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 ≈ 0.3).
- Strong preferential diffusion effects.

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

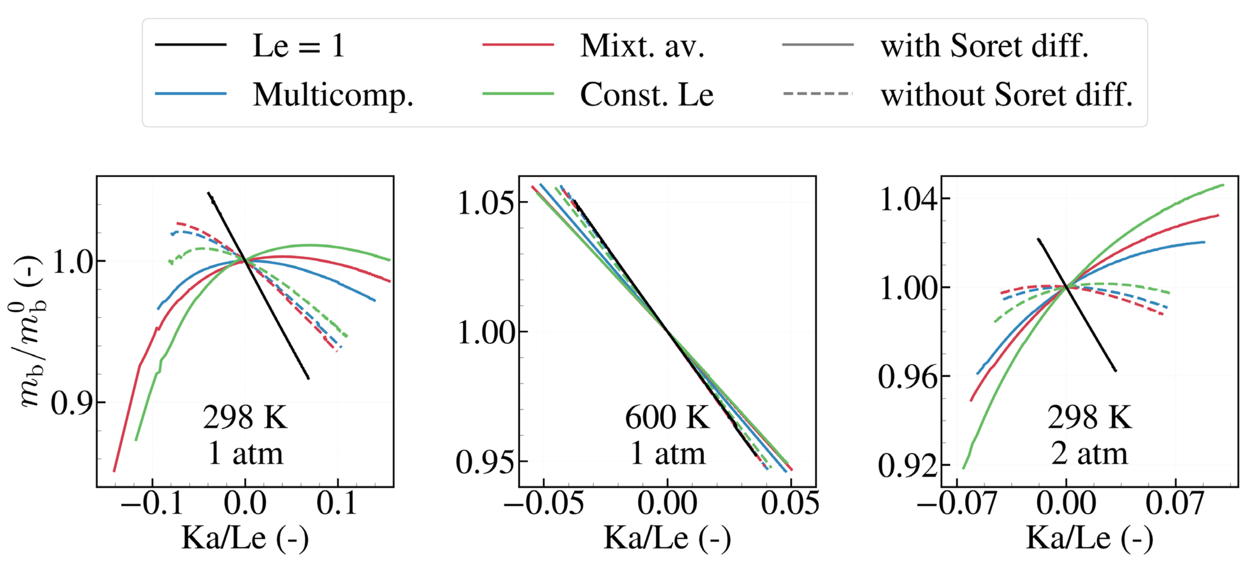
1-D stretched flamelets

Mass burning rate m_b of stretched flames [1]

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

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:

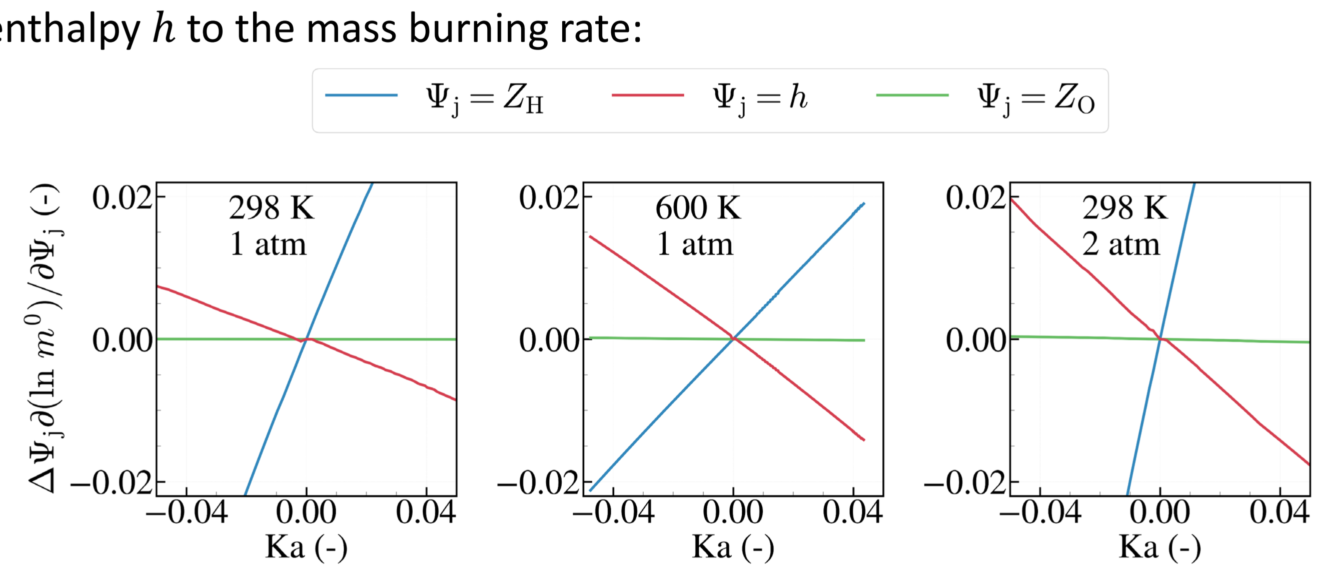


Le = 1 ⇒ Direct stretch effect ⇒ m_b decreases linearly with Ka

Le ≠ 1 ⇒ Preferential diffusion effects ⇒ m_b increases with respect to the unity Le case

Constant Le model + Soret diffusion ⇒ 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:

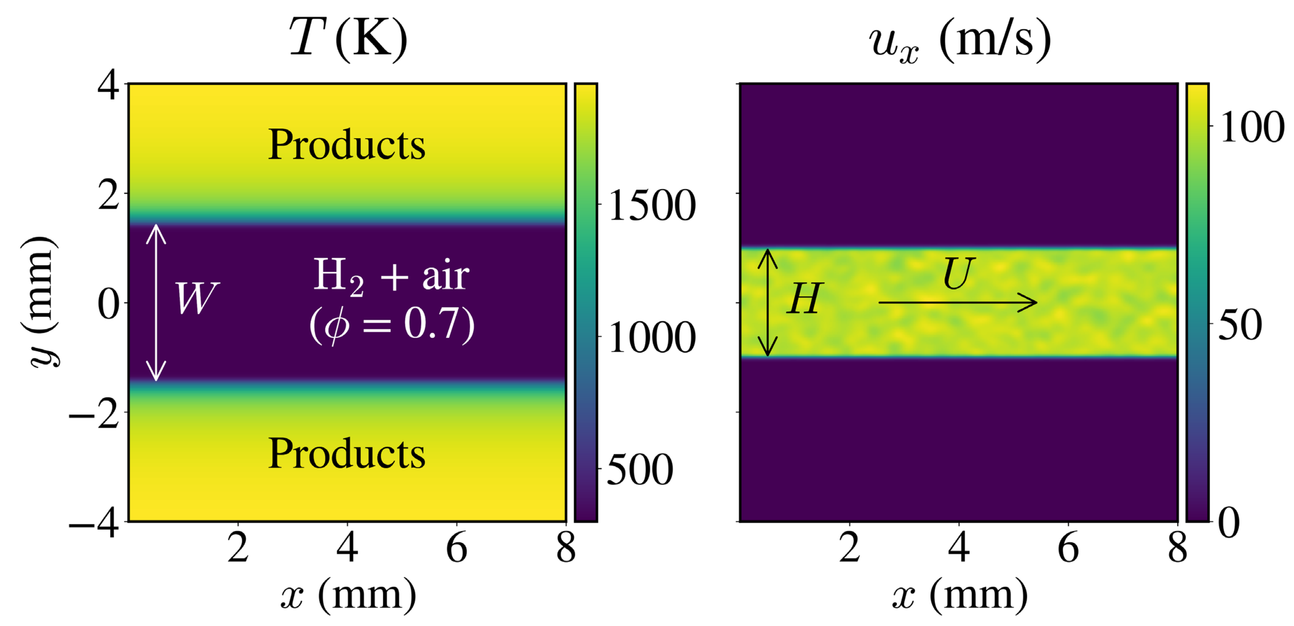


298 K 1 atm ⇒ Important contribution from ΔZ_H and lower influence of Δh ⇒ **High preferential diffusion**

600 K 1 atm ⇒ Contribution of Δh increases, compensating that of ΔZ_H ⇒ **Lowered preferential diffusion**

298 K 2 atm ⇒ Contribution of ΔZ_H becomes more important than that of Δh ⇒ **Enhanced preferential diffusion**

DNS of turbulent planar mixing layers

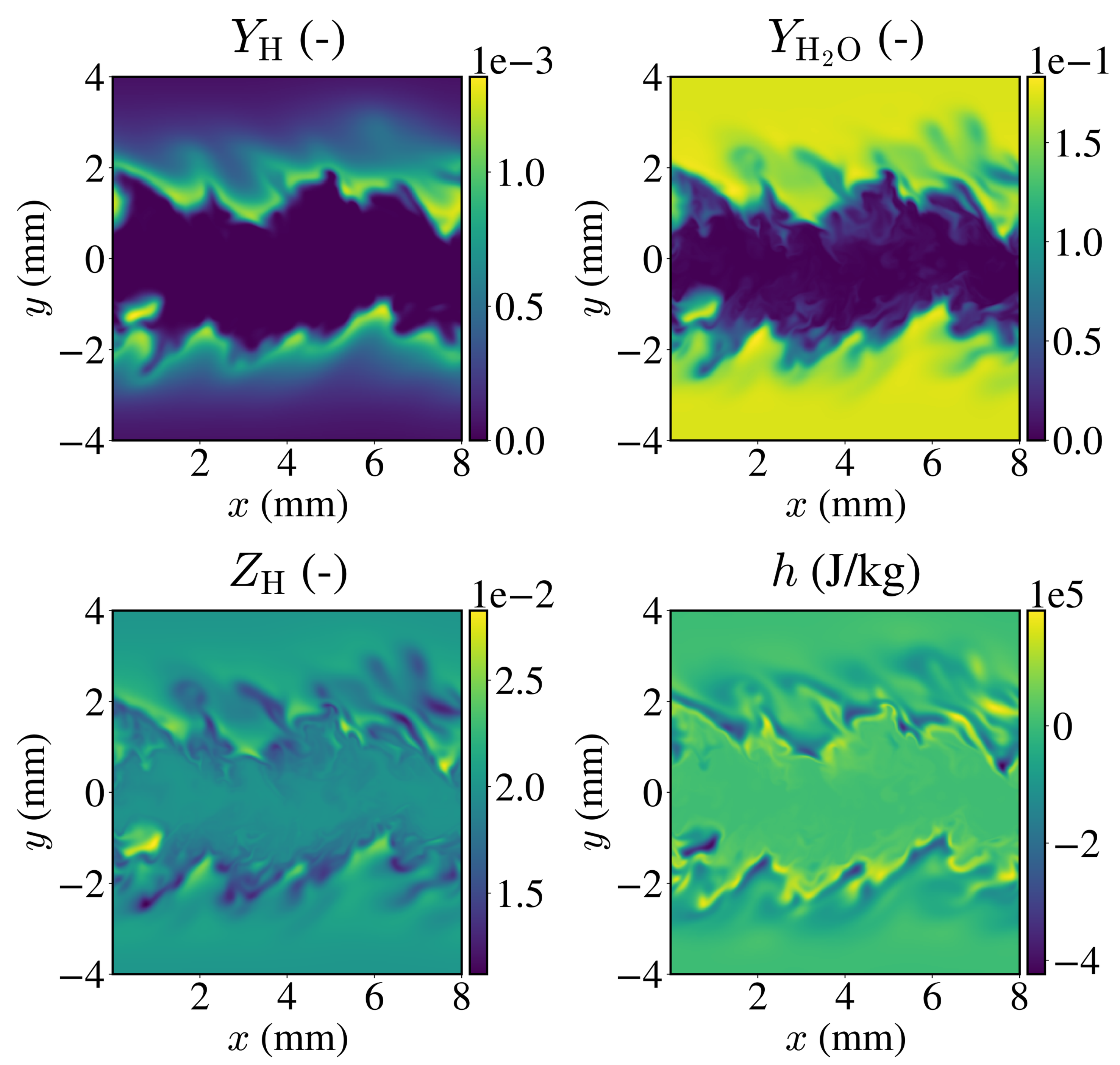


Case	T300 (Ref)	T400
U (m/s)	100	128
H (mm)	2.0	2.6
W (mm)	3.0	3.7
T (K)	300	400
s_L (m/s)	1.236	2.130
Re_{jet}	10206	10206
Da_{jet}	0.07	0.11

$\Delta x = 25$ µm

$\Delta t = 10$ ns

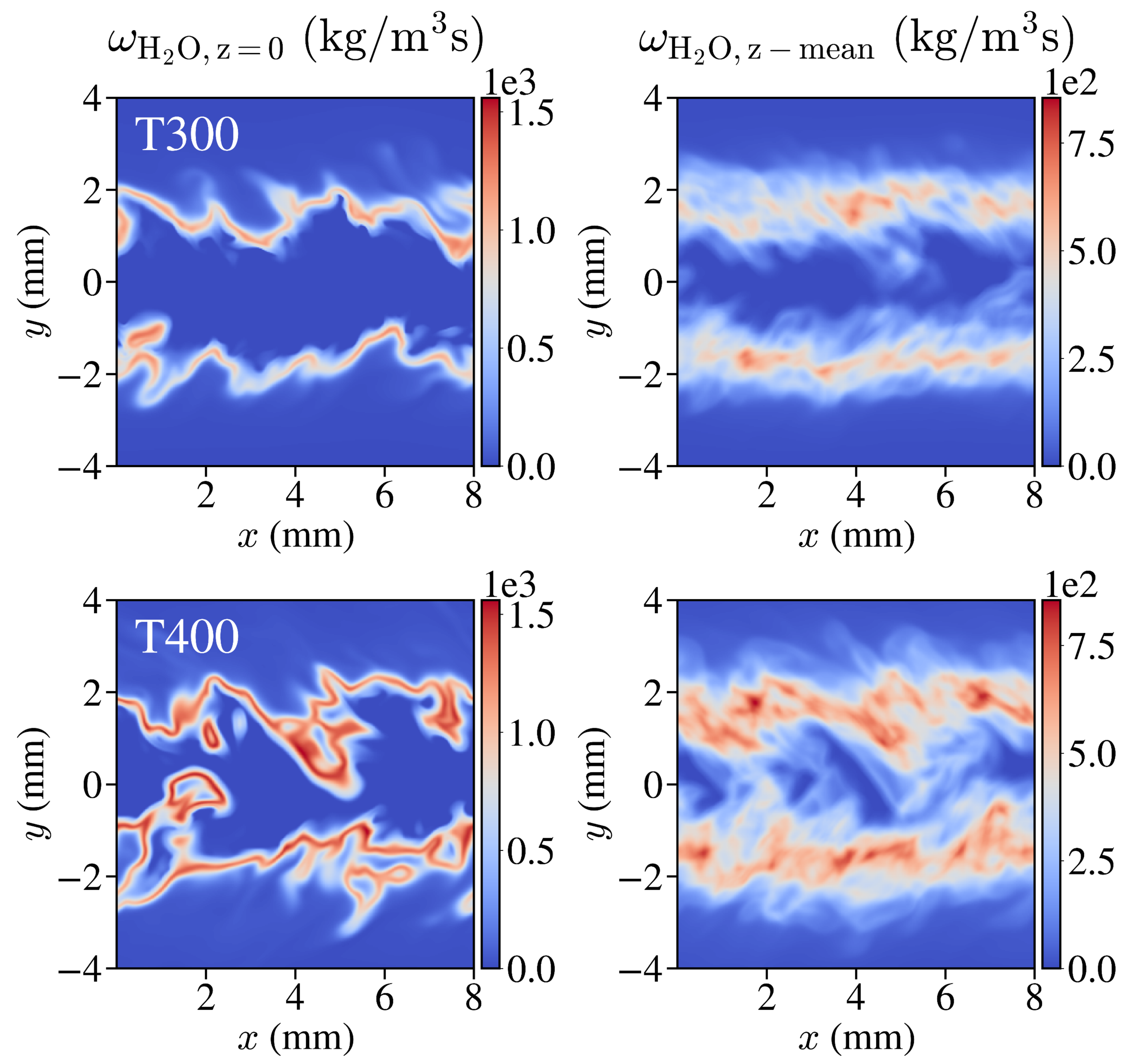
Reference case



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

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References

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

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