

# Preferential diffusion behavior of turbulent premixed hydrogen combustion

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# Preferential diffusion behavior of turbulent premixed hydrogen combustion

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## Hydrogen as alternative fuel

- Simplest fuel to produce from renewable electricity.
- Carbon-free.
- High burning velocity → Stabilization problems.
- High diffusivity ( $Le \approx 0.3$ ).
- Strong preferential diffusion effects.

Lean ( $\phi = 0.7$ ) premixed hydrogen-air mixtures are studied in order to understand its combustion properties.

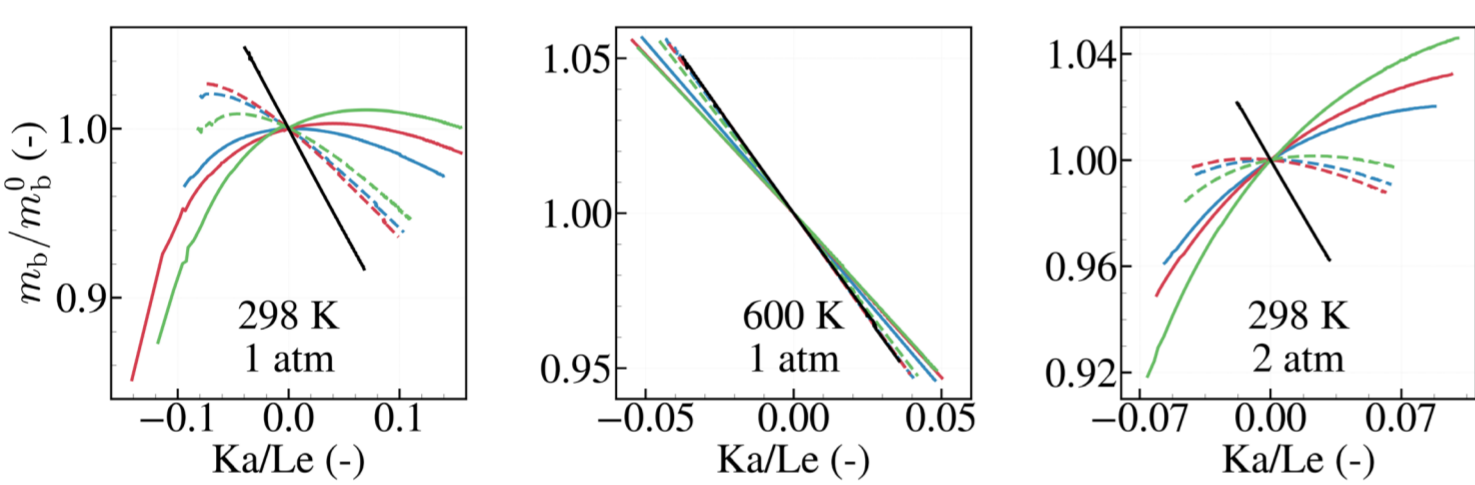
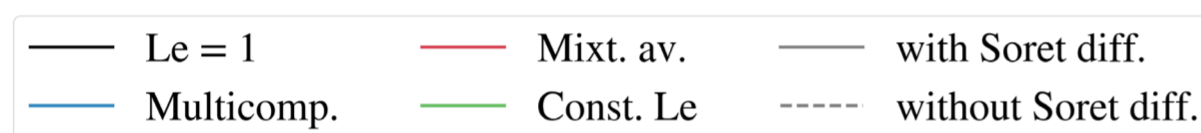
## 1-D stretched flamelets

### Mass burning rate $m_b$ of stretched flames [1]

$$\frac{m_b}{m_b^0} = 1 - \frac{Ka_i}{Le_i} + \Delta h_b \frac{\partial}{\partial h_b^0} (\ln m_b^0) + \sum_{j=1}^{N_e} Z_{j,b} \frac{\partial}{\partial Z_{j,b}^0} (\ln m_b^0)$$

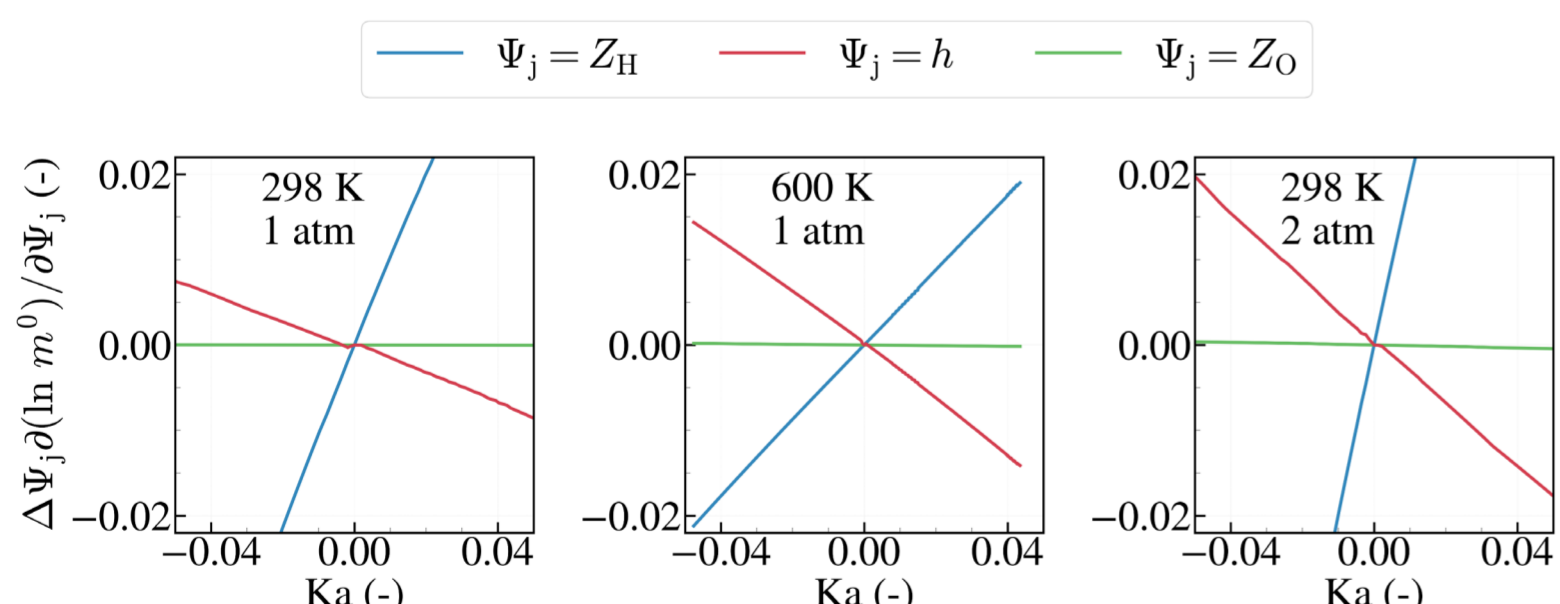
Direct stretch effect    Non-unity Lewis numbers effect

Scaled mass burning rate of 1-D freely propagating flames vs. Karlovitz number  $Ka$  (dimensionless stretch rate), for different transport models:



- $Le = 1 \Rightarrow$  Direct stretch effect  $\Rightarrow m_b$  decreases linearly with  $Ka$
- $Le \neq 1 \Rightarrow$  Preferential diffusion effects  $\Rightarrow m_b$  increases with respect to the unity  $Le$  case
- Constant  $Le$  model + Soret diffusion  $\Rightarrow$  Good approximation for lean  $H_2$  flames

Contribution of changes hydrogen content  $Z_H$ , oxygen content  $Z_O$  and enthalpy  $h$  to the mass burning rate:



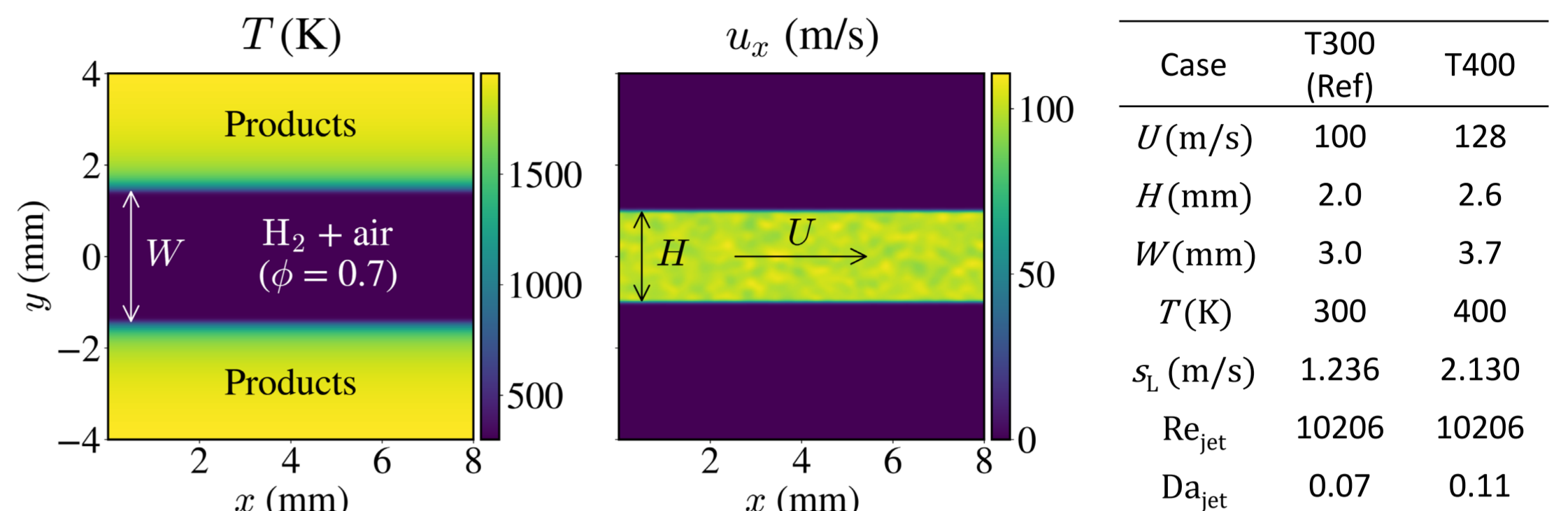
- 298 K 1 atm  $\Rightarrow$  Important contribution from  $\Delta Z_H$  and lower influence of  $\Delta h$   $\Rightarrow$  High preferential diffusion
- 600 K 1 atm  $\Rightarrow$  Contribution of  $\Delta h$  increases, compensating that of  $\Delta Z_H$   $\Rightarrow$  Lowered preferential diffusion
- 298 K 2 atm  $\Rightarrow$  Contribution of  $\Delta Z_H$  becomes more important than that of  $\Delta h$   $\Rightarrow$  Enhanced preferential diffusion

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Power and Flow  
Department of Mechanical Engineering

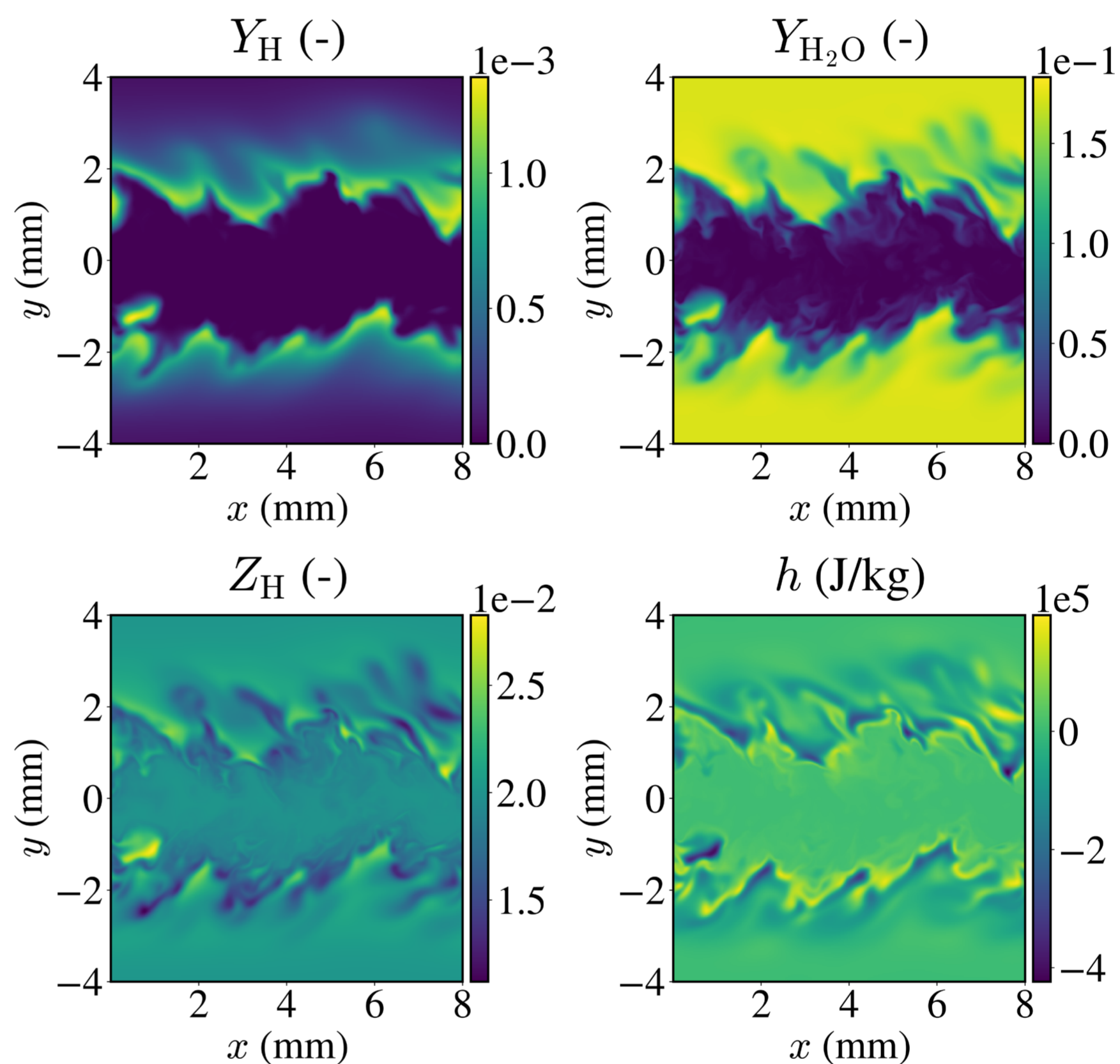
## DNS of turbulent planar mixing layers



$\Delta x = 25 \mu m$

$\Delta t = 10 ns$

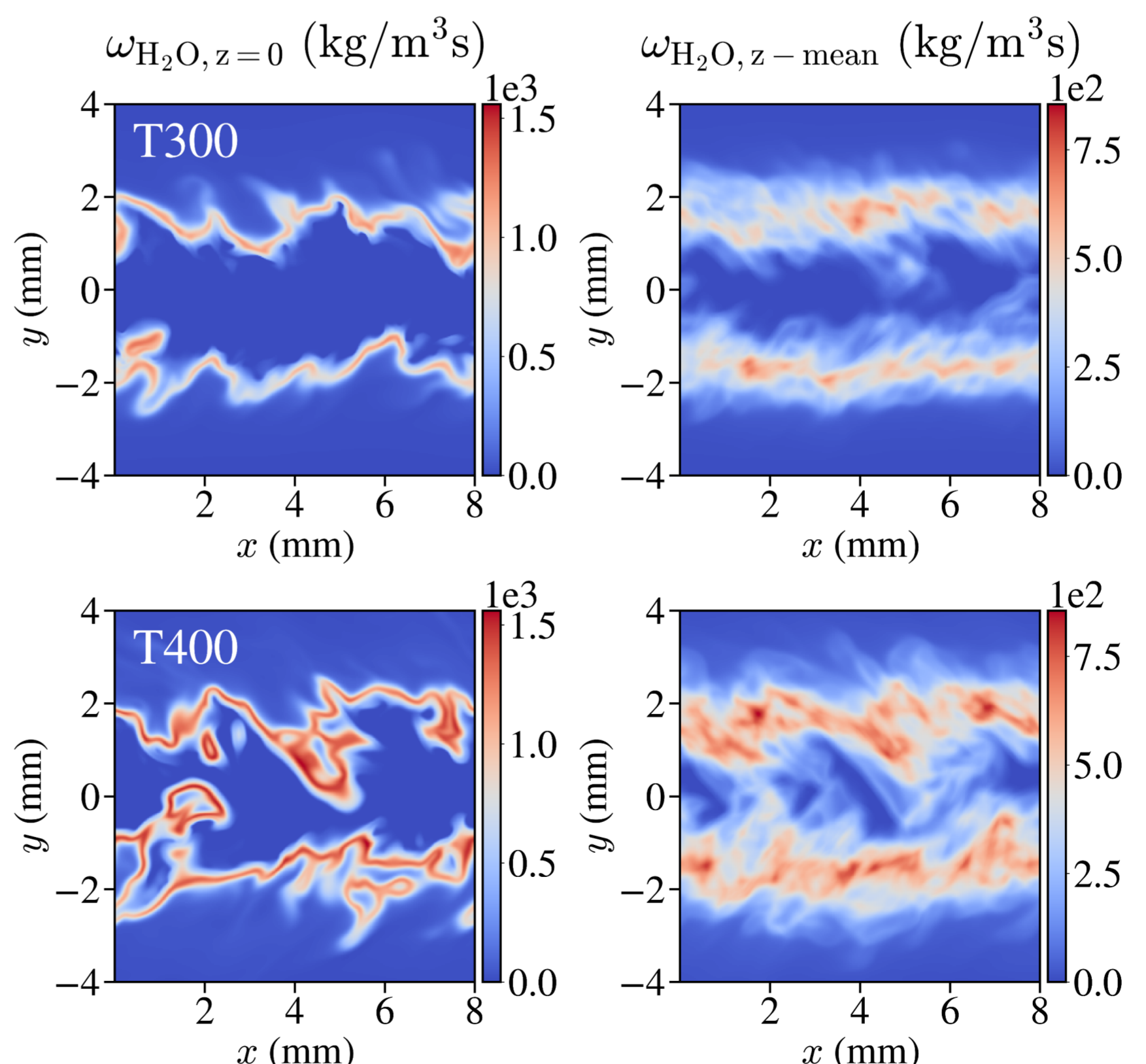
### Reference case



Regions with fuel enrichment by diffusion and accumulation of products.

Variation of  $Z_H$  and  $h$  along the flame front due to stretch. This leads to higher burning rates.

### Effect of increasing temperature



- Enhanced burning rates
- Larger scale structures
- More equal distribution of source terms along the flame front

## References

[1] van Oijen et al. (2016). Prog. Energy Combust. Sci. 57, 30.