XV JORNADA DE JÓVENES INVESTIGADORES/AS DEL I3A

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Chemiluminescence from Hydrogen-Methane Laminar Premixed Flames: Experiments and Numerical Comparison

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Introduction

- Blending hydrogen with hydrocarbon fuels leads to a reduction in carbon emissions, but the tendency to flashback increases with H_2 content
- H_2 has significantly different properties from hydrocarbon fuels, requiring accurate continuous monitoring of the fuel blends and prevent hazards
- Measuring the natural light emissions from the flame (**chemiluminescence**) is a non intrusive diagnostic tool and can be used to measure fuel composition
- The aim is to study the characterize the effect on the radiation emission from H_2 blended flames

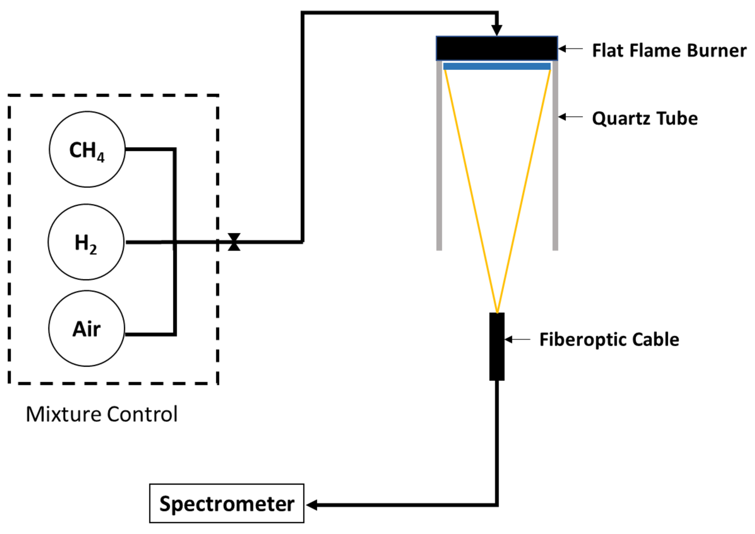
Experimental Setup

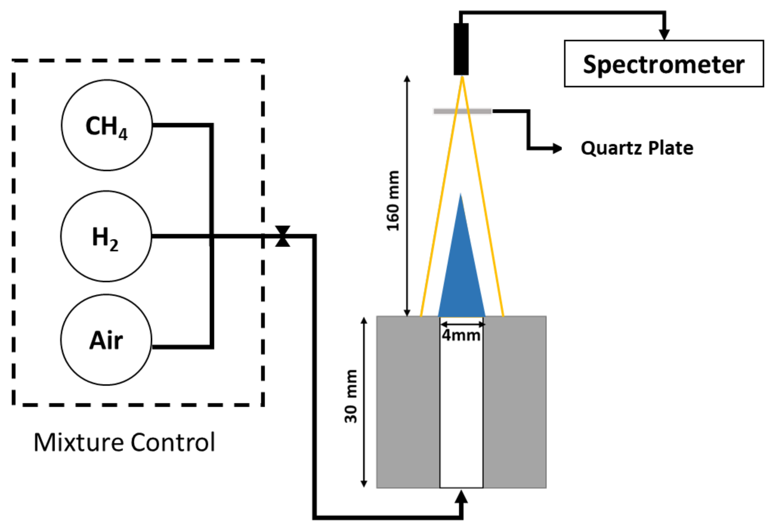
Flat Flame Burner

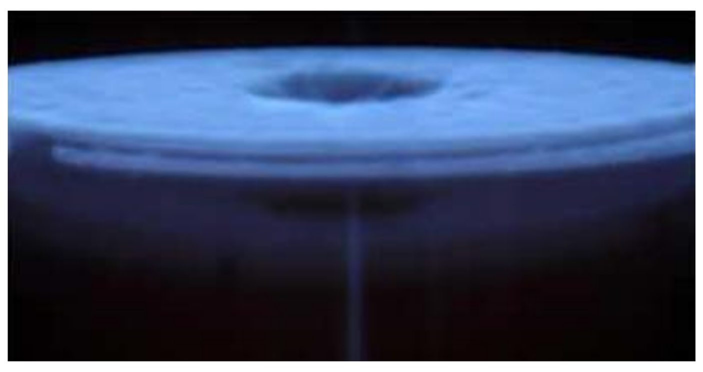
- Downfired McKenna Burner
- Unstretched Flat Flame
- Wide Operability Range
  - H_2 : 0 – 60% (by volume)
  - ϕ : 0.7 – 1.25

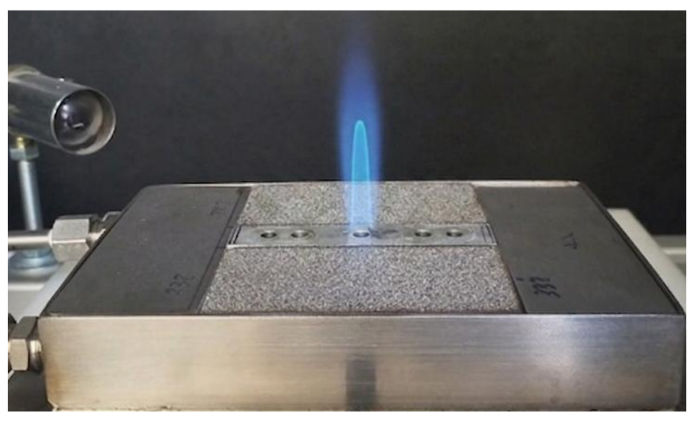
Conical Flame Burner

- Designed to test Conical Laminar Flames with variable mixture compositions
- Consists of 4mm square ports
- Operated with 60% H_2 for ϕ=0.83-1.67
- Introduces flame stretch and tip curvature









Numerical Model

- **Flat flame burner**
  - 1D simulations in Cantera
  - Burner Stabilized Flame Model
- **Conical flame burner**
  - 2D CFD simulations using OpenFOAM
  - Mixture-averaged + Soret effect
  - 100μm structured mesh
  - OH* and species are calculated using quasi-steady state approximation

Baseline Chemistry
- Reduced GRI30 (Laera et al.)

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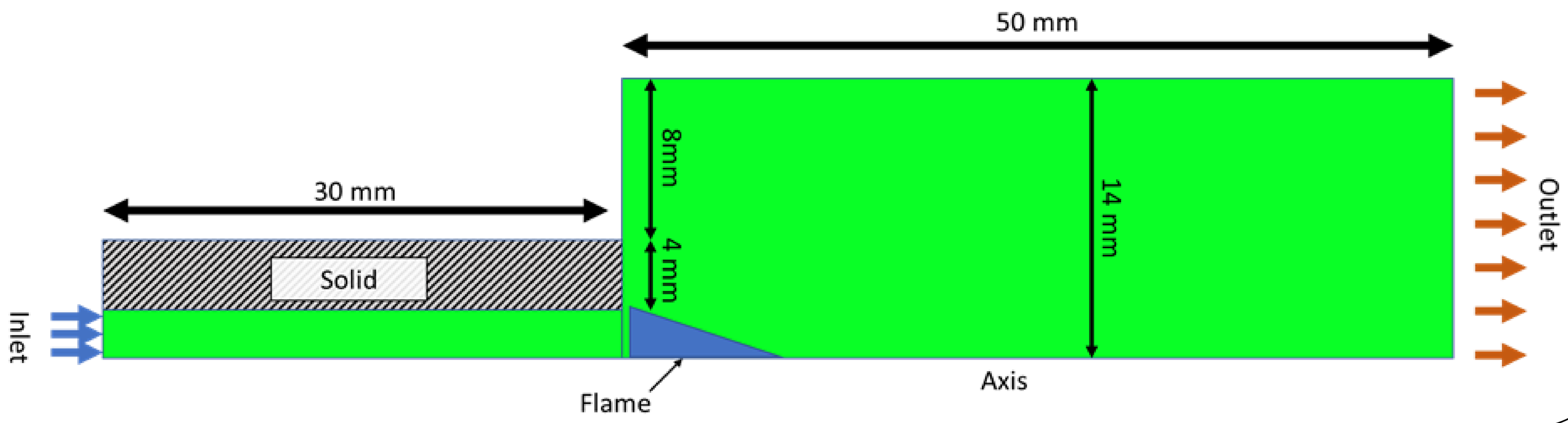
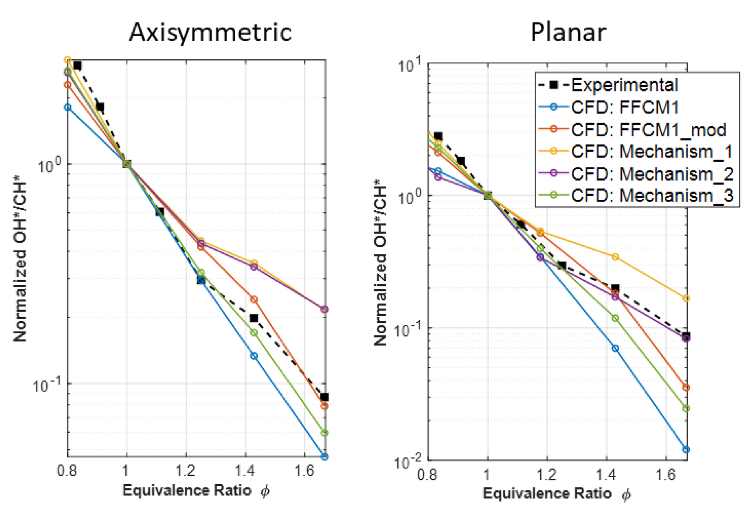
Chemiluminescence Sub-Mechanism
- Mechanism-1 (Walsh et. al)
- Mechanism-2 (Luque et al.)
- Mechanism-3 (Tian et al.)
- FFCM1 (Smith et al.)
- FFCM1 (Modified)



Implications for Chemiluminescence Monitoring

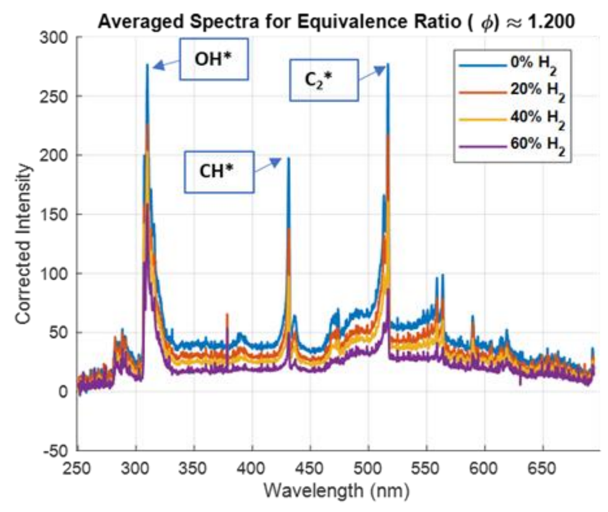
- Develop diagnostic techniques to measure the properties of the flame
- OH*/CH* show monotonic behavior for both H_2 blending and equivalence ratio
- OH*/CH* trends are less affected by strain rate
- This can be used to determine either the equivalence ratio or H_2 content

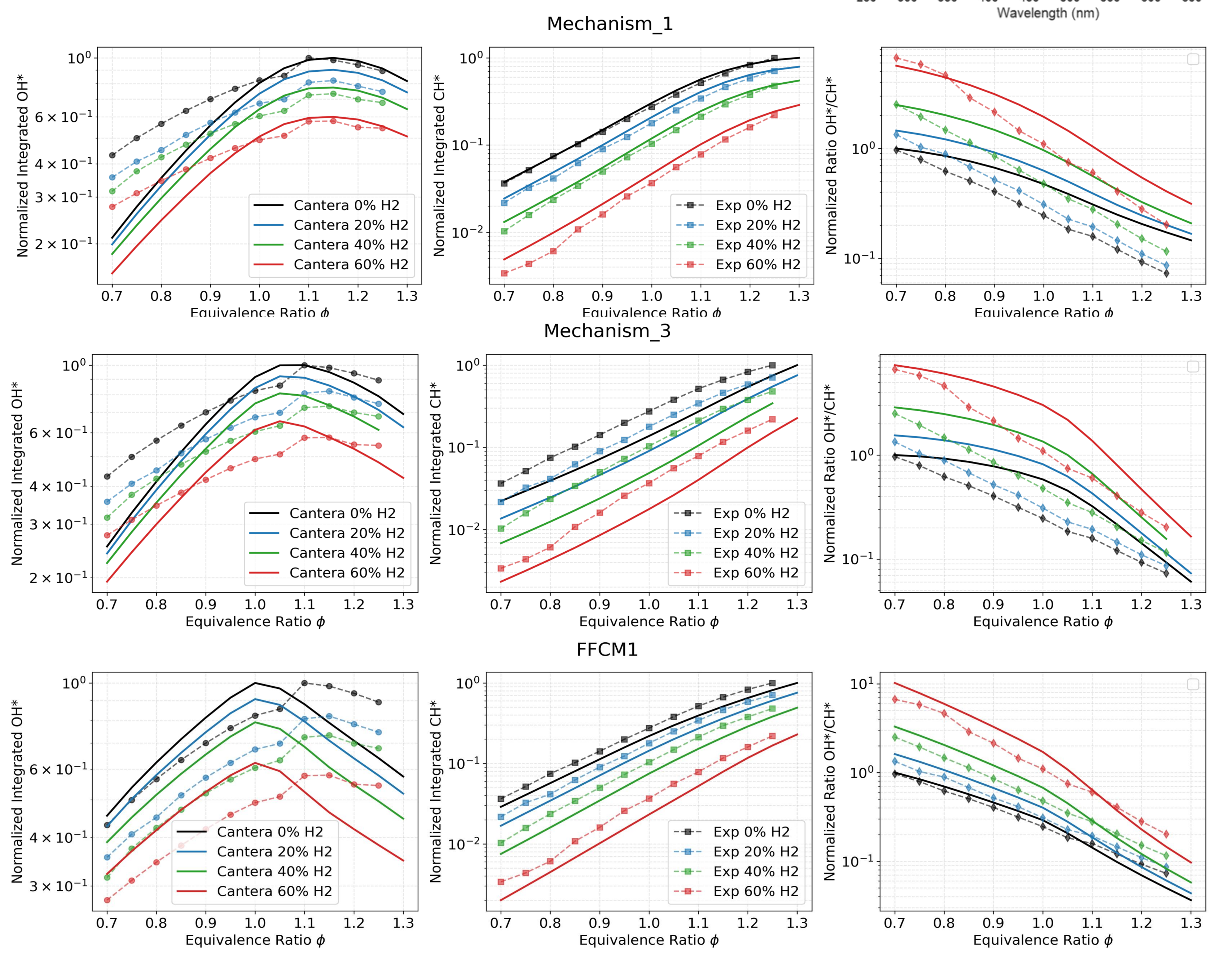


Results – Flat Flame Burner

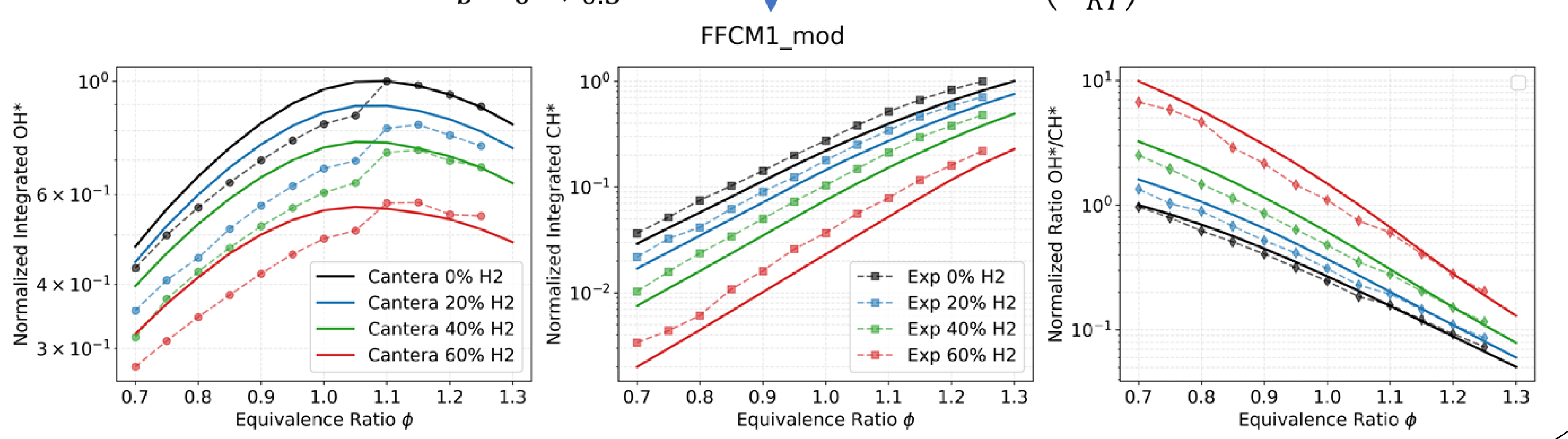
- Both **OH*** and **CH*** reduce with increasing **H_2** ratio
- Reduction due to **CH** and **C_2H** radicals
- **CH*** increases with equivalence ratio while OH* peaks at around **ϕ=1.1**

$$\boxed{\begin{array}{l} CH \\ C_2H \\ C_2H \end{array}} \begin{array}{l} + O_2 \rightarrow OH^* + CO \\ + O \rightarrow CH^* + C \\ + O_2 \rightarrow CH^* + CO_2 \end{array}$$



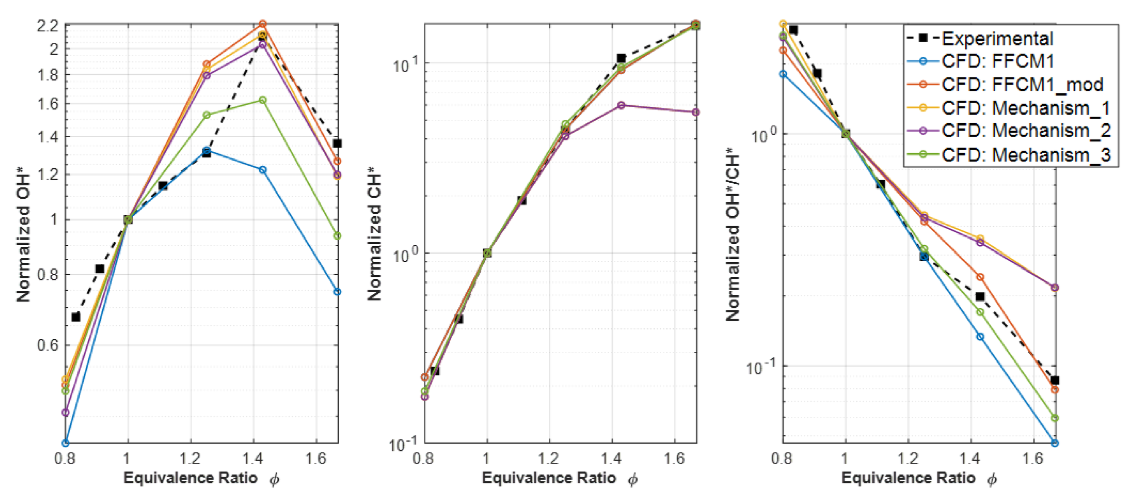


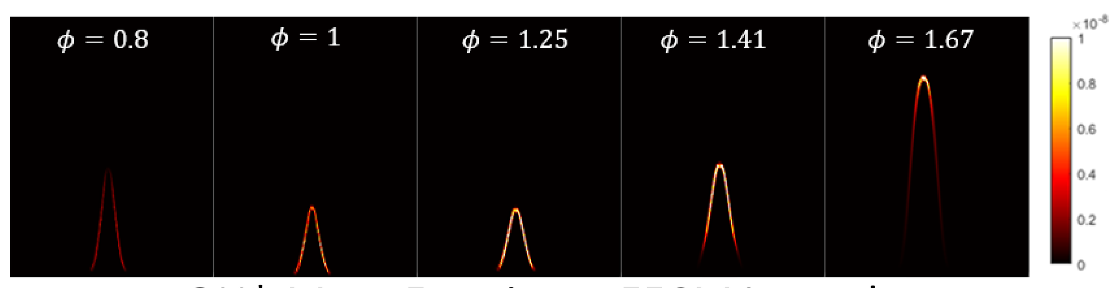
$$CH + O_2 \rightarrow OH^* + CO \qquad k = AT^b \exp\left(-\frac{E_a}{RT}\right)$$
$$b = 0 \rightarrow 0.5$$



Results – Conical Flame Burner

- OH* peaks shifts to **ϕ=1.4**
- Mech. 1, 2, and modified FFCM1 capture this peak whereas the baseline FFCM1 model peaks at ϕ=1.25
- CH* chemiluminescence matches well for all values of ϕ
- The ratio of OH*/CH* is well predicted by Mech. 3 and both FFCM1 mechanisms





OH* Mass Fraction – FFCM1_mod

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