Imperial College London

Numerical Simulation of Flame-Flame Interaction and Indirect Noise

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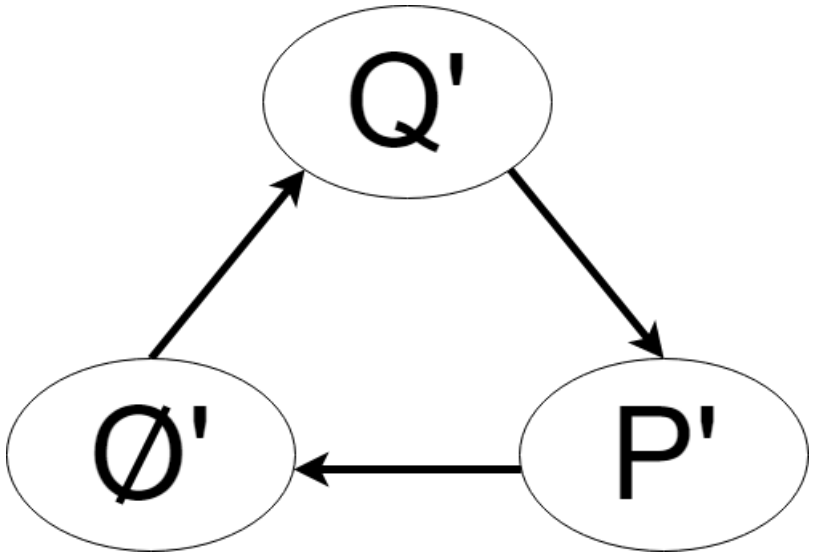
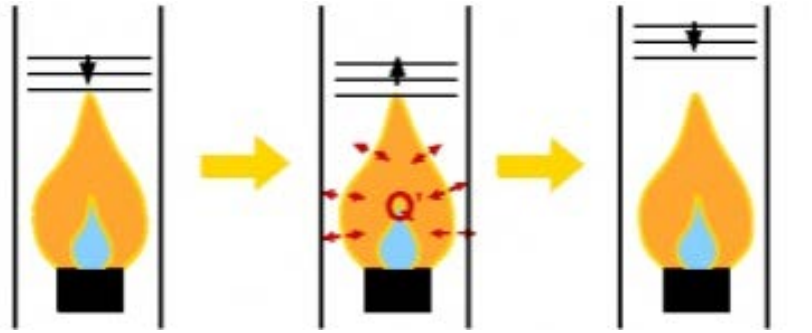
UKCTRF Annual Meet 2019

Thermoacoustics

- Interaction between pressure and heat release fluctuations
- Potential for positive feedback loop leading to flashback/structural failure
- Common approaches:
  - Helmholtz solvers
  - Network models
  - LES/DNS





Numerical Methodology

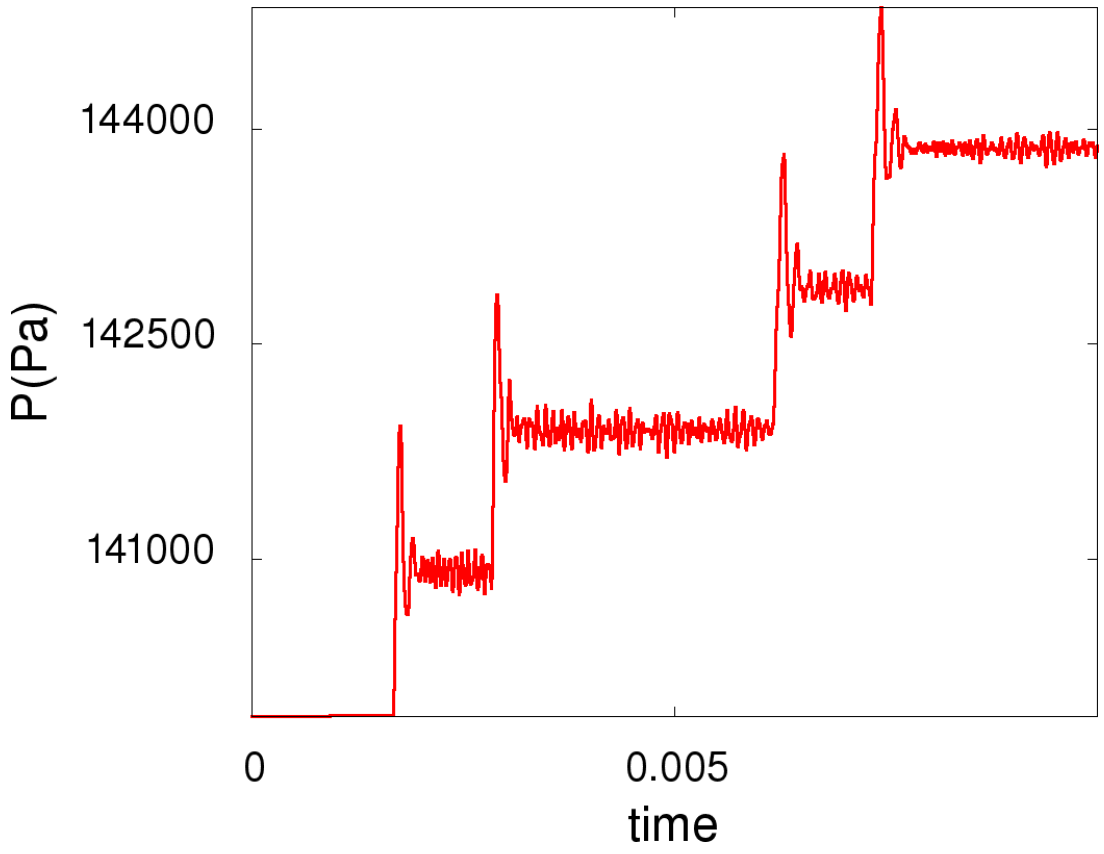
- CompReal- inhouse, finite difference LES/DNS code
- Fully compressible, density based solver
- Dispersion Relation Preserving (DRP) schemes/ Riemann Solver hybrid
- Skew-symmetric (4^{th} order)
- High order Runge-Kutta integration in time (3^{rd} order)
- Interface with CHEMKIN and multi-step chemistry
- Immersed Boundary Methods for solid boundaries
- Navier-Stokes Characteristic Boundary Conditions: transverse corrections, chemical source terms and relaxation parameters

Boundary Treatments

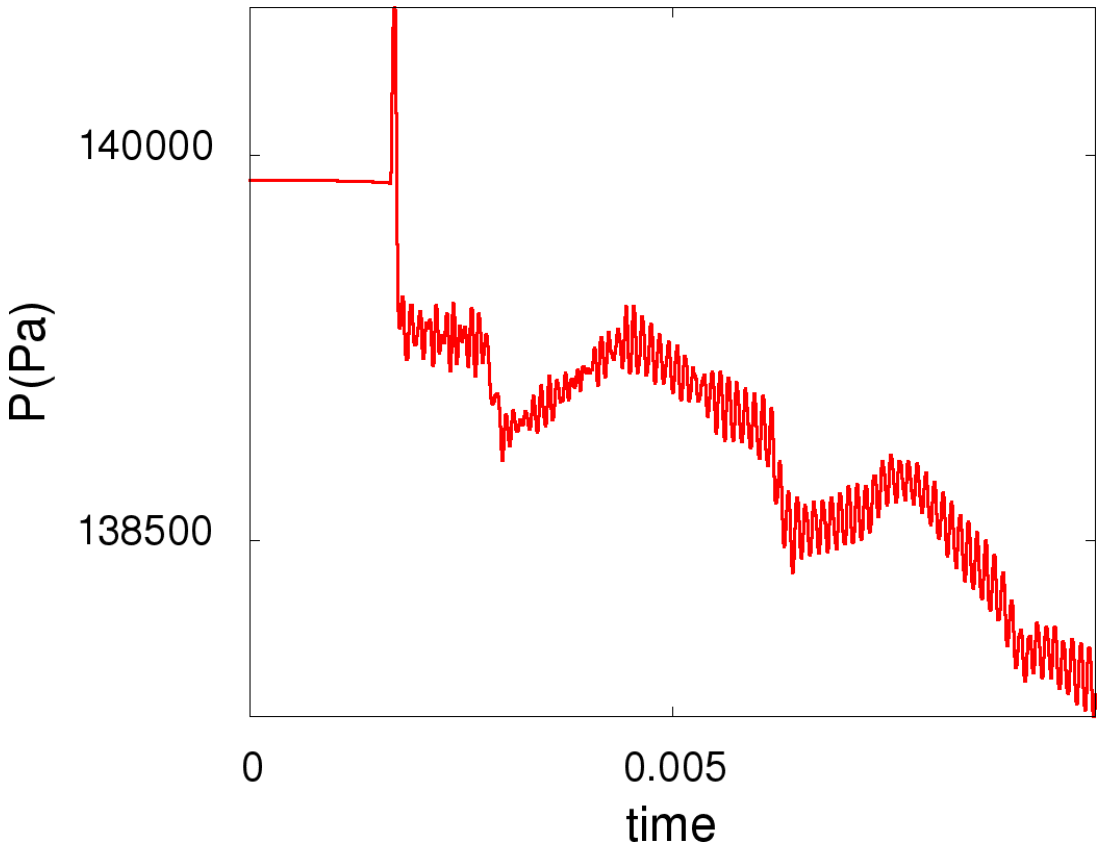
- Engines are complicated!
- Central differences schemes particularly prone to spurious oscillations at boundaries
- Tainting of acoustic field
- Open questions with Navier-Stokes Characteristic Boundary conditions (NSCBCs):
  - How far is farfield?
  - Importance of chemical source terms
  - Choosing relaxation parameters
  - Selecting type of inflow
  - Shock/farfield interactions

Indirect Noise

Upstream Pressure

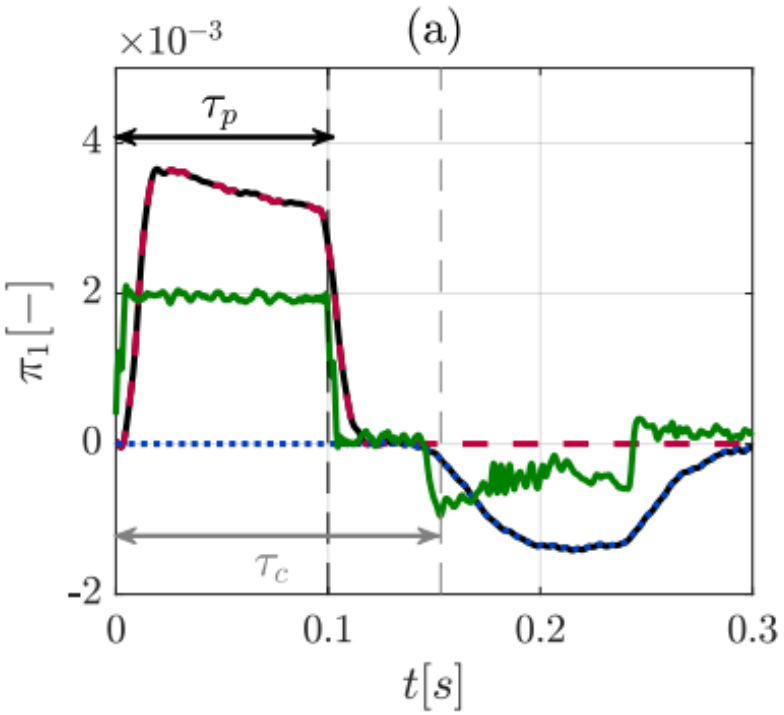


Soft Inflow

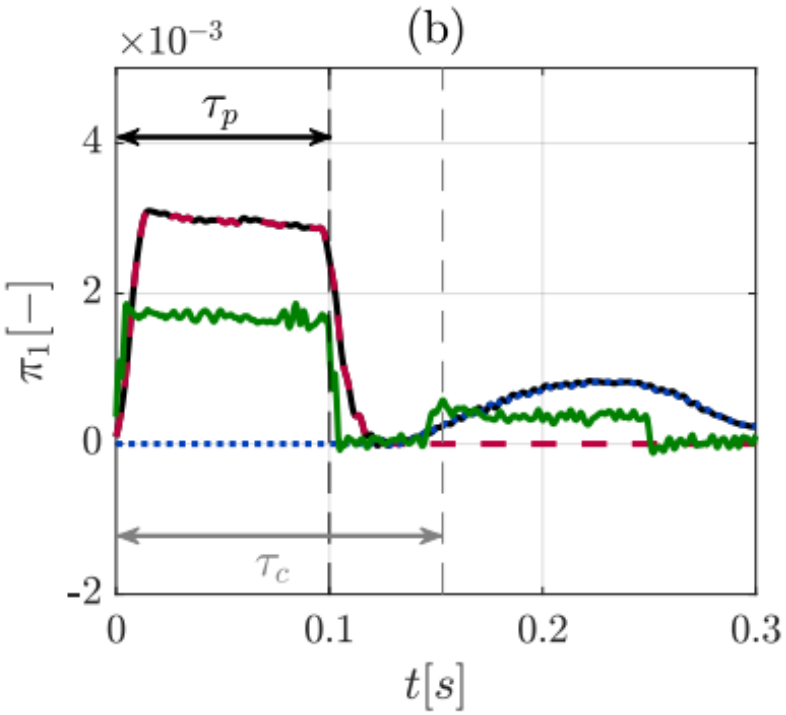


Pure non-reflective inflow

Experimental Validation



Helium



Carbon Dioxide

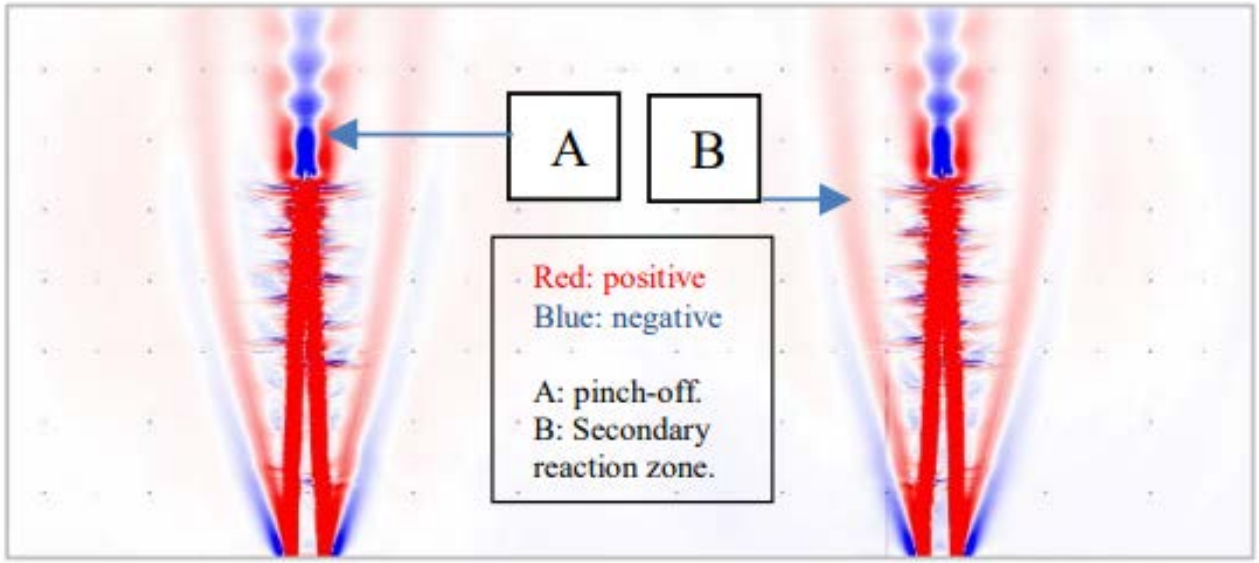
Conclusions

- Choice of relaxation parameters is important but not straightforward
- Non-reflecting inflows are often less strictly tested
- Shocks can destabilise non-reflecting inflows- they need tuning!
- How far **really** is farfield?

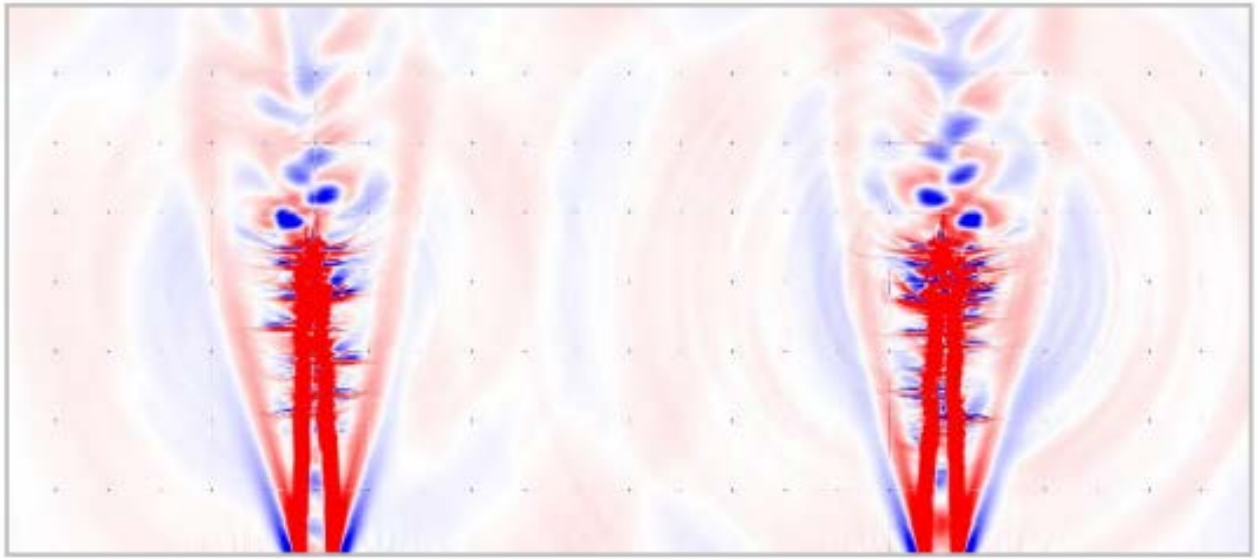
- Results presented at NC19

Flame-Flame Interaction

2D Laminar Flames – Intrinsic Instability



Initial Dilatation Field



Transient Dilatation Field

2D Laminar Flames- Acoustic Forcing

Methane mass fraction. Yellow=fresh premixed fuel, Black= zero

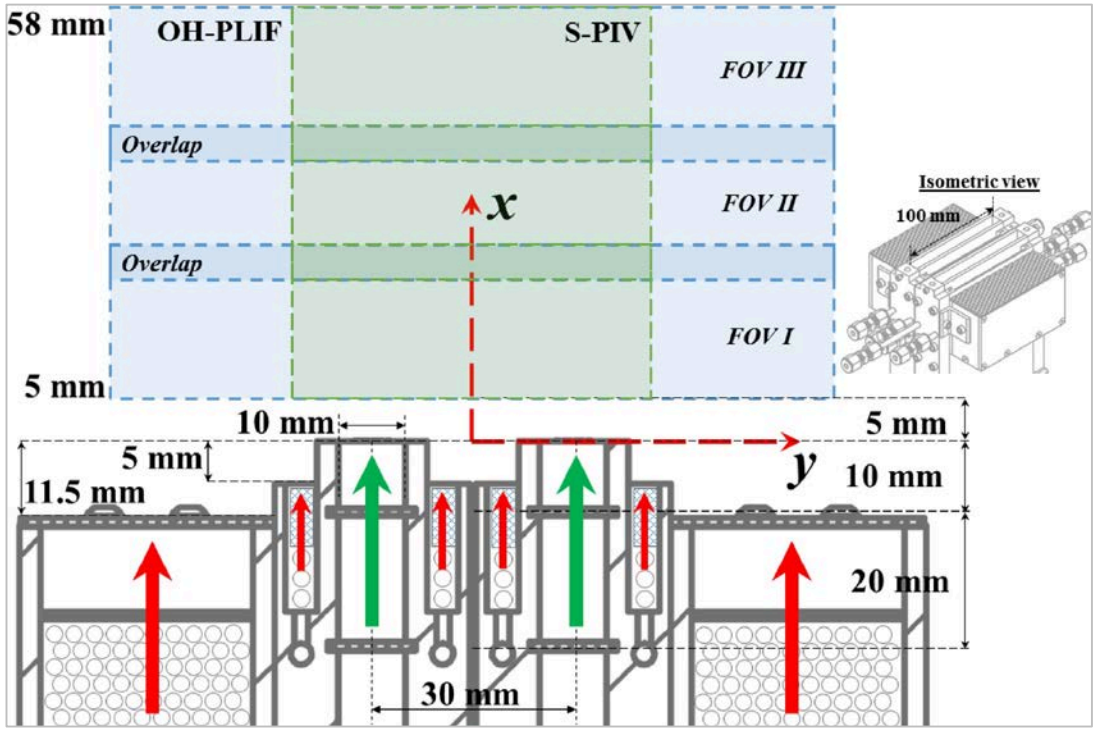
Observations

- Coupling of intrinsic instability with thermoacoustics
- Pinch off events across various scales
- Rayleigh integral showing effect of burning pockets
- Influence of secondary reaction zone
- Acoustic field untainted by boundaries

- Results presented at ECM2019

3D Slot Burners - Experiments

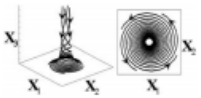
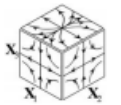
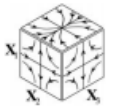
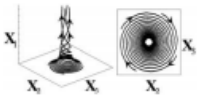
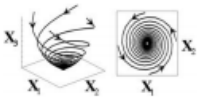
- Premixed Methane/air flame
- Variable flow rate and burner spacing
- Image registration technique used to identify *local interaction events*
- Topological study: reactant vs product side interactions



Tyagi, Ankit, et al. Combustion and Flame (2019).

3D Slot Burners - CompReal

- 4 step chemistry
- LES
- Artificial Flame Thickening (ATF)
- 4th Order Discretisation
- Turbulent inflow generator
- Topological Study: changes in local flame/scalar structures

Acronym	Description	Sketch
UFC	Unstable focus/compressing	
UN/S/S	Unstable node/saddle/saddle	
SN/S/S	Stable node/saddle/saddle	
SFS	Stable focus/stretching	
SFC	Stable focus/compressing	
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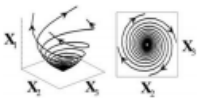
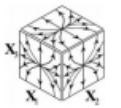
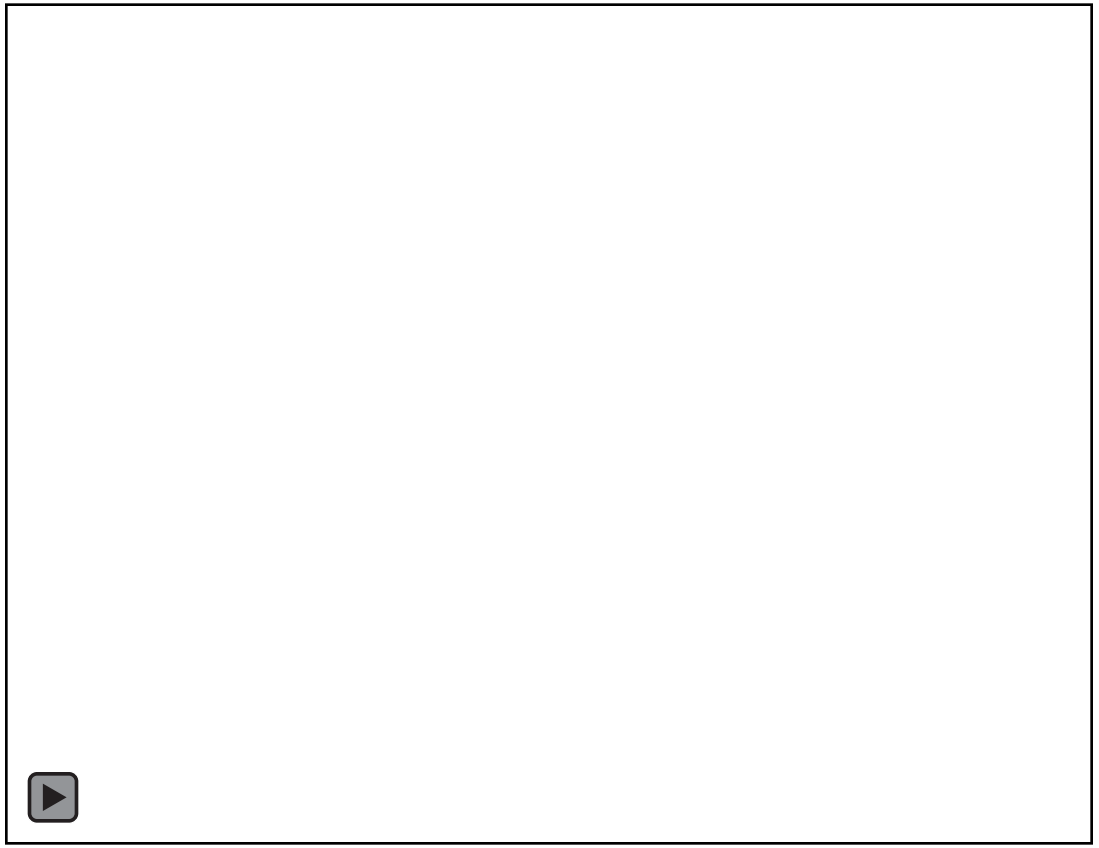
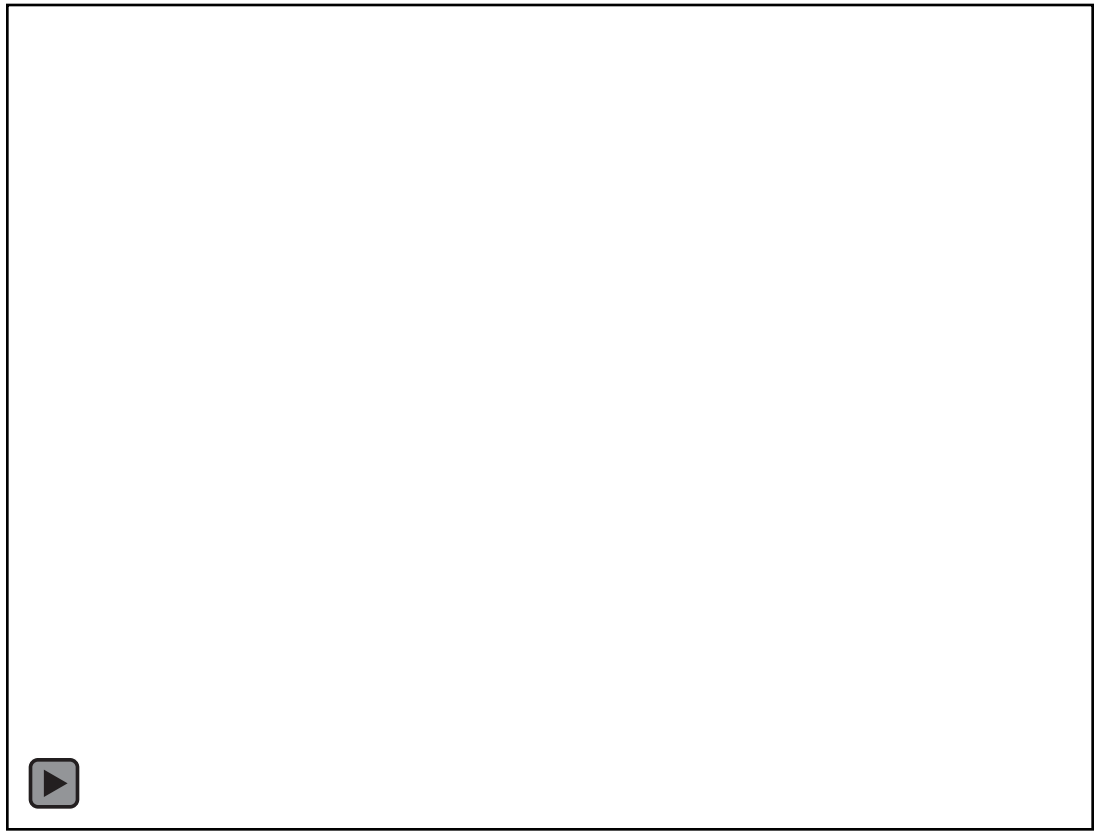
UFS	Unstable focus/stretching	
UN/UN/UN	Unstable node/unstable node/unstable node	

Cifuentes, Luis, et al. Flow, Turbulence and Combustion (2016)

Current State





Future Work

- Interpolate onto finer mesh
- Add adjacent flame
- Compare local flame topologies and the effect of P’

Thanks for listening

Any questions ?