P0019: *Flame transitions and stabilization mechanisms in a freely falling fuel droplet encountering a co-flow*

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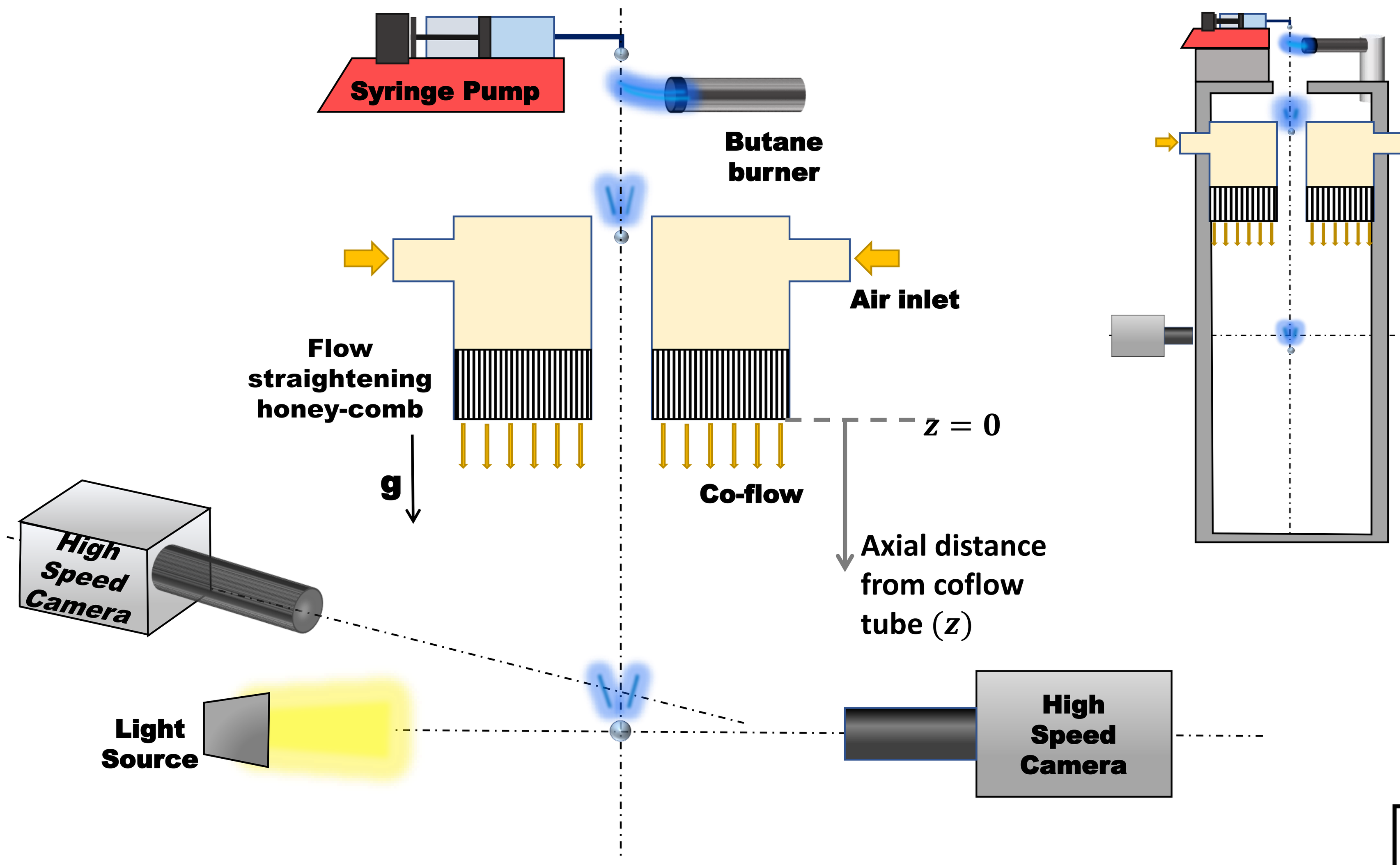
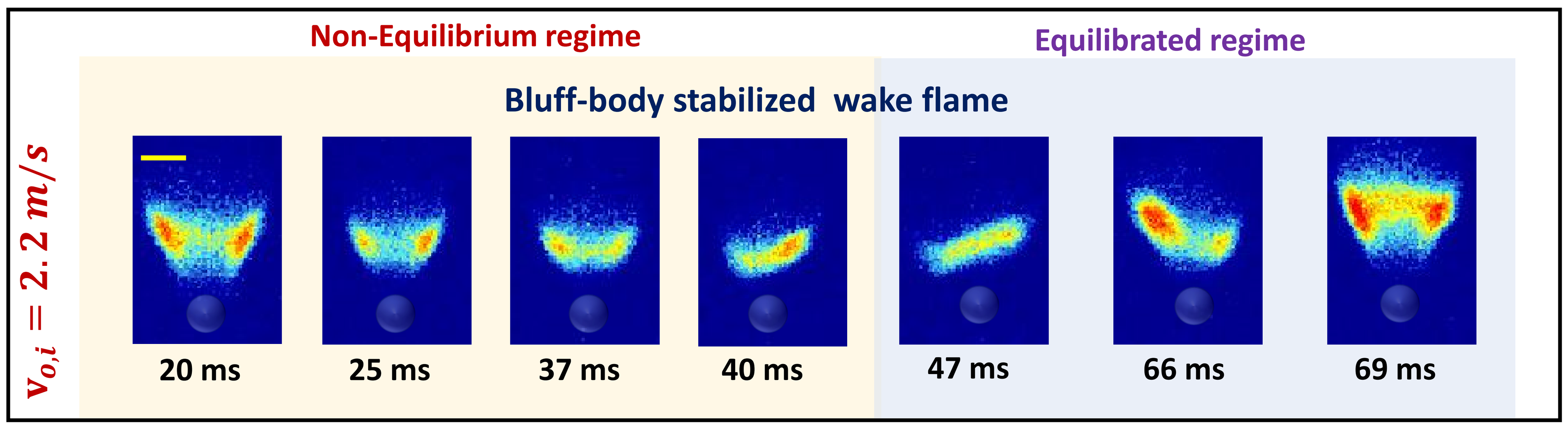


- Droplet is allowed ignite under fall freely using a pilot flame.
- The droplet flame stabilizes at the rear stagnation point, near the recirculation zone formed in the wake (20 < Re < 150) – Bluffbody stabilized flame.
- The flame height is analogous to a round jet and can be scaled as : $v_{rel} \sim \frac{h}{d}$
- The Bluffbody flame height (h) evolves with the droplet velocity as it accelerates due to gravity.
- The relative flow velocity due to droplet motion ($v_{rel} = u_o$) is upwards, and the wake flame shape is established and stabilized based on this v_{rel}.



Effect of co-flow on droplet flame

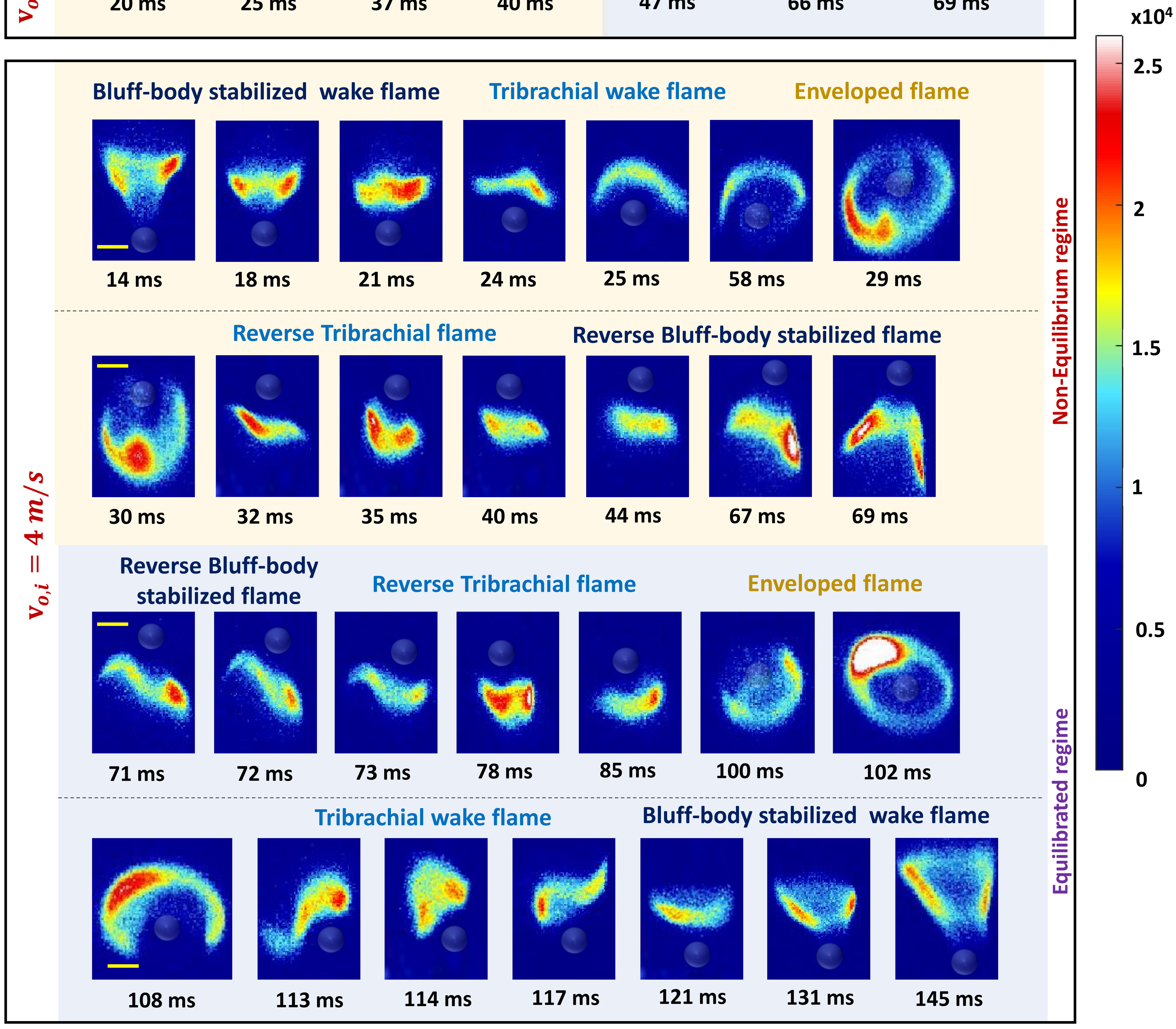
When the droplet encounters co-flow, it experiences a sudden change in the relative flow velocity to $v_{rel,NEW}$.

Low co-flow velocity, $v_o < u_o$; $(v_{o,i} \sim 2.2\ m/s)$

- The relative velocity $v_{rel,NEW} = u_o - v_o$ also remains upwards, however $v_{rel,NEW} < v_{rel,OLD}$.
- The droplet flame which had been stabilized at $v_{rel,OLD}$ is no longer in equilibrium with $v_{rel,NEW}$.
- Hence, Re-adjustment of the droplet flame occurs to equilibrate with $v_{rel,NEW}$.
- Once, the equilibrium is achieved, the flame shape starts to respond to the variation of instantaneous relative flow.

High co-flow velocity, $v_o > u_o$; $(v_{o,i} \sim 4\ m/s)$

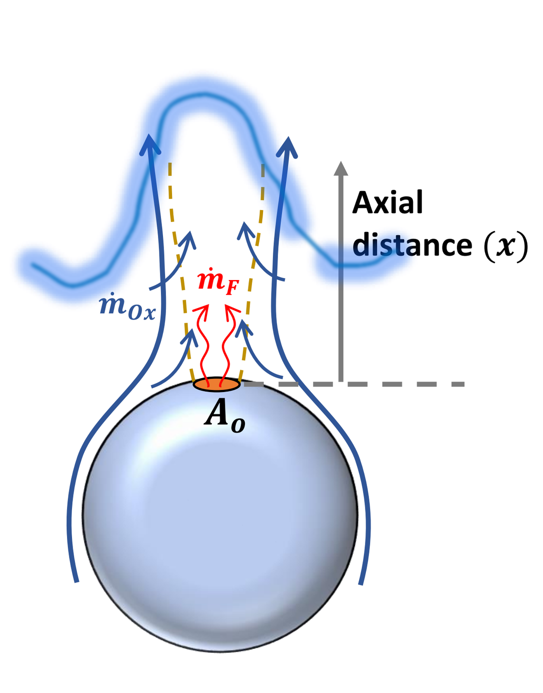
- The relative velocity $v_{rel,NEW} = u_o - v_o$ becomes downwards, which is complete direction change from $v_{rel,OLD}$.
- The droplet flame which had been stabilized at $v_{rel,OLD}$ is no longer in equilibrium with $v_{rel,NEW}$.
- Re-adjustment of the droplet flame occurs to equilibrate with $v_{rel,NEW}$.
- Once, the equilibrium is achieved, the flame shape starts to respond to the variation of instantaneous relative flow.
- The flame undergoes a series of transitions and shape evolutions, based on the instantaneous flow characteristics.



Droplet flame Transitions

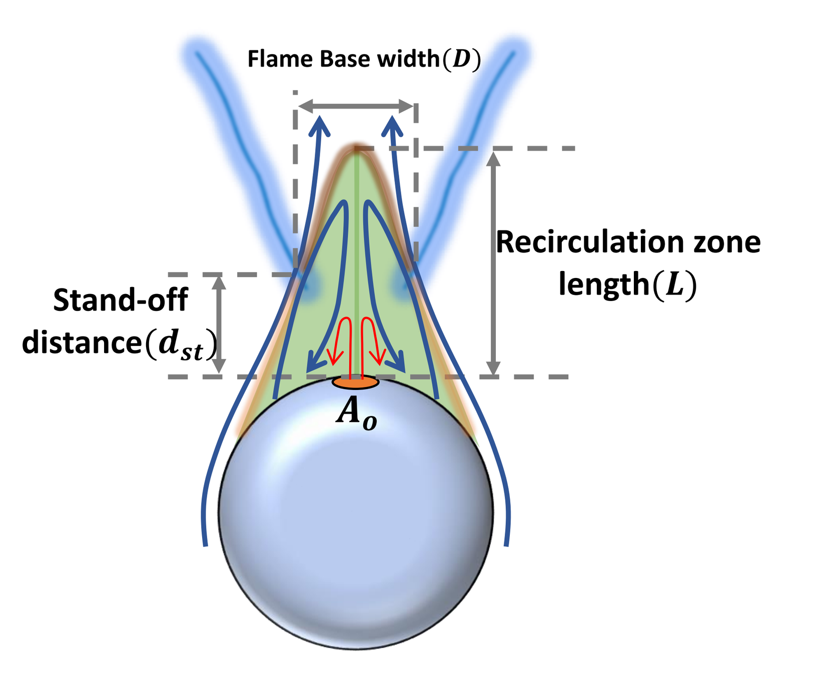
- The droplet flame stabilizes in the droplet wake in two configurations based on the flow characteristics.
  - 10 < Re < 20 : tribrachial flame structure ; (no wake eddies)
  - 20 < Re < 150 : Bluffbody stabilization ; (symmetrical wake eddies).
- The droplet flame becomes fully Enveloped spherical flame ($v_{rel,NEW} = u_o - v_o = 0$).
- After stabilization, when $v_{rel,NEW}$ is downwards, the wake flame also gets stabilized below the droplet (referred to as reverse flame).
- The flame shape transitions occur based on the instantaneous relative flow characteristics around the droplet.

10 < Re < 20



Branched-edge wake flame

20 < Re < 150



Bluffbody stabilized wake flame