Structure of Turbulent, Lean, H_2/Air Flames

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Introduction

Motivation

- Understanding the physical mechanisms through which the thermal-diffusive properties of the fuel/air mixture influence the overall turbulent burning rate [1].
- Laminar burning velocity is altered by flame strain K_S and flame curvature K_C. The total flame stretch rate is given by

$$\kappa = K_S + s_d K_C$$

- The burning rate sensitivity to stretch exists because local species and radical concentrations, as well as temperature profiles, are altered by strain and curvature.
- Characterize the mechanisms through which the average reactant consumption rates increase with increasing turbulence intensity.
- Use an approach to understand how turbulence modifies global burning rates based upon so-called "leading points" [2], which are intrinsically *local* properties of the turbulent flame.

Methods

- Direct numerical simulations (DNS) of highly stretch-sensitive flames, described by Aspden et al. [3].
- Lean H_2/Air flames (ϕ = 0.31) at moderate and high turbulent intensities.
- Flame is chosen as an isotherm of T=1088K where the fuel consumption peaks as shown in Figure 1.

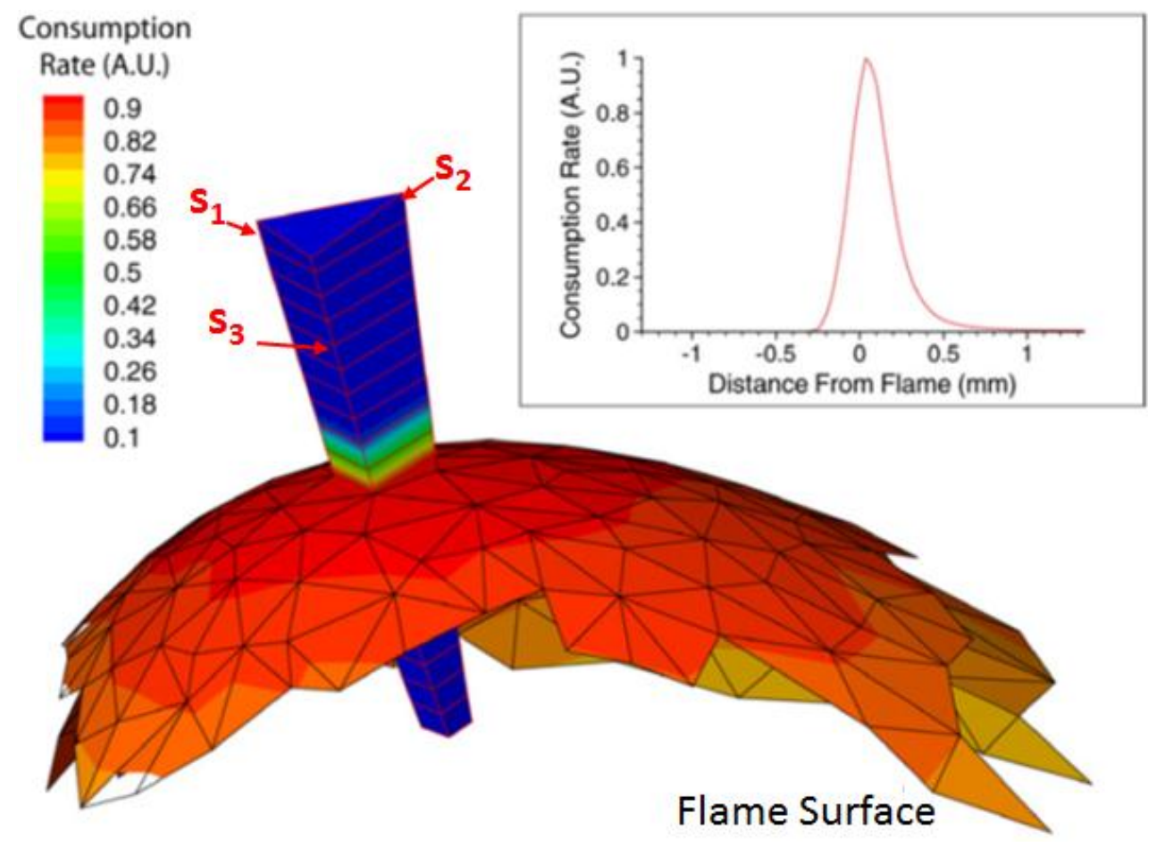

Figure 1. Prism shaped volume constructed using curves locally normal to the isotherm [4]

Objectives

WHAT?
To characterize the structure of a strongly stretch-sensitive flame brush.

HOW?
By comparing local statistics with those averaged over the entire brush

Results

Case	Turbulence Intensity,	Turbulent straining rate,
A31	3.69 $\left(s_{L0}/\delta_{T0}\right)$	7.38
B31	17.1 $\left(s_{L0}/\delta_{T0}\right)$	34.2
C31	32.9 $\left(s_{L0}/\delta_{T0}\right)$	65.8
D31	107 $\left(s_{L0}/\delta_{T0}\right)$	213.6

Table 1. Summary of cases[5]

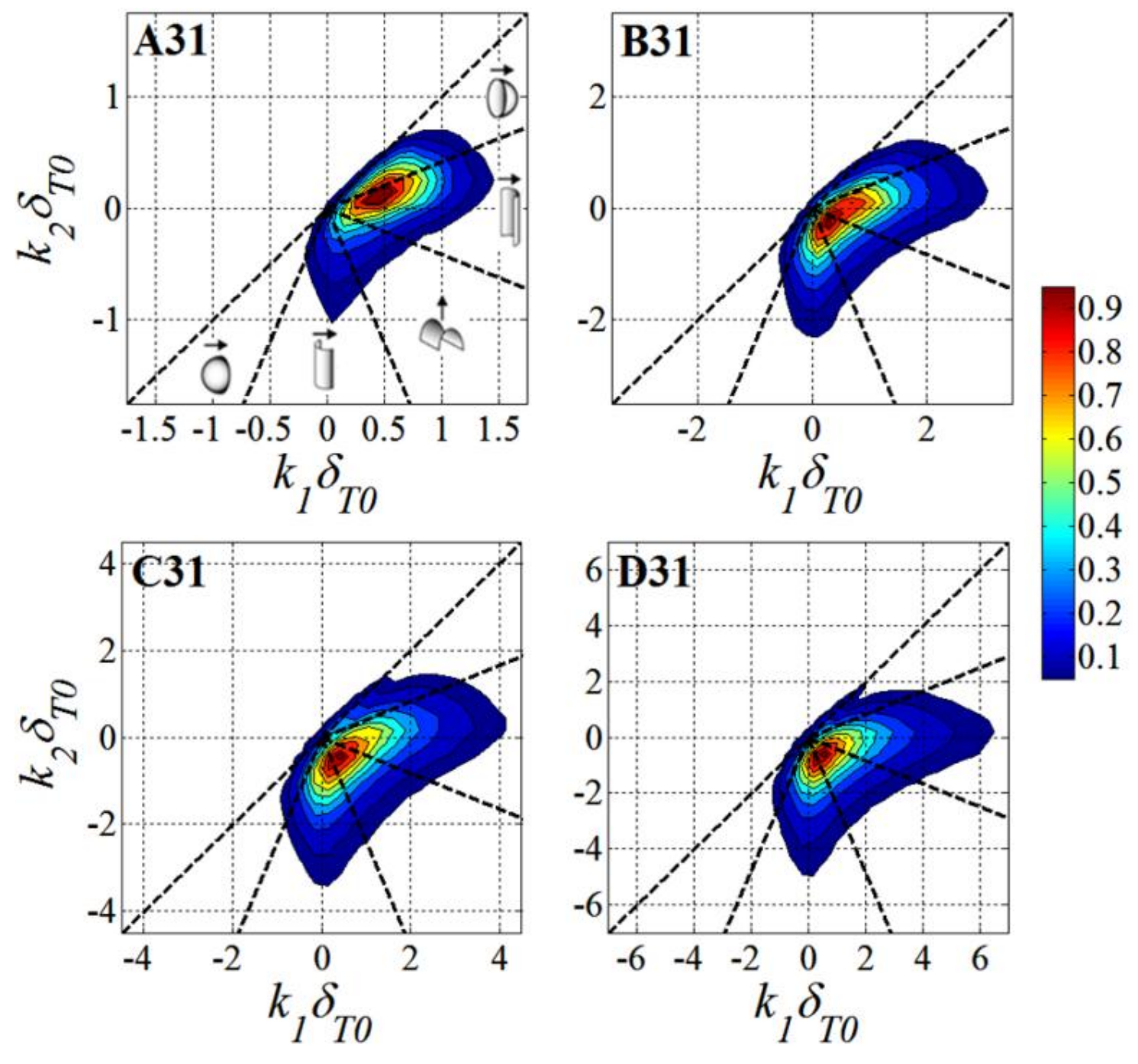

Figure 2. Fuel consumption weighted JDF's of principal curvatures

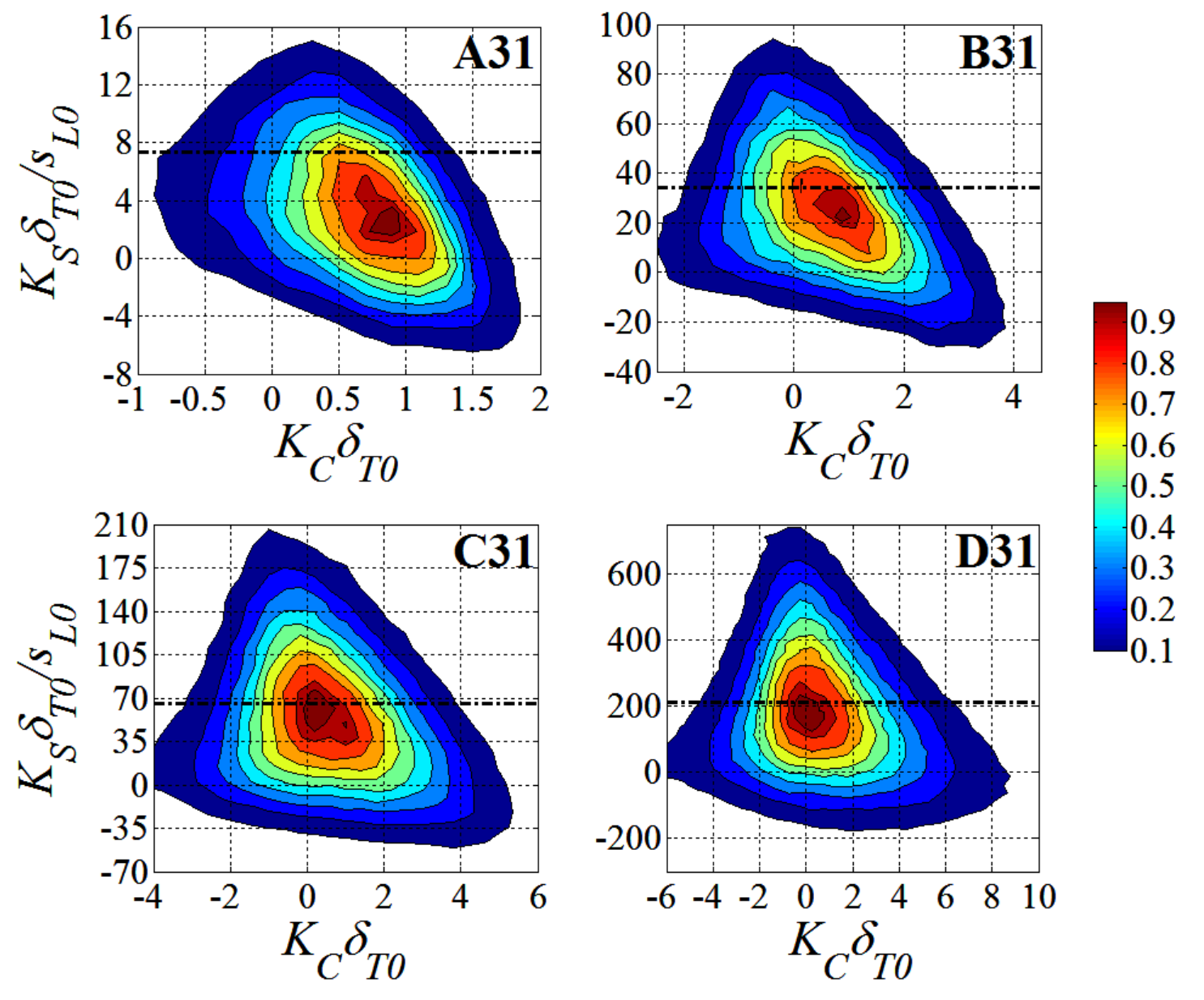

Figure 3. JDF of curvature and strain on isotherm T=1088K.

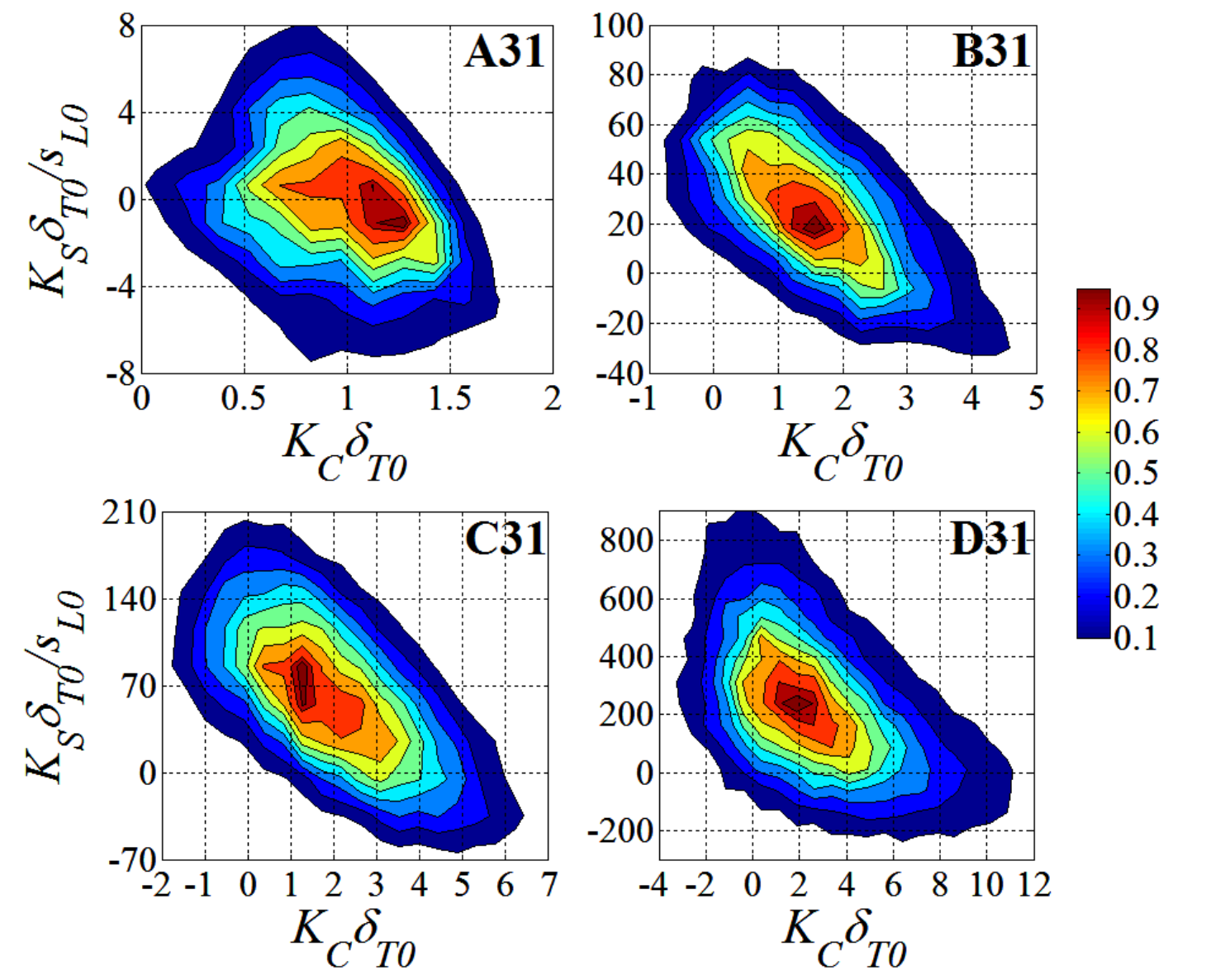

Figure 4. JDF of curvature and strain at the leading edge.

Observations

1. Flame elements

- Cylindrical/spherical shape convex toward the reactants for low turbulence.
- Wider variety of geometries for higher turbulence.

2. **The largest range of K_S** values occurs at locations where $K_C \sim 0$ and the range of K_S increases with turbulence.

Analysis

1. Local chemical time scales are the same order of magnitude as the eddy turnover time with increasing turbulent.
2. The leading edge of the flame was "critically stretched" – and the burning velocity approaches its maximum value,
3. Low curvature regions occur most frequently as seen in Figure 6.
4. Much of the fuel is consumed by flame elements with $K_C \sim 0$. The importance increases with increasing turbulence intensity.

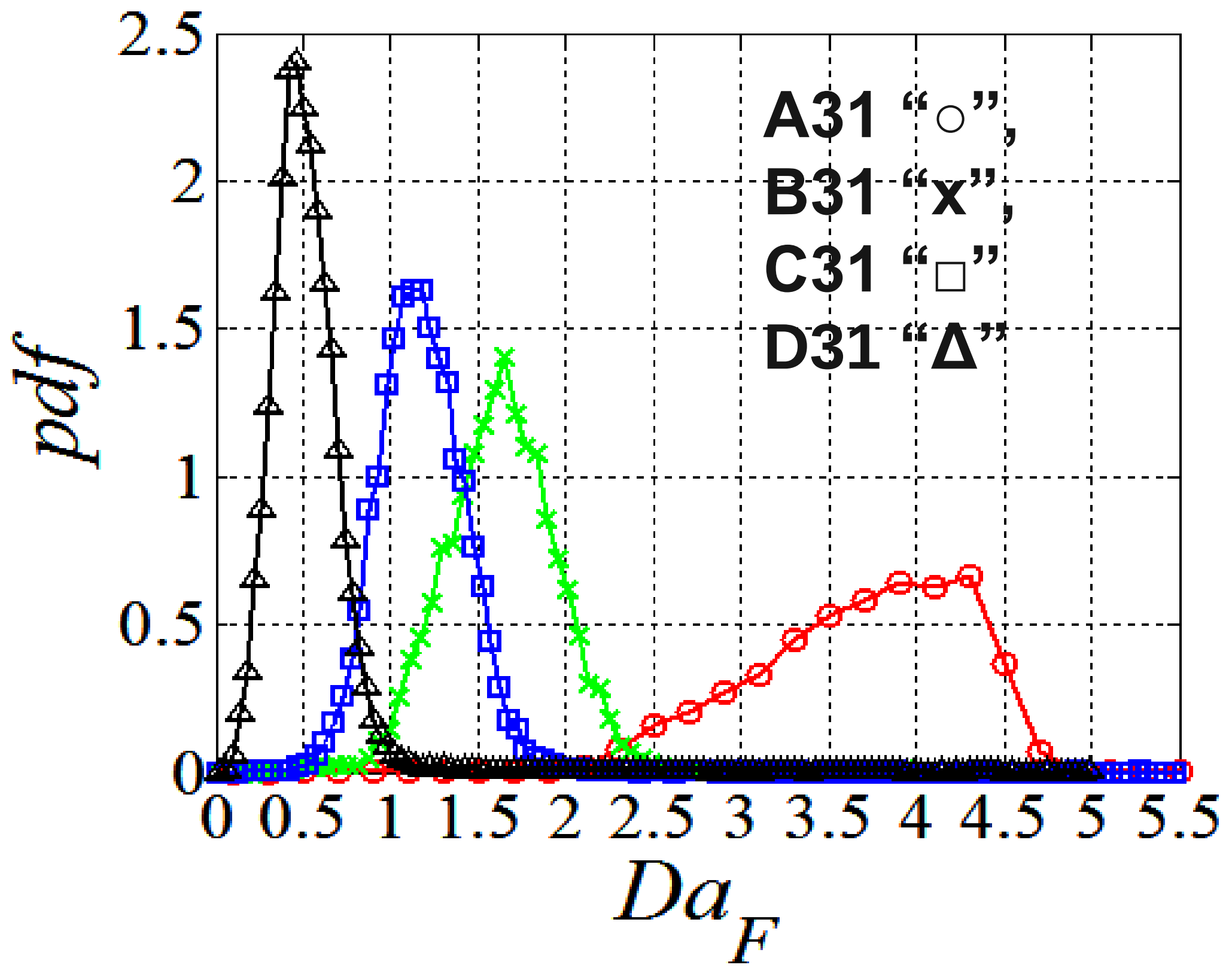

Figure 5. PDF of leading edge Damkohler number.

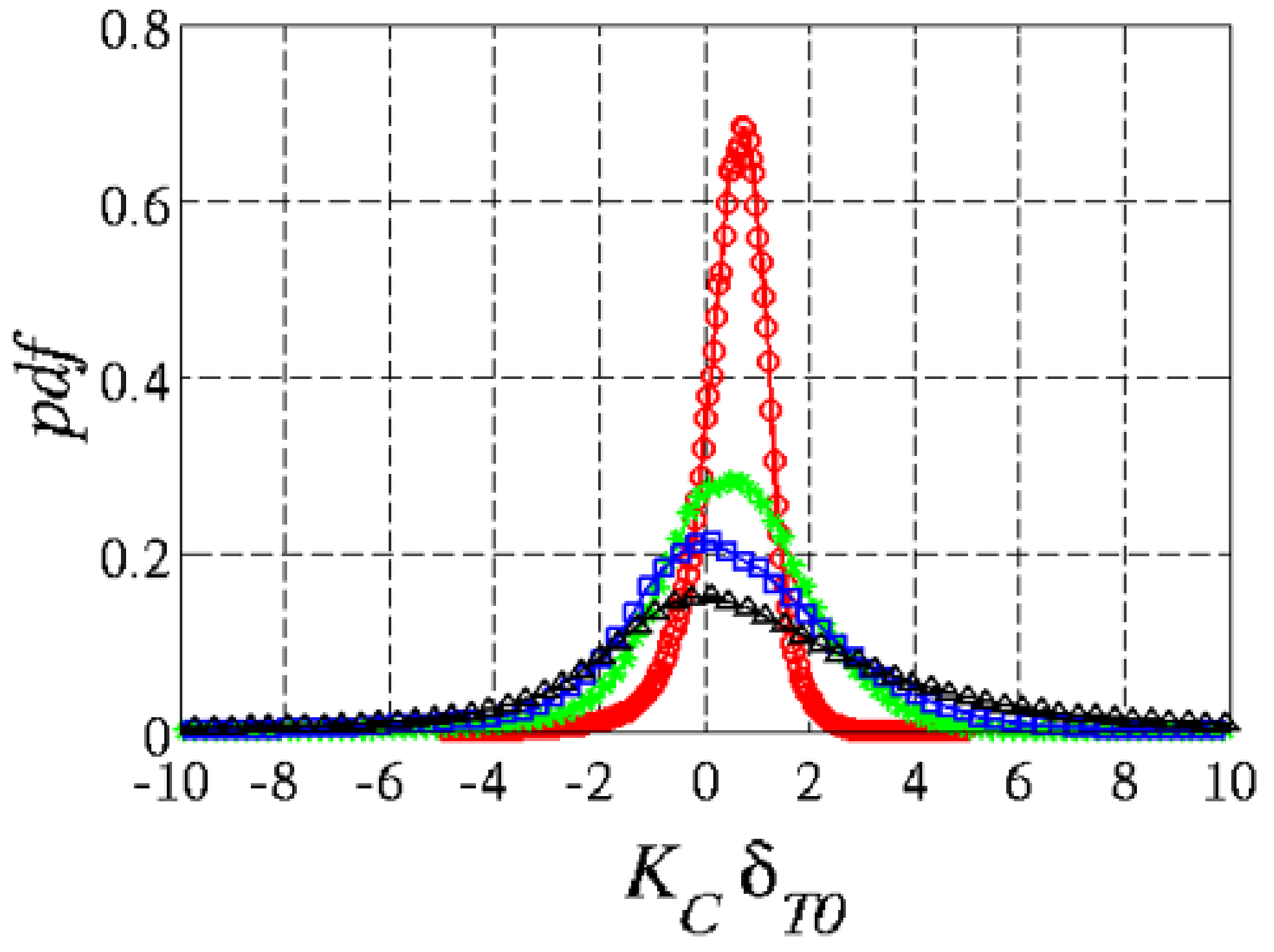

Figure 6. PDF of K_c

Conclusions

1. Strongly positive curved flamelet geometries dominate the topology of the flame front.
2. The local structure of the lowest turbulent correlate well with local flame front curvature. In the turbulent flame, curvature and strain rate are negatively correlated

Acknowledgements

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References

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