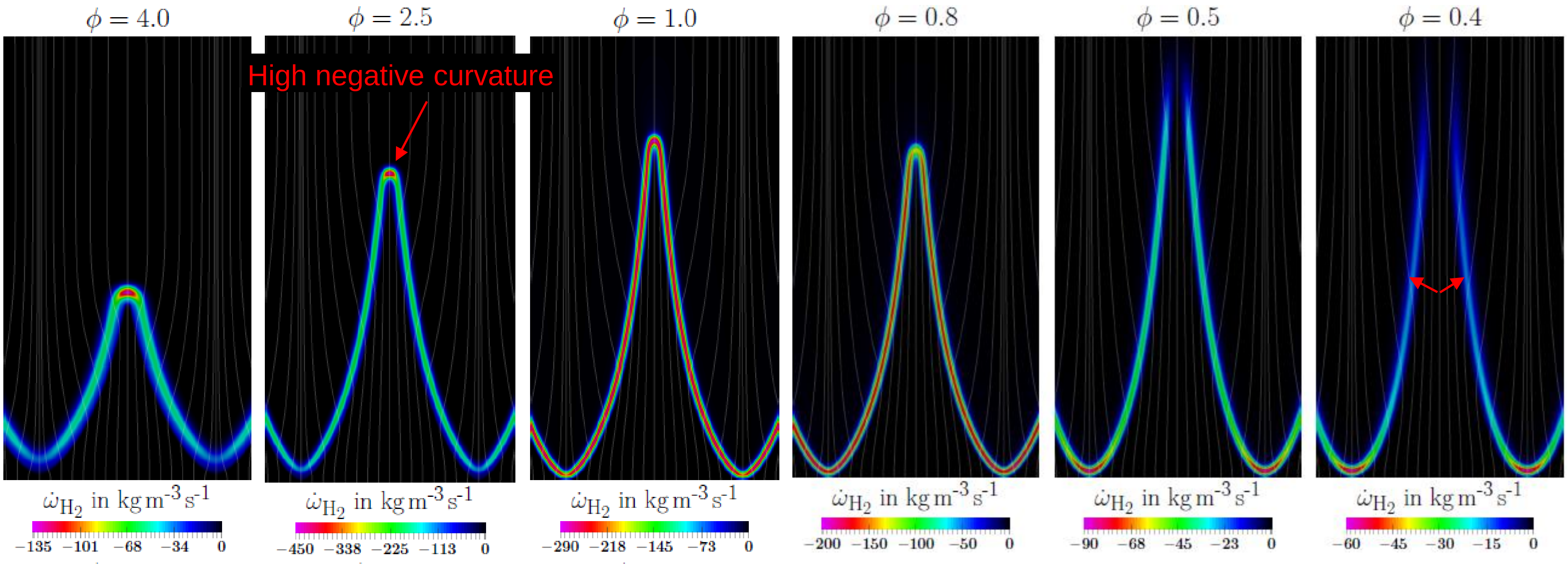
31. Deutscher Flammentag
Berlin, 27.-28. September 2023

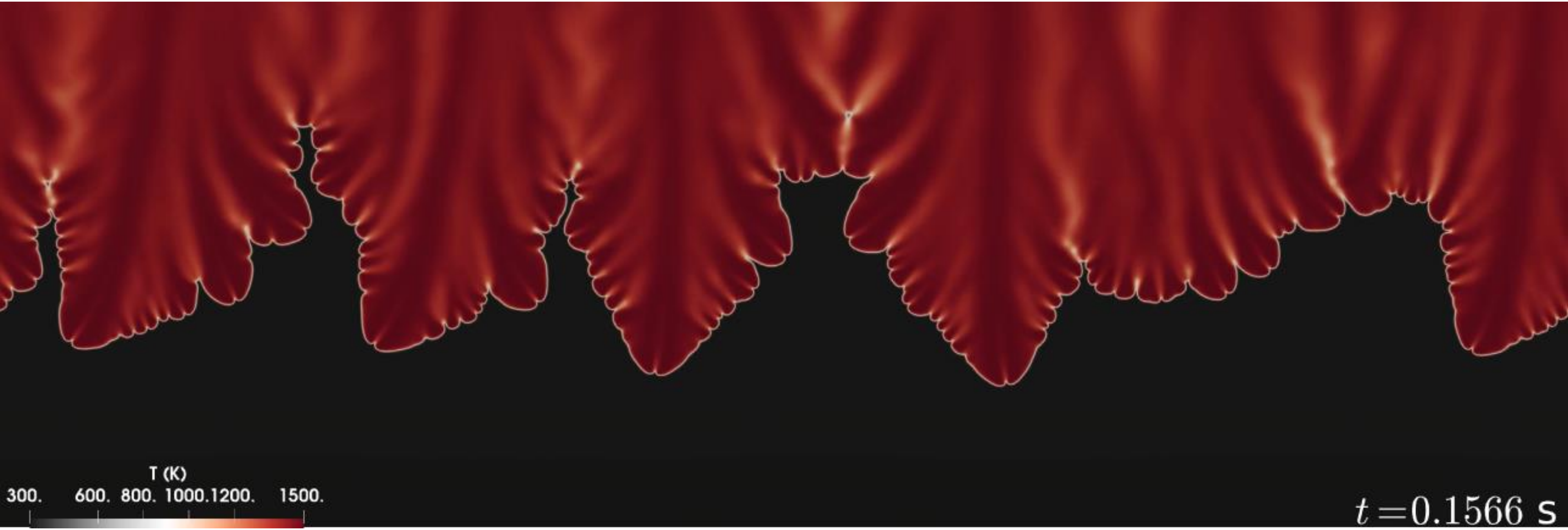
Thermo-diffusive effects in 2D Plane-Jet Flames



- Hydrogen/air at different ϕ
- Negative flame stretch at flame tip

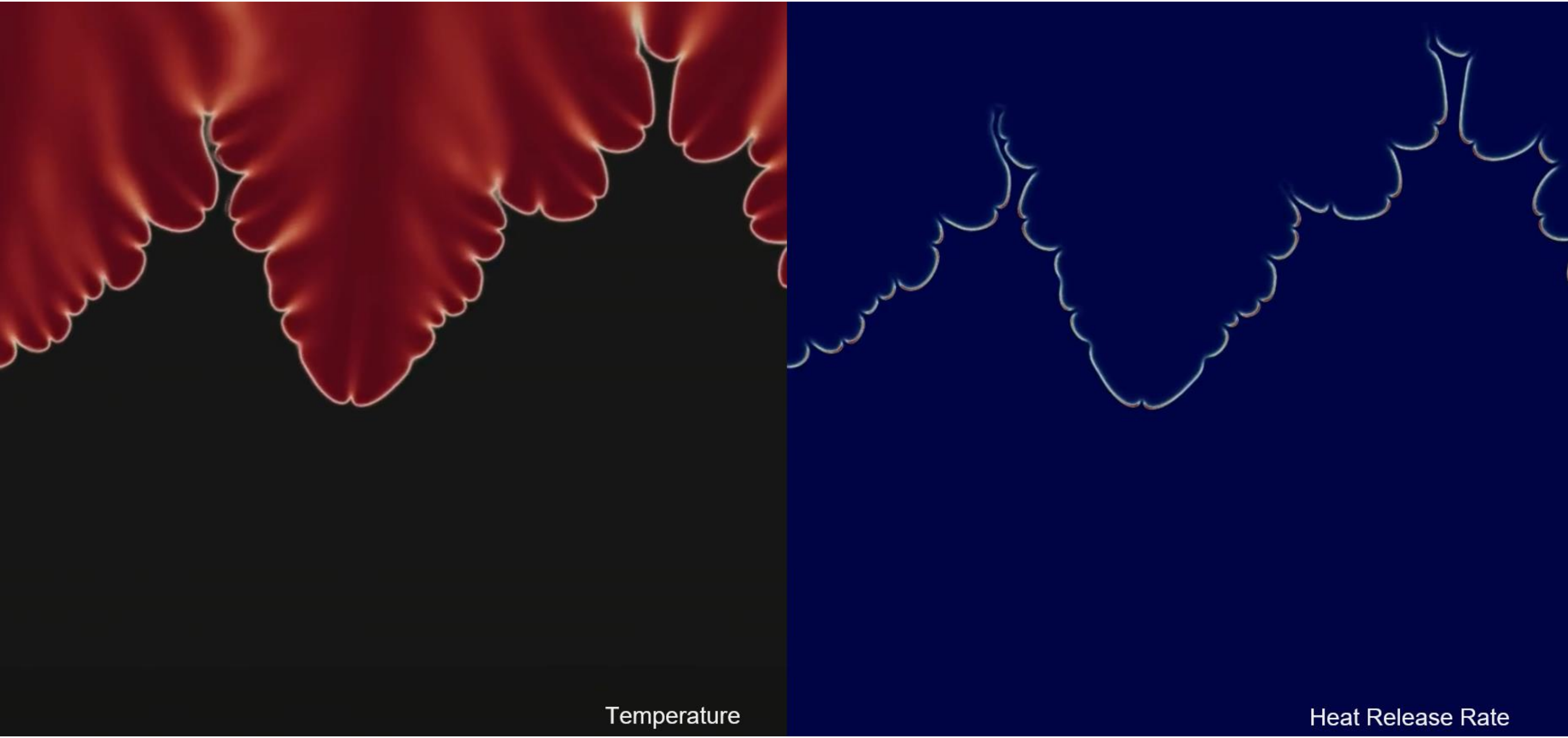
Example of thermo-diffusive instabilities

- H_2/air, $\phi = 0.4$, atmospheric conditions, initial perturbation $6\delta_{th}$
- 2D, 100 Mio. cells, 12 cm x 36 cm



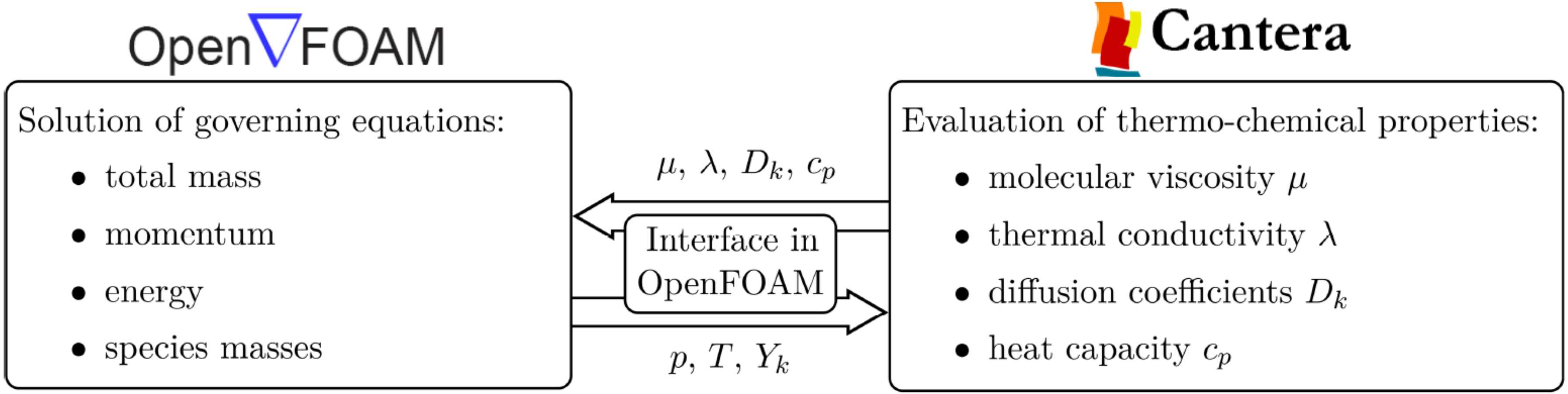
Inlet: $u = s_L$

Example of thermo-diffusive instabilities



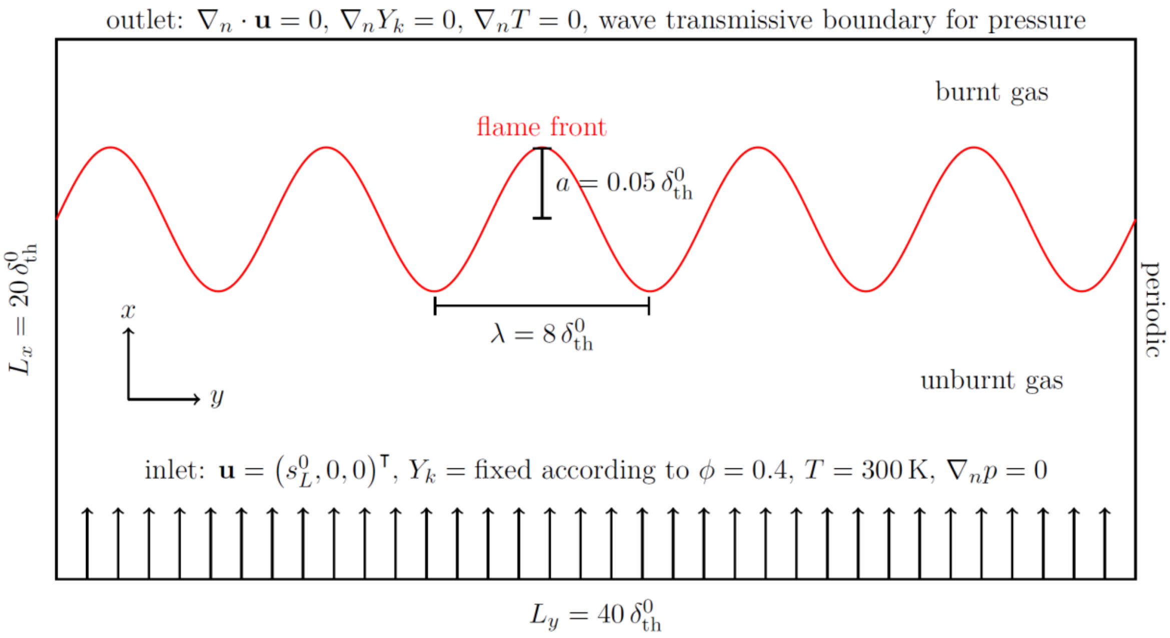
In-house OpenFOAM solver for reacting flows with preferential diffusion

- OpenFOAM has no models for detailed transport
- Reactive flow solver EBIdnsFoam uses Cantera for transport coefficients



Formation of cellular structures

Computational Setup

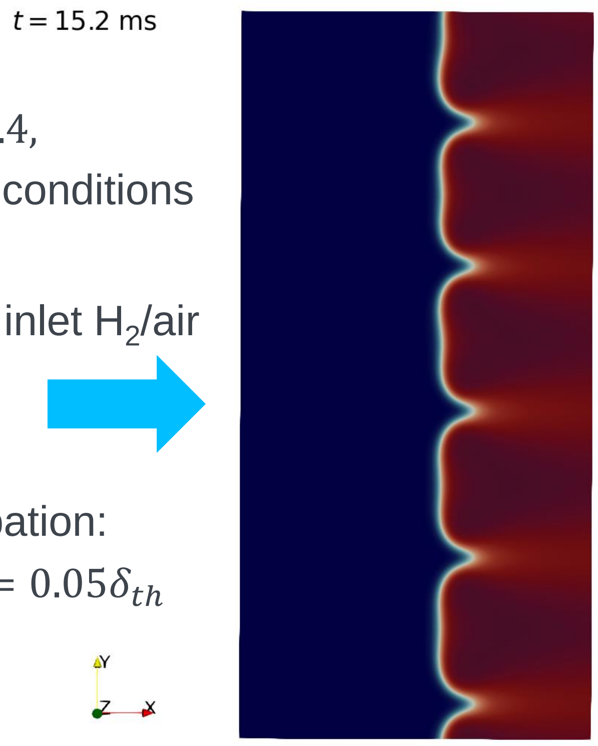


- H_2/air, $\phi = 0.4$
- Mixture-averaged diffusion vs. multi-component diffusion with Soret effect
- 2D vs. 3D

- $\vec{J}_{k,\mathrm{Mix-avg}} = -\rho D_{m,k} \nabla Y_k$
- $\vec{J}_{k,\mathrm{Multi-comp}} = \rho Y_k \frac{1}{X_k M} \sum_{i \neq k} M_i D_{k,i} \nabla X_i - D_k^T \frac{1}{T} \nabla T$

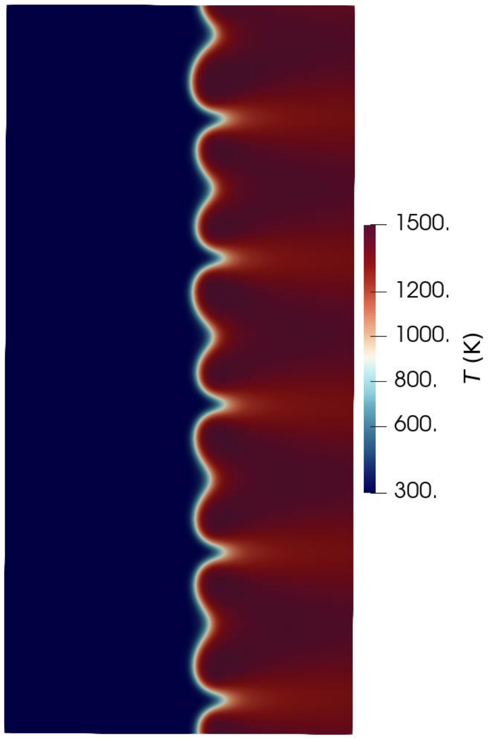
Cell formation in 2D

- H_2-air, $\phi = 0.4$, atmospheric conditions
- Initial perturbation: $\lambda = 8\delta_{th}, \mathrm{a} = 0.05\delta_{th}$



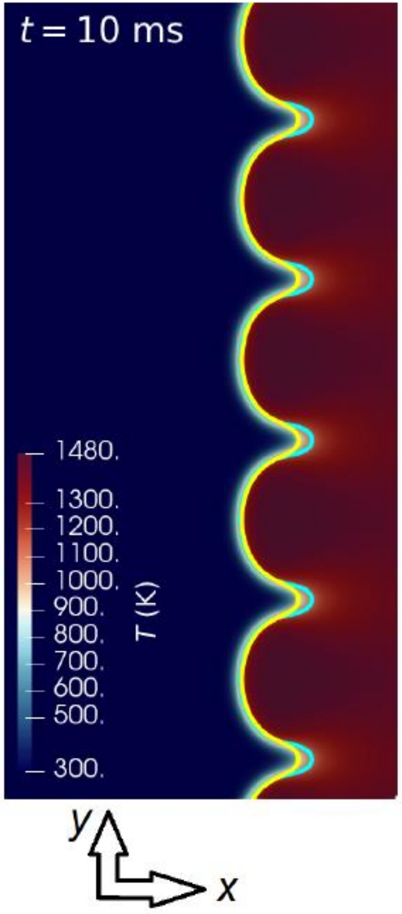
Mix.-avg.

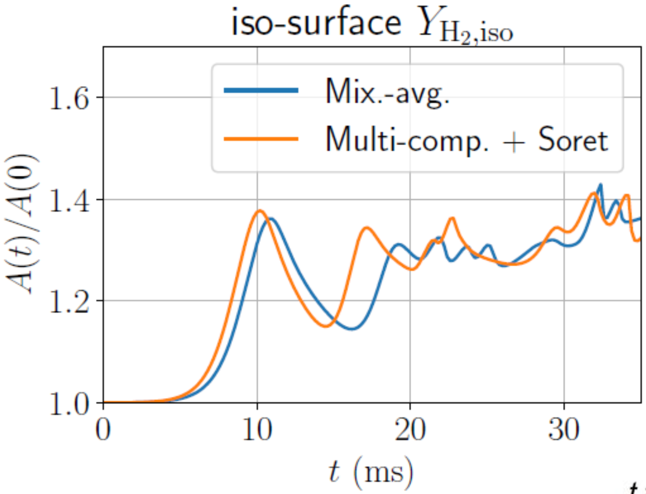
- Breakdown into secondary structures earlier with Multi-comp. diffusion

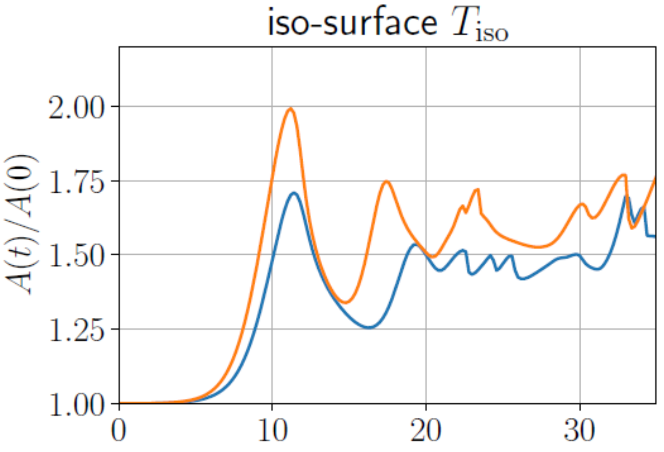


Multi-component + Soret

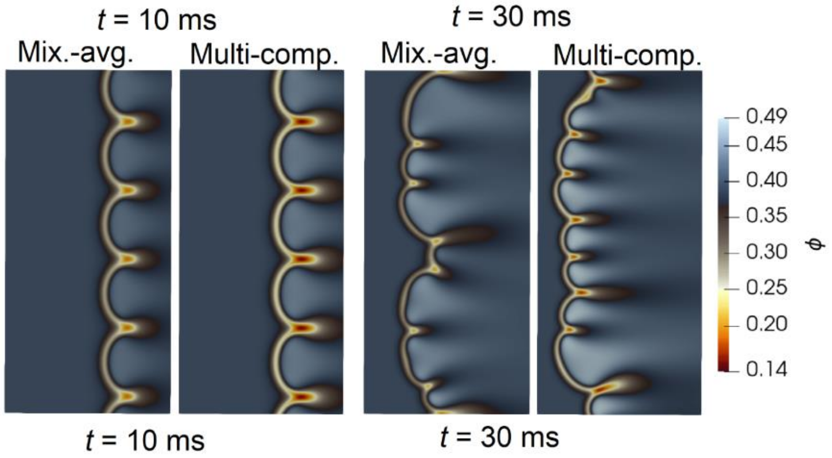
Cell formation in 2D







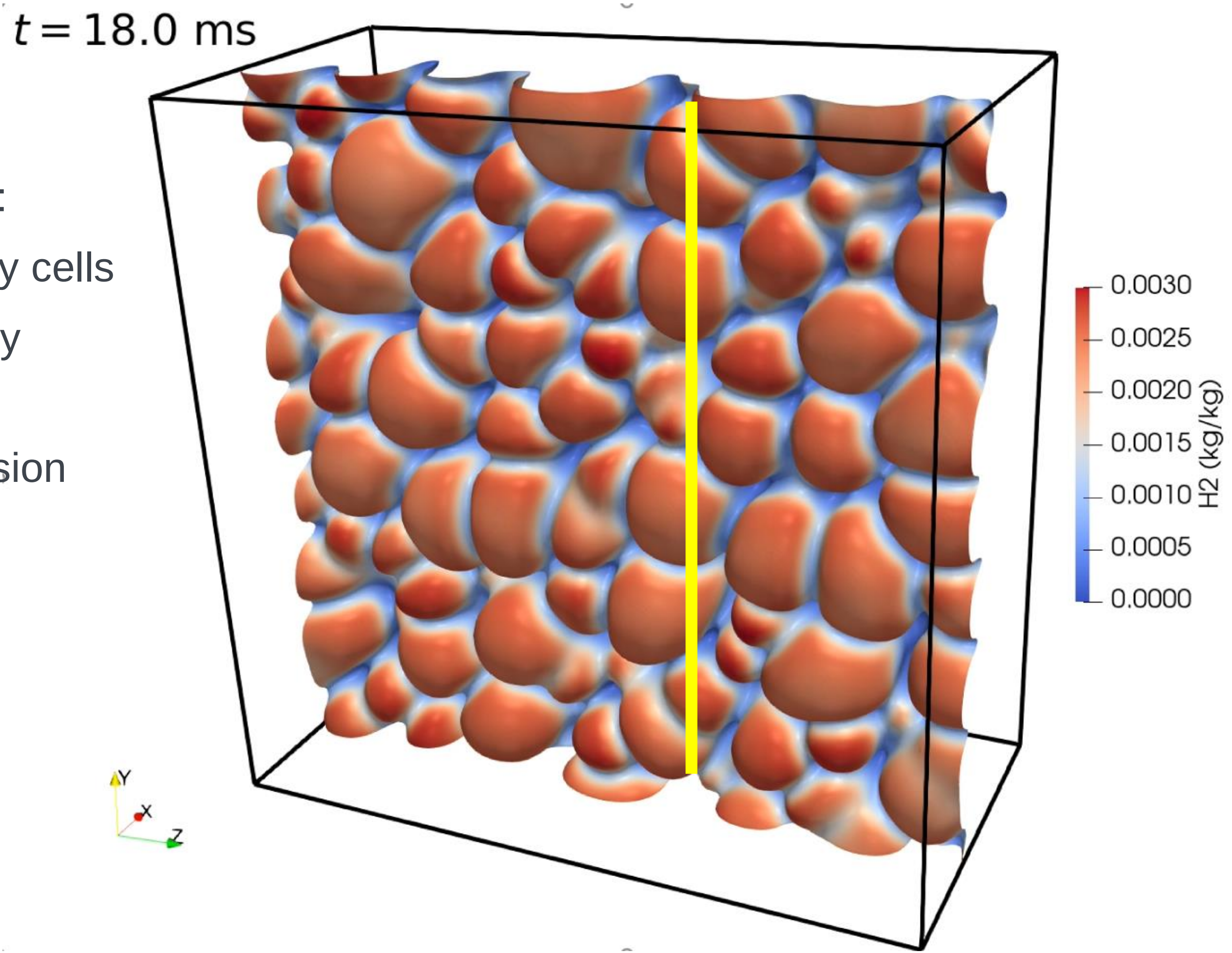
- Primary structures form at a similar rate
- Collapse into secondary structures faster with Multi-comp. + Soret



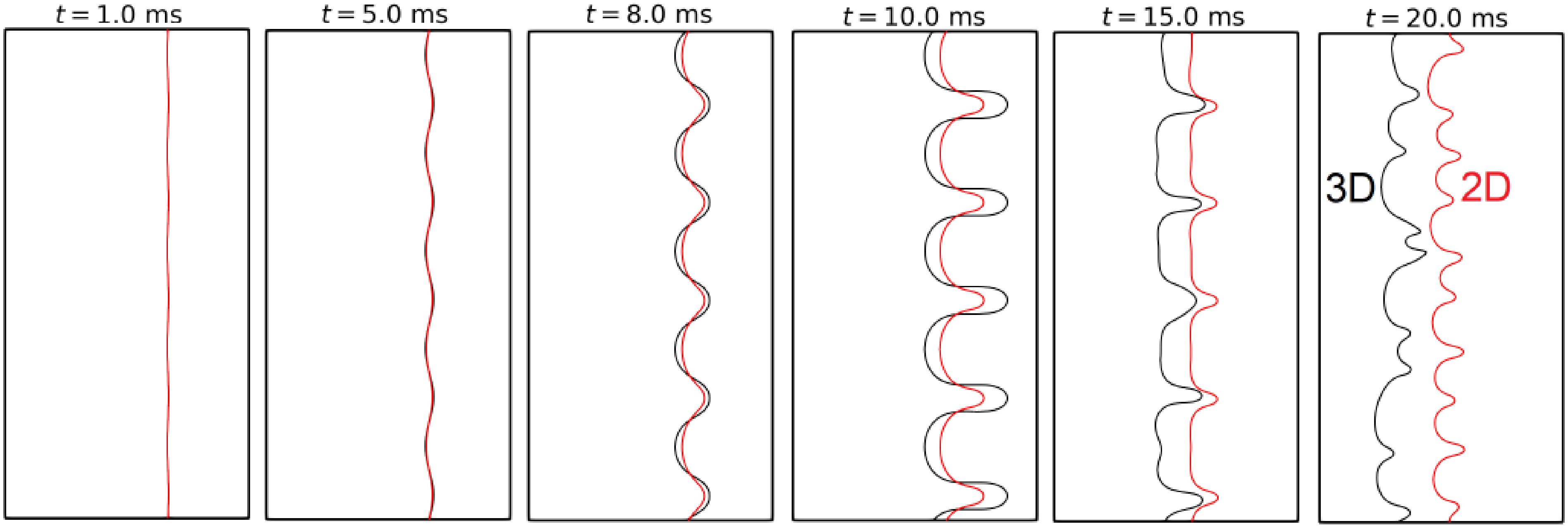
2D vs. 3D

Cell formation in 3D

- Same morphology as 2D:
  - Development of primary cells
  - Collapse into secondary structures
  - mixture-averaged diffusion model



Cell formation in 3D

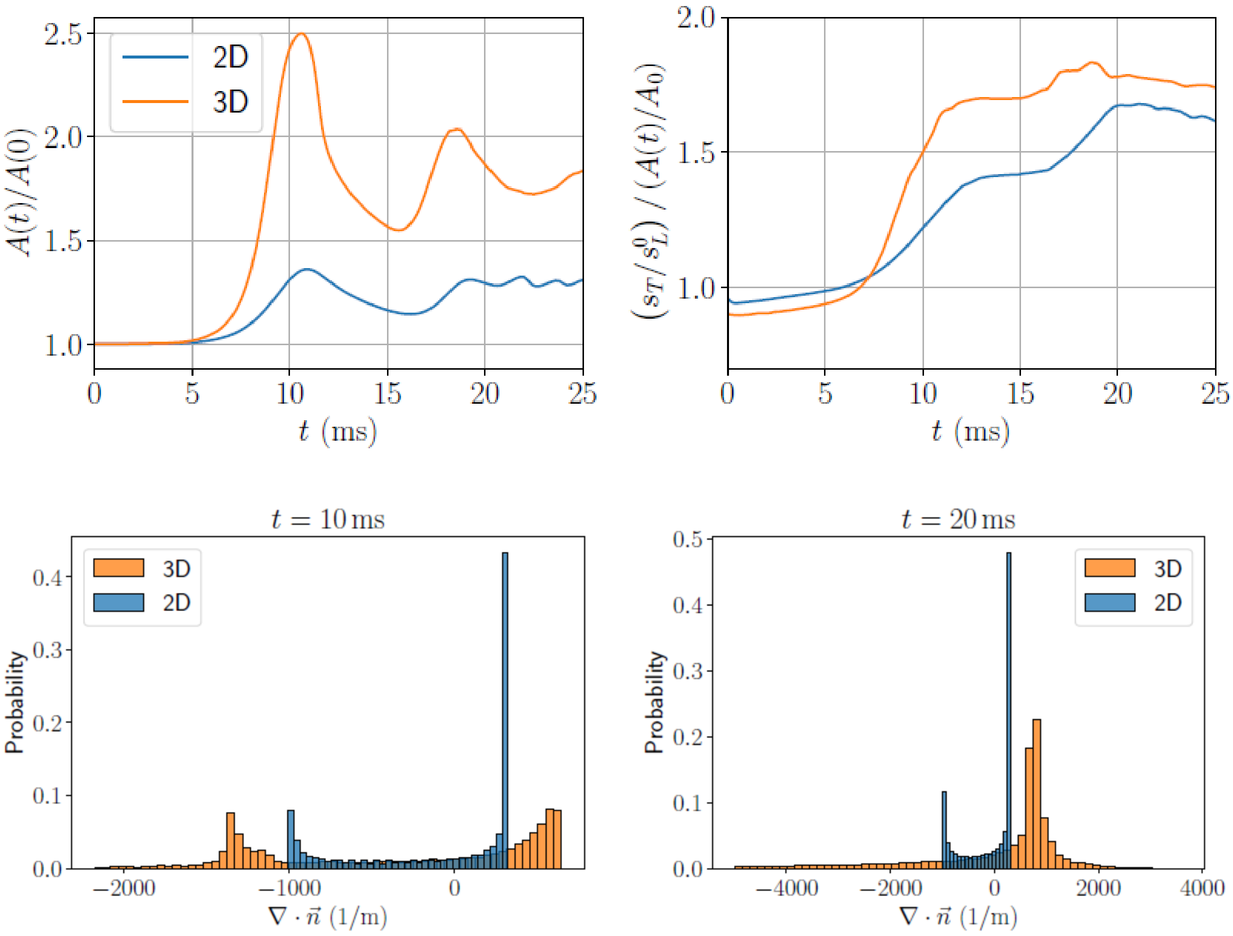


- Temperature iso-surfaces at 1100 K

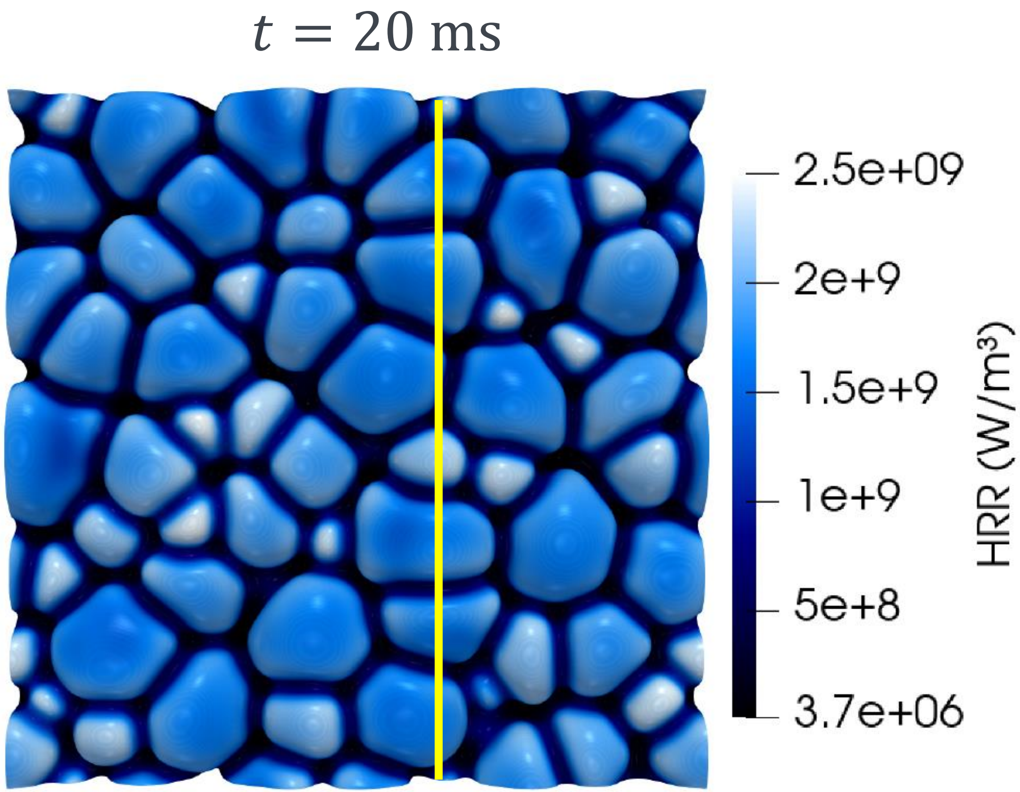
Cell formation in 3D

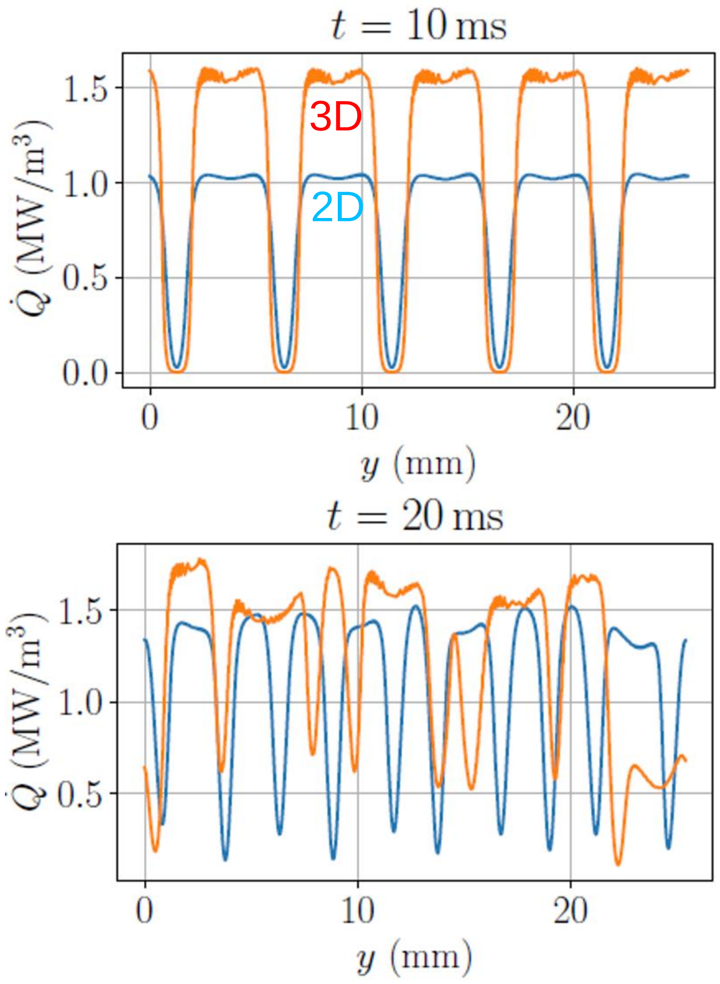
- Area growths faster in 3D

- More extreme curvatures in 3D



Cell formation in 3D





Conclusions

- Numerical investigation of preferential diffusion effects with resolved simulations
- Cell formation of lean hydrogen flames depends on diffusion model
  - Multi-component diffusion and Soret diffusion do not significantly affect linear stability regime
  - But acceleration of non-linear secondary cell formation
- 3D simulations compared to 2D simulations exhibit:
  - larger curvature ranges
  - locally more strongly enhanced heat release rates
  - faster propagation and relative surface growth
  - Influence of 3D vs. 2D larger than influence of diffusion model

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Thank you!

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