Flight Physics

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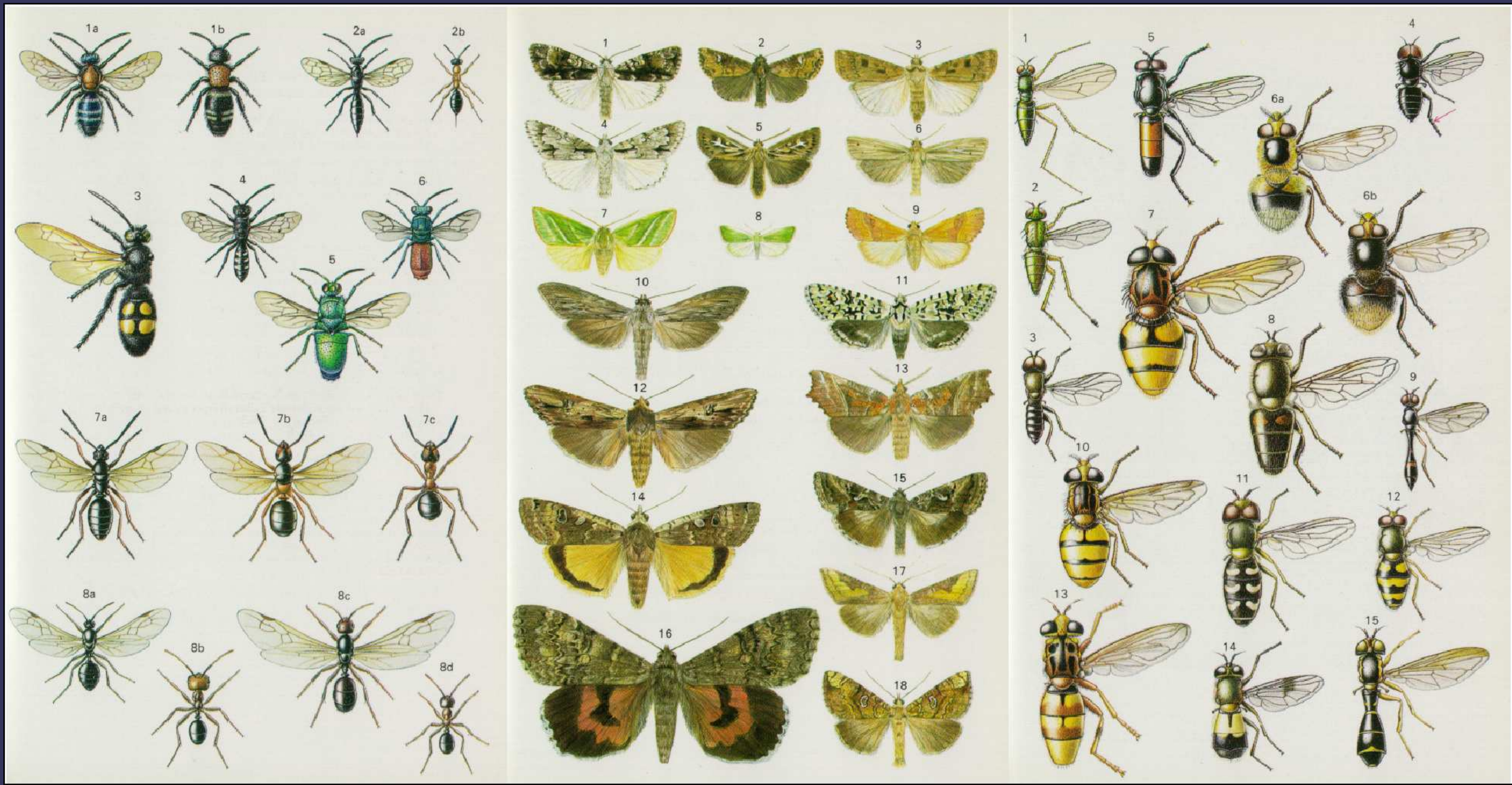
Insect variety: What is a good model for a biomimetic MAV?

30,000,000 species

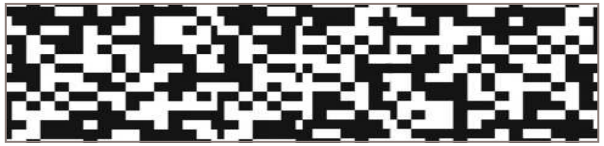


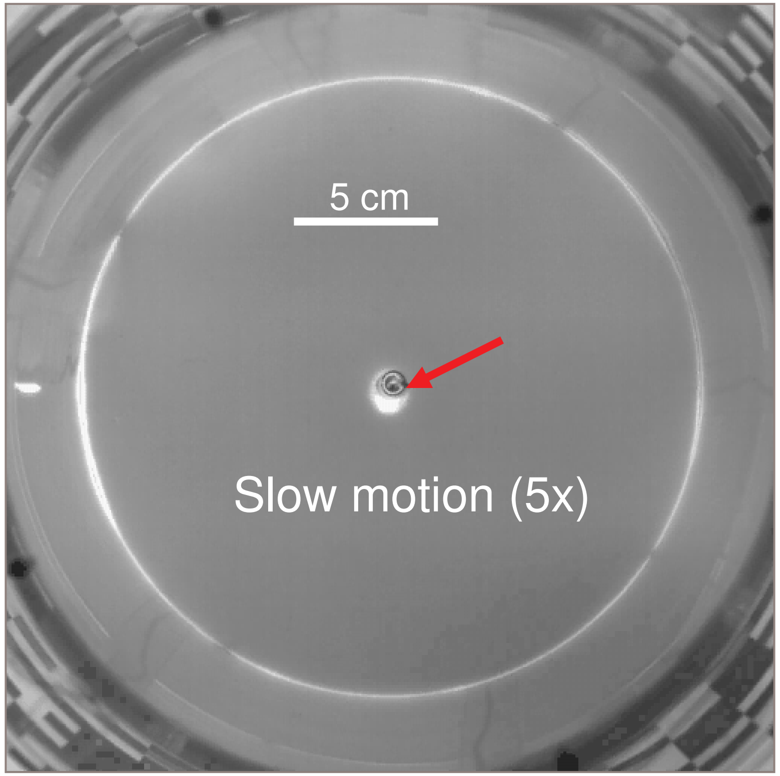
Biomimetic MAVs: Visuo-motor reflexes of a fruit fly

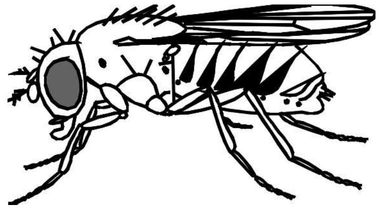
Visual environment

Stationary

20 cm







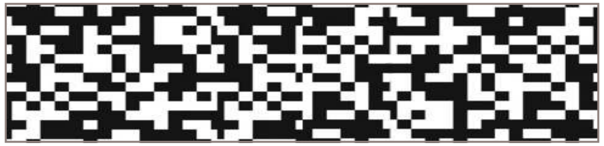
1 mm

Body mass = 1.0 mg
Forward speed = 300 body lengths / s
Angular speed = 1200°/s
Pay load = 100%
Total flight efficiency = 3%
Reaction time = 5-30 ms
Endurance = several hours

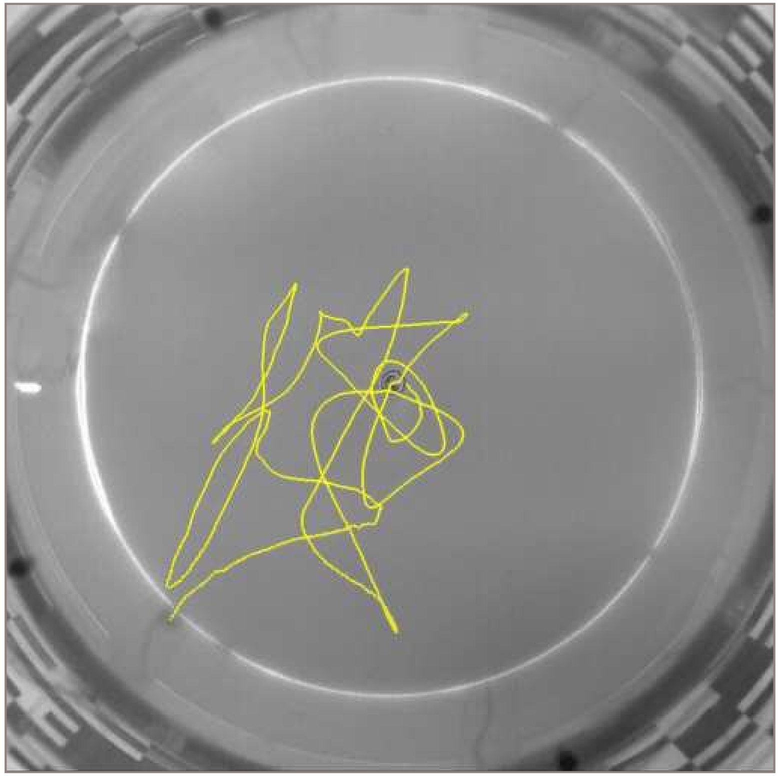
Biomimetic MAVs: Visuo-motor reflexes of 1.0 mg fruit fly

Visual environment

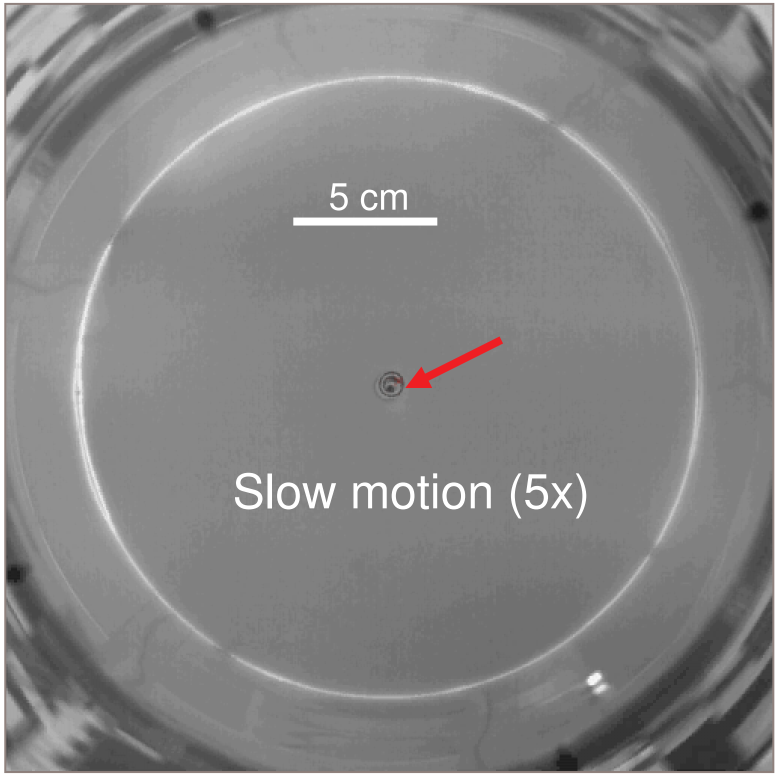
20 cm



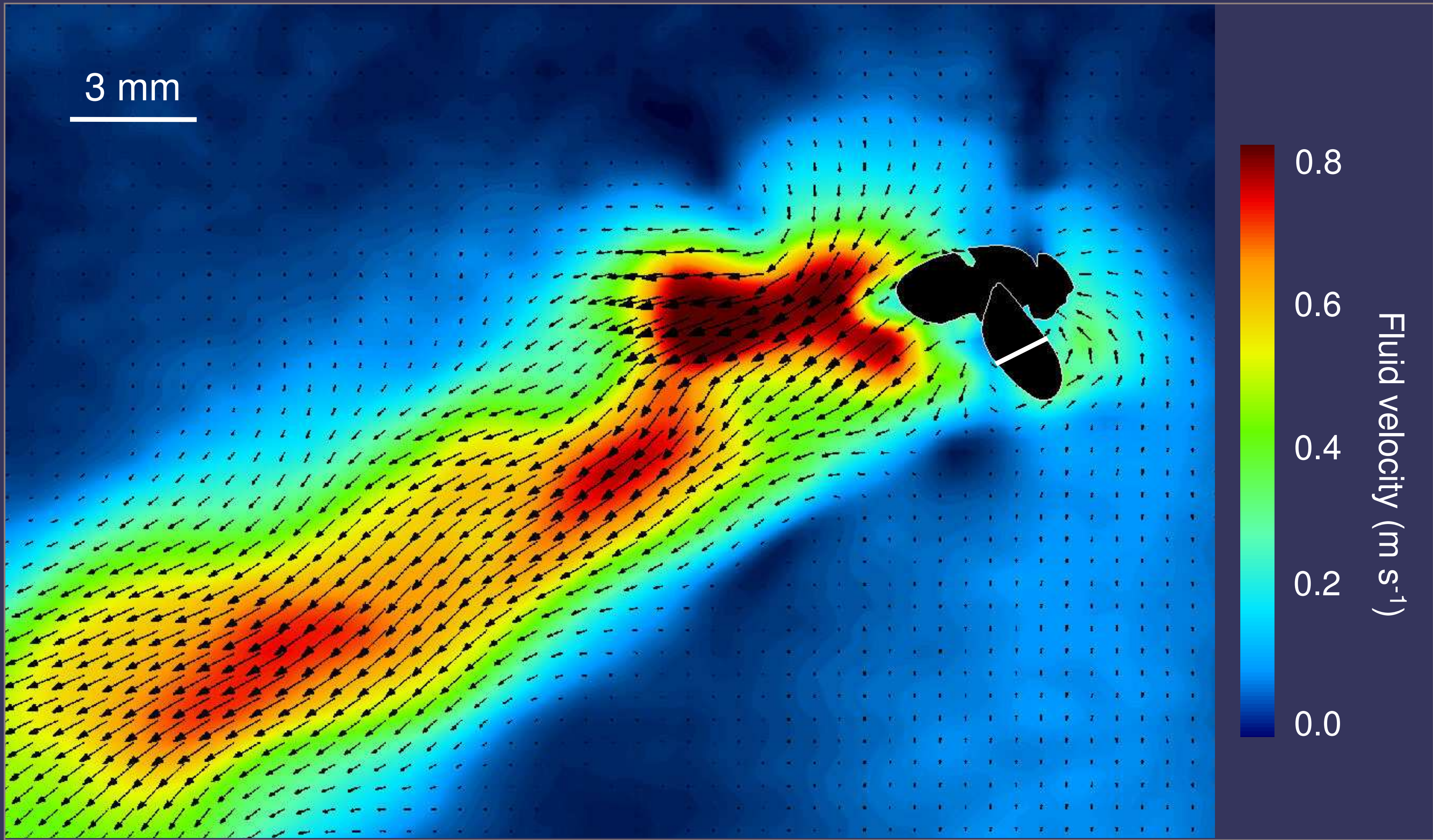
Stationary

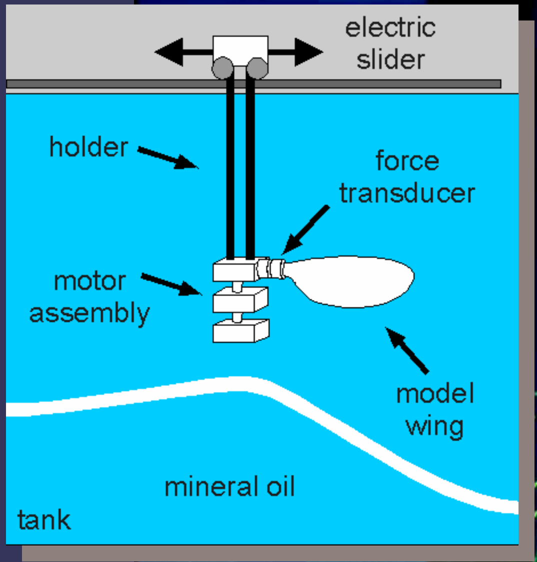


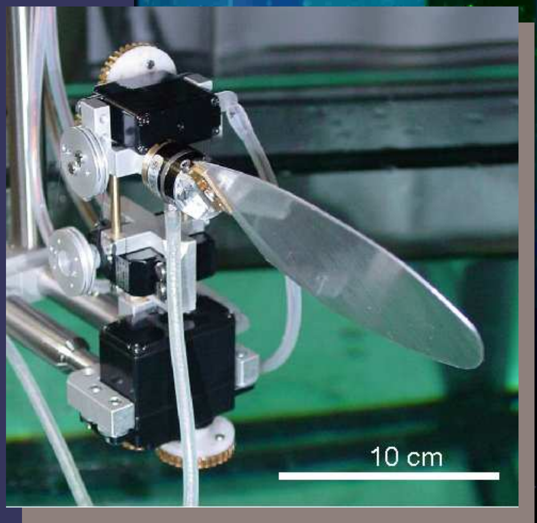
Optomotor reflex



Digital Particle Image Velocimetry (DPIV) – Imaging of *Drosophila* wake



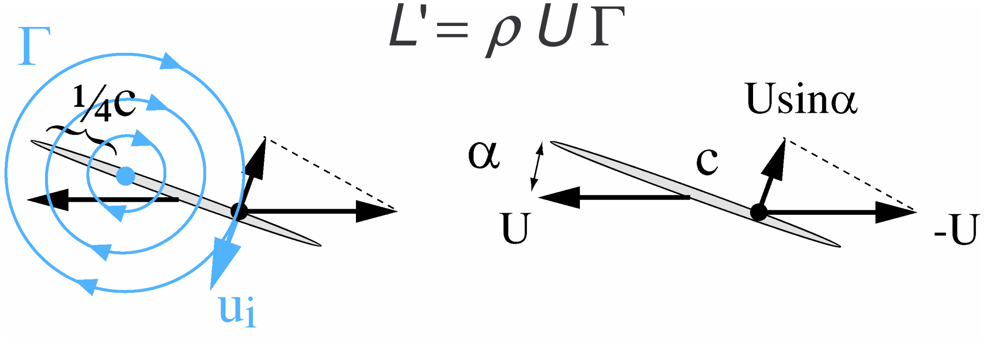

electric slider
holder
force transducer
motor assembly
model wing
mineral oil
tank


10 cm


SNAPER

Force enhancement during 3-D wing translation: leading edge vortex (LEV)

$$L' = \rho U \Gamma$$

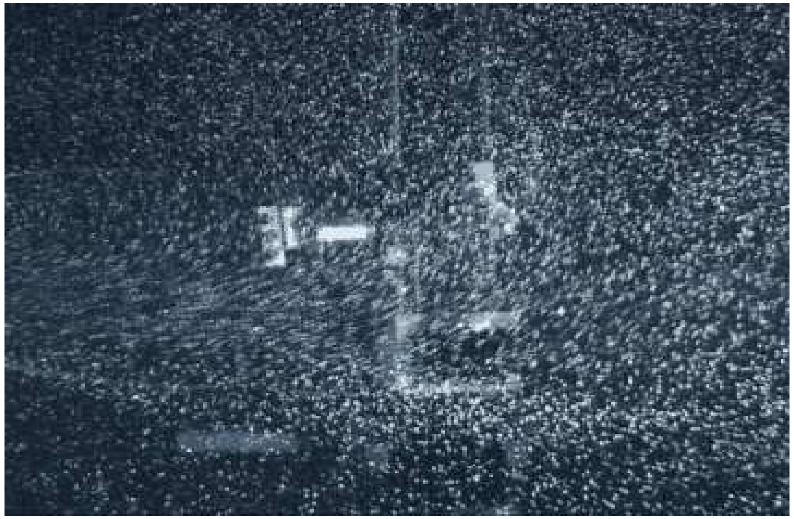


$$\Gamma_T = \pi U c \sin(\alpha)$$

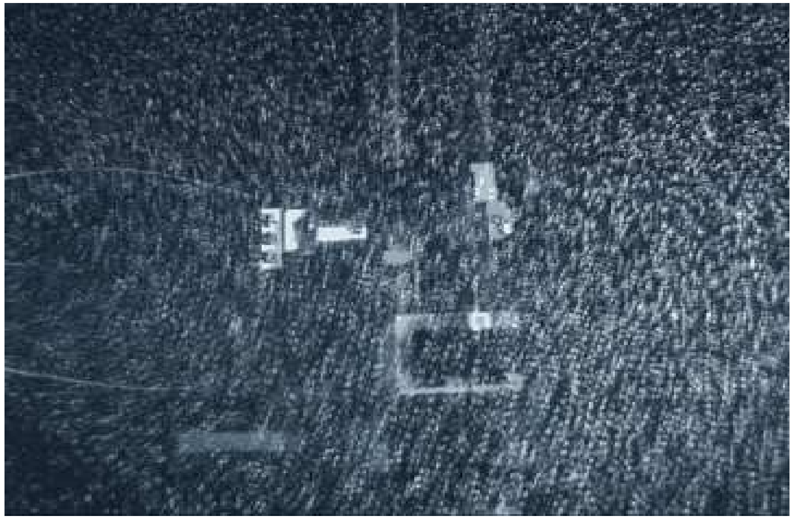
$$+$$

$$\Gamma_{LEV} = \pi d_\theta U_\theta$$

15 degs angle of attack



45 degs angle of attack

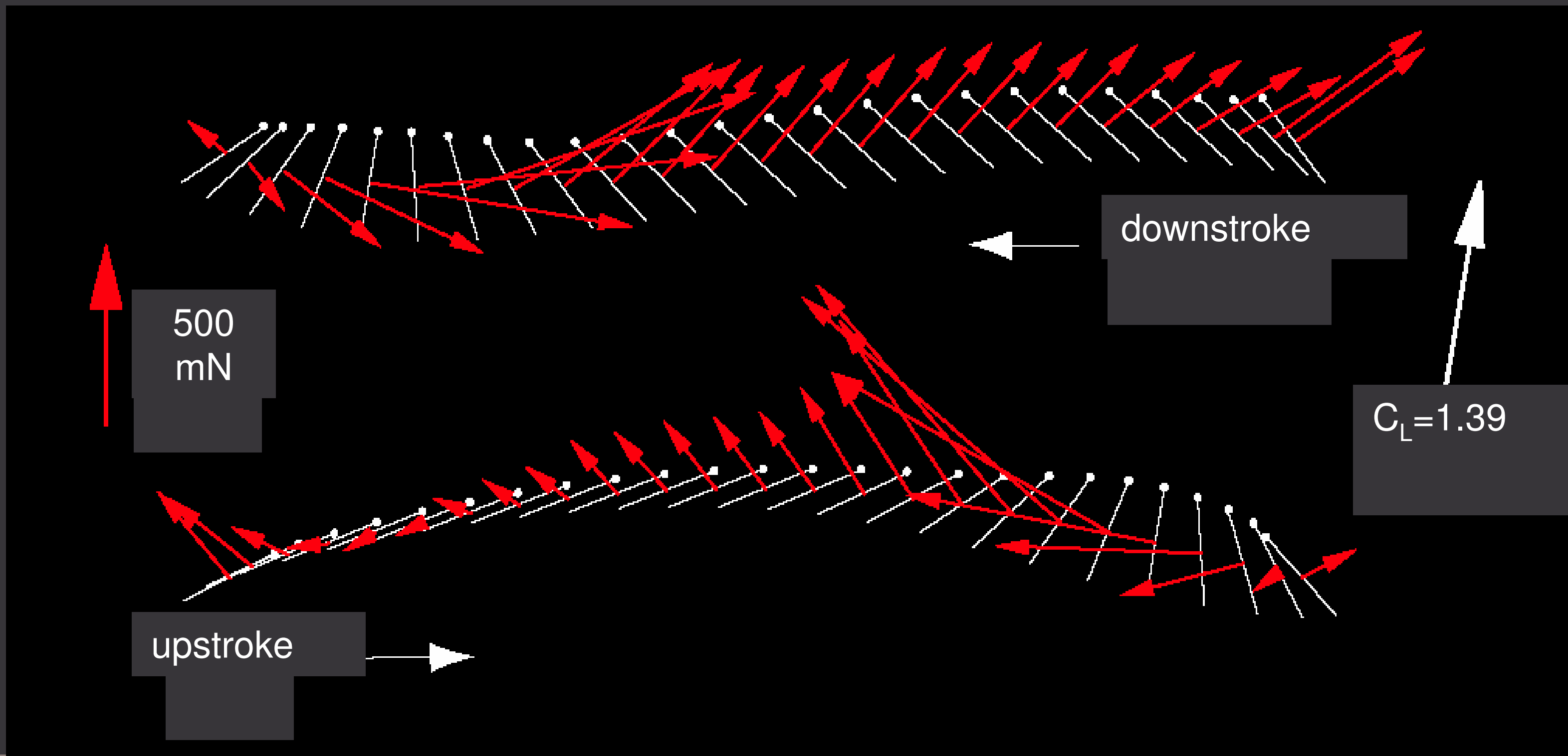


LEV is not sufficient to explain performance of flapping low AR wings

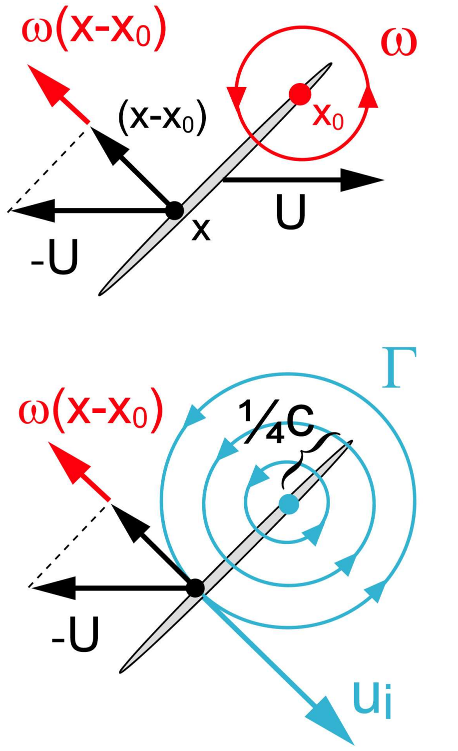
- LEV may explain only 35- 50% of total flight force production in biomimetic robotic models of insects.

- LEV can not explain why maximum force peaks in insects occur at the end of each halfstroke (stroke reversals) and not during wing translation.

Biomimetic robotics: Wing rotation is a source for enhanced lift production

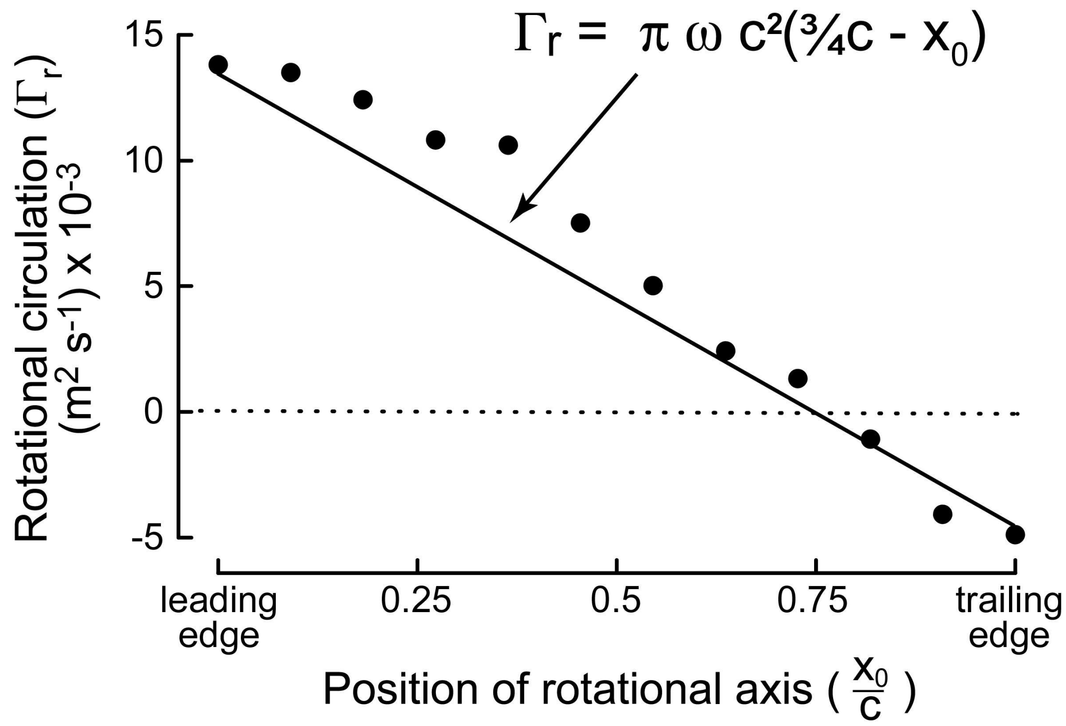


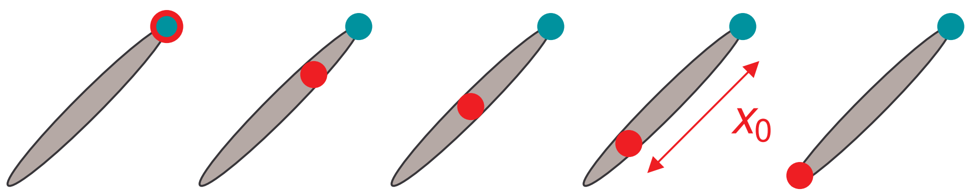
Rotational circulation changes with rotational axis of an insect wing



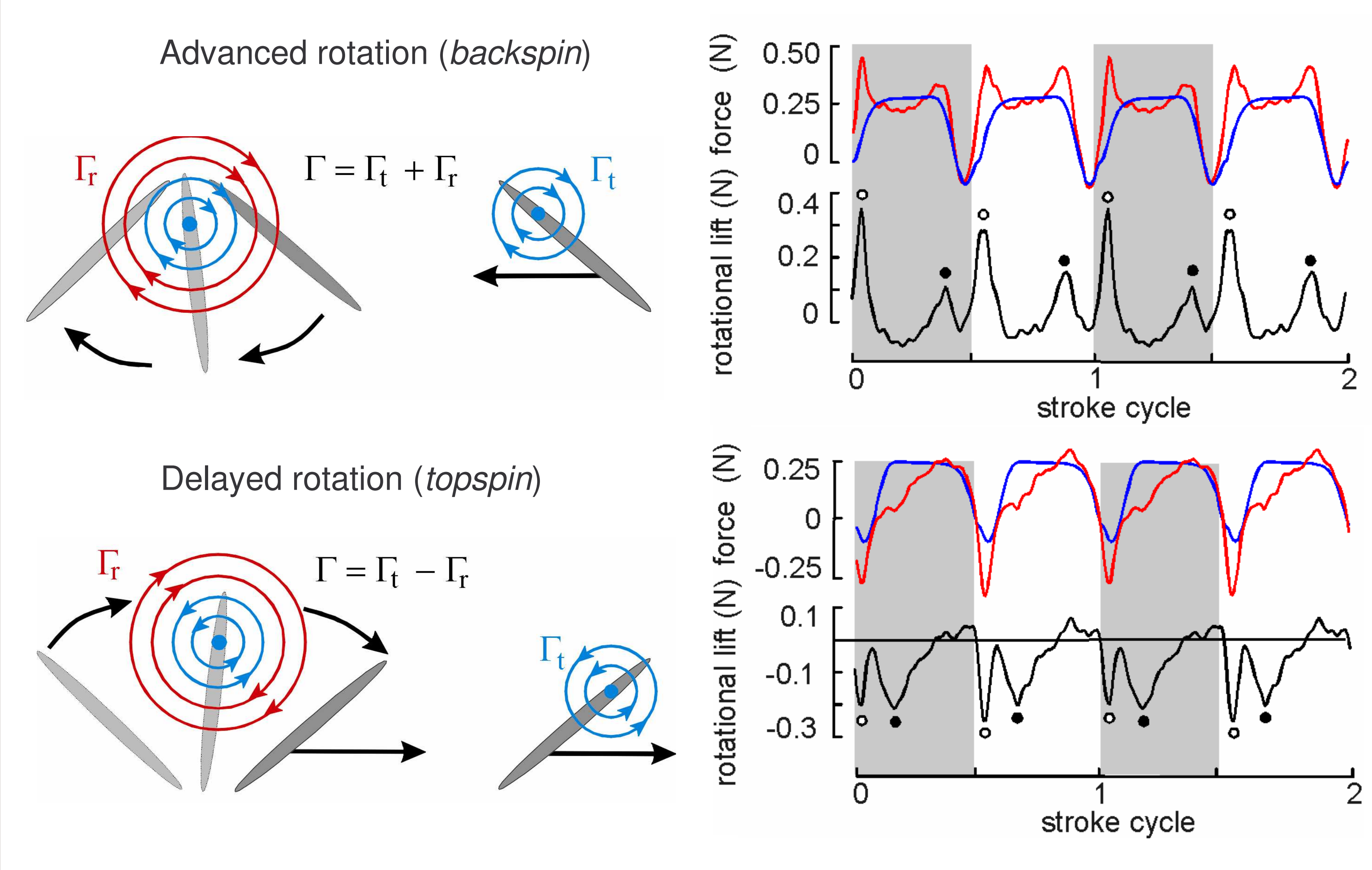
= rotational axis

= leading wing edge

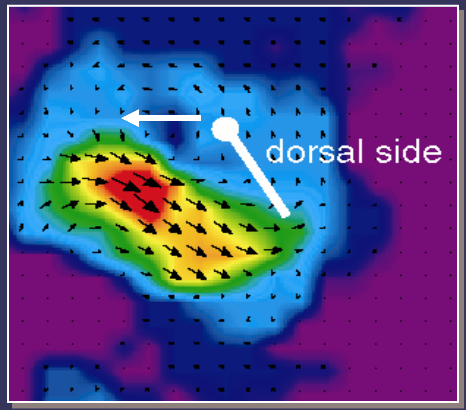




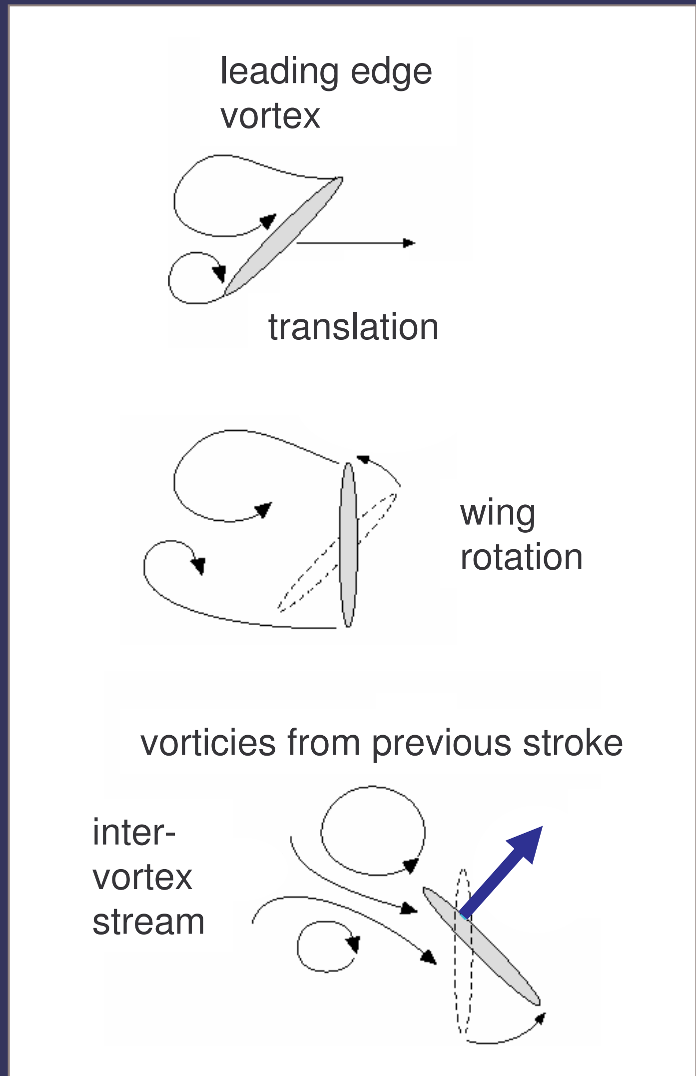
Flight force production at different rotational timings



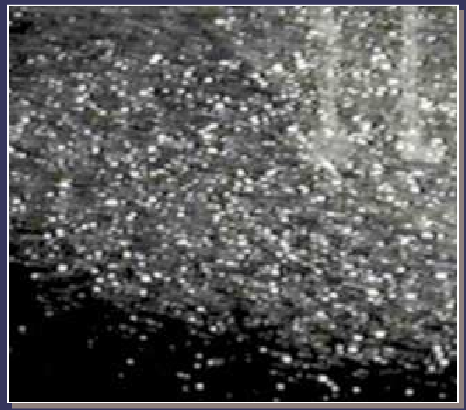
Modifications of unsteady aerodynamics: wing-wing & wing-wake interactions

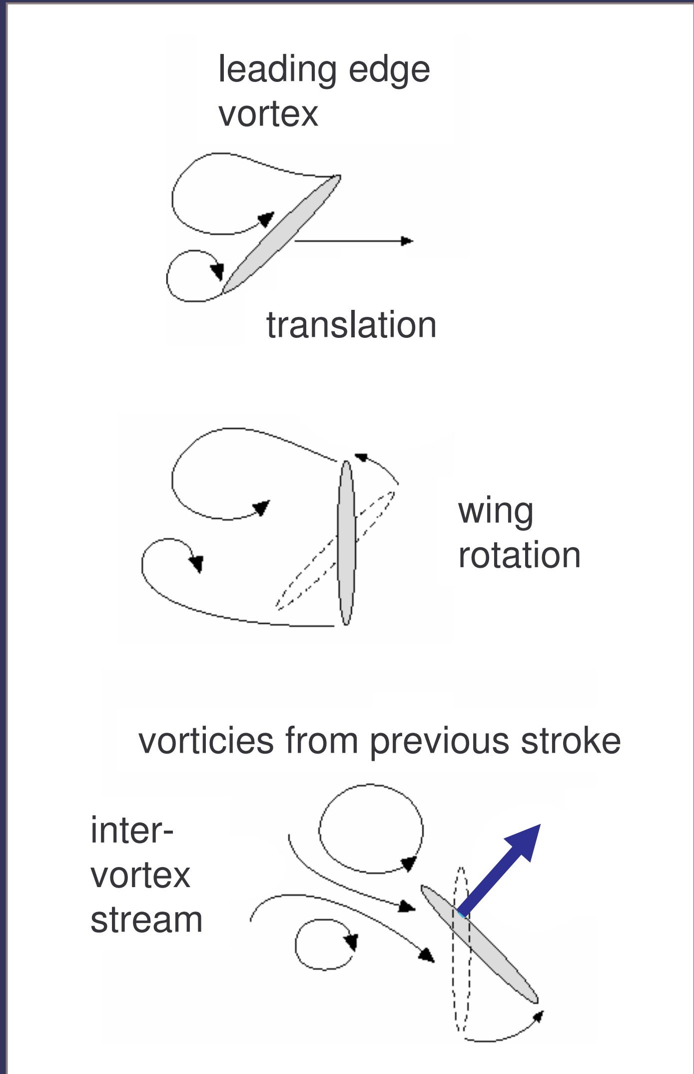


- Wing configuration — Single wing
- Time of interaction — Stroke reversal
- Fluid dynamic mechanism — Recapture of flow produced during preceding half stroke, momentum transfer



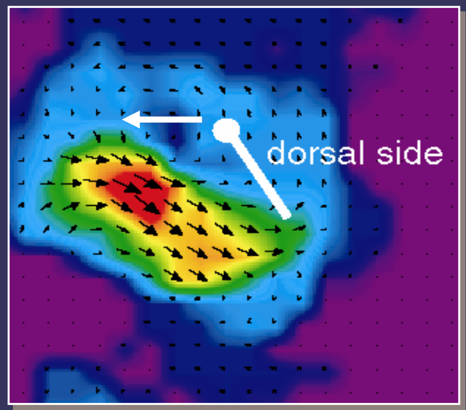
Modifications of unsteady aerodynamics: wing-wing & wing-wake interactions

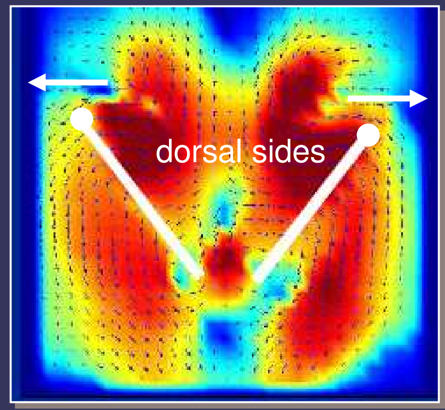


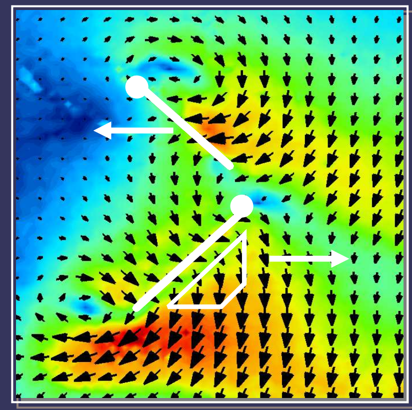


Wing configuration	Single wing
Time of interaction	Stroke reversal
Fluid dynamic mechanism	Recapture of flow produced during preceding half stroke, momentum transfer

Modifications of unsteady aerodynamics: wing-wing & wing-wake interactions





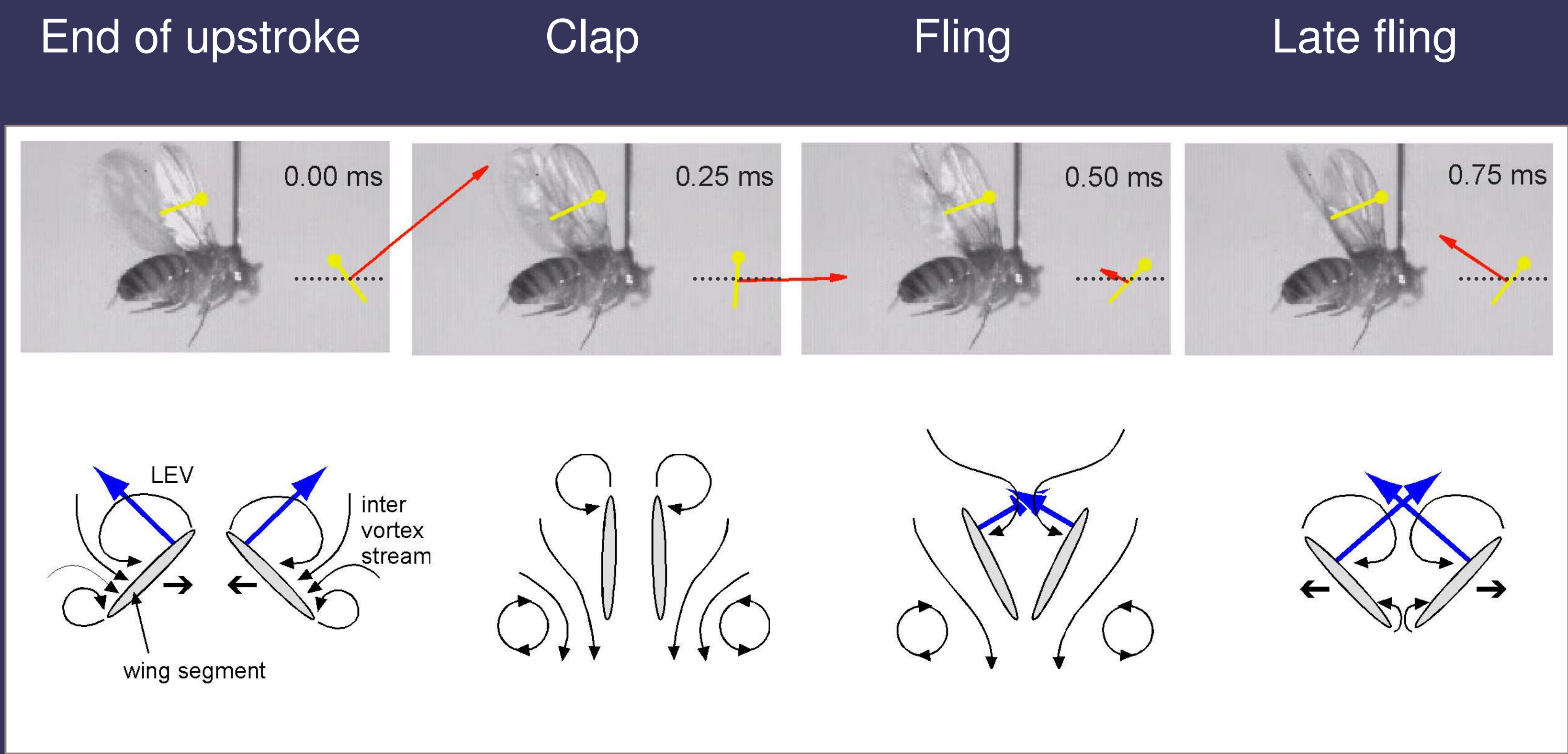


Wing configuration	Single wing	Ipsi-contral lateral	Fore-hind
Time of interaction	Stroke reversal	Stroke reversal	Entire stroke cycle
Fluid dynamic mechanism	Recapture of flow produced during preceding half stroke, momentum transfer	LEV induction and alteration in wake capture	LEV desctruction and fore wing wake capture by hind wing

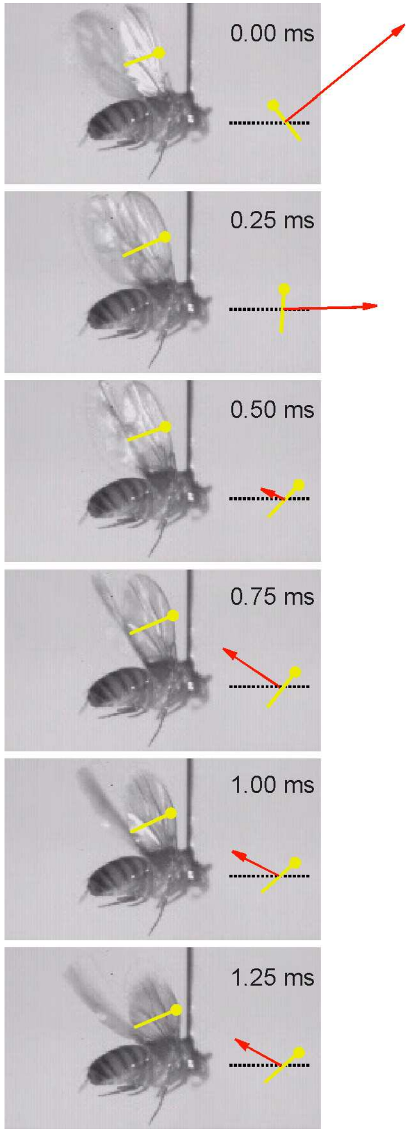
Ispi-contral lateral wing-wing interaction (clap and fling)

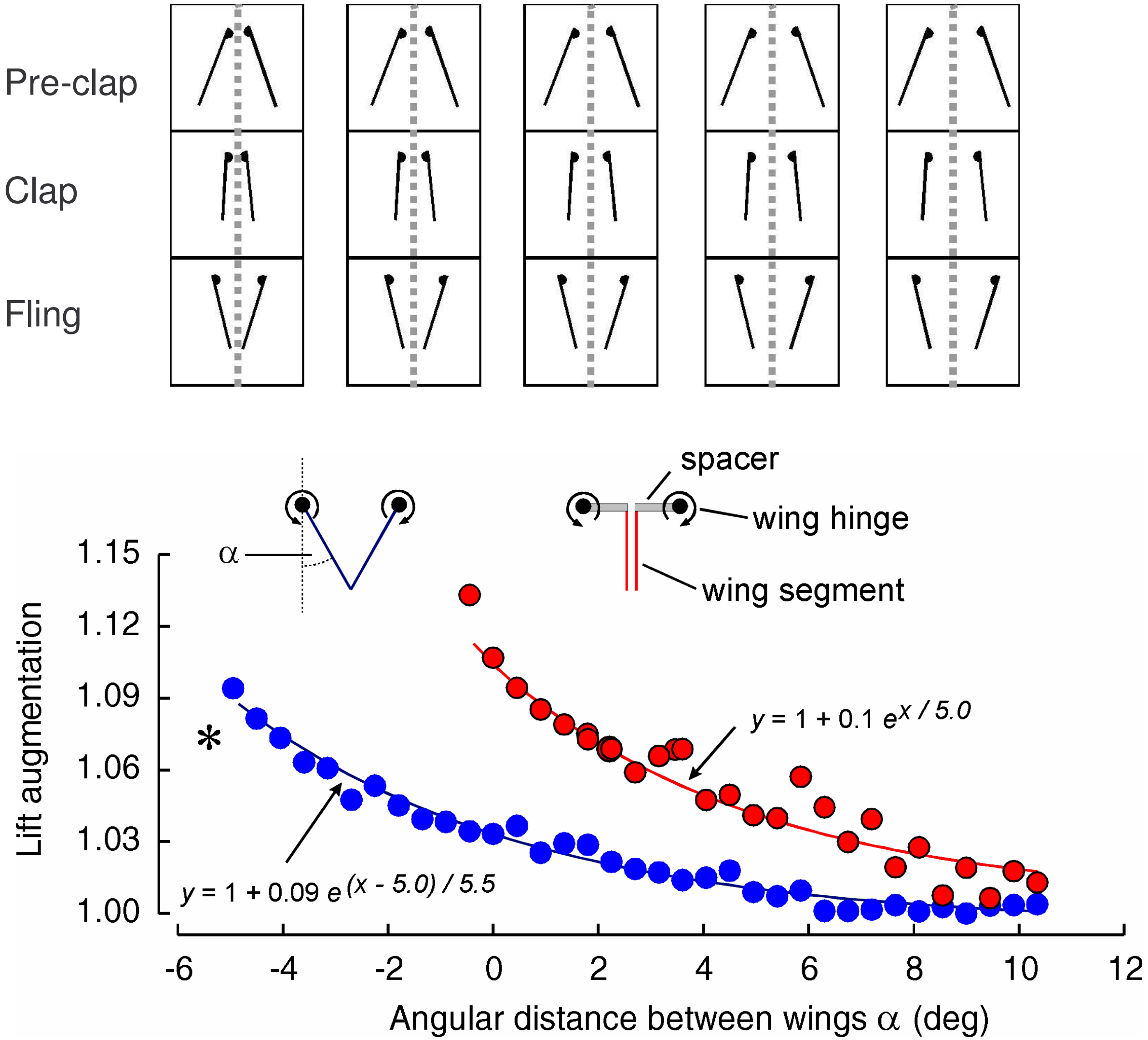
I. „force control without changes in kinematics“

Wing-wing interaction: A source for lift enhancement?

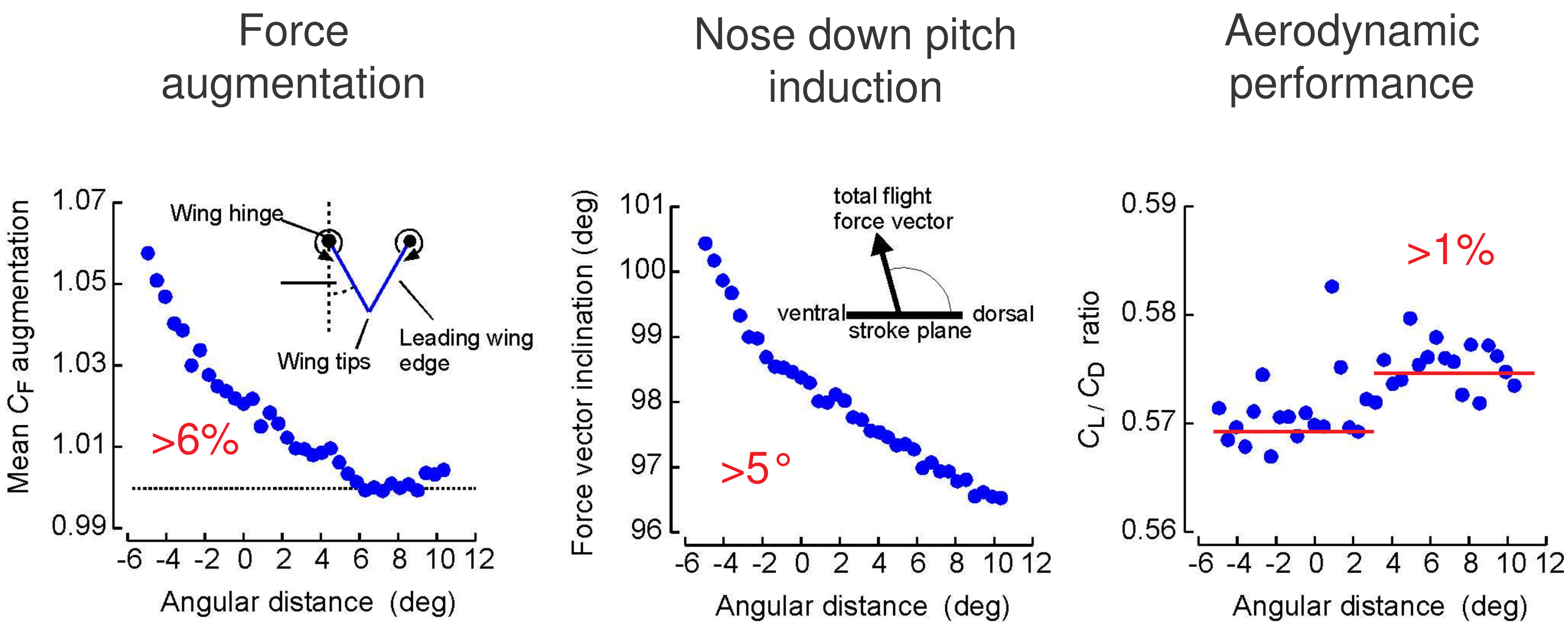


Lift enhancement by wing-wing interaction using a 3-D robotic model (Re=134)



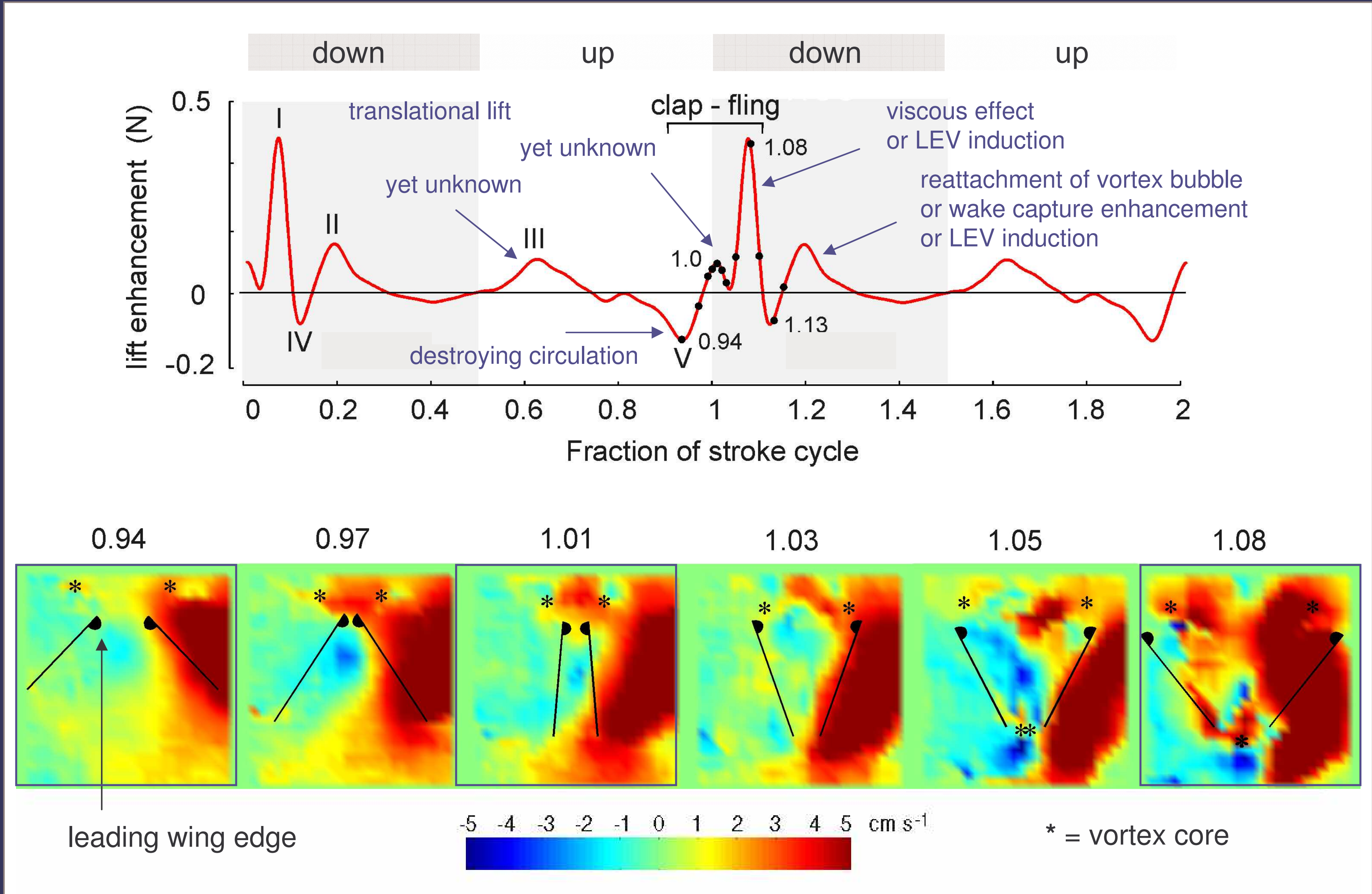


Aerodynamic effects of clap and fling: Fruit fly kinematics



Values scaled to performance of 1 wing

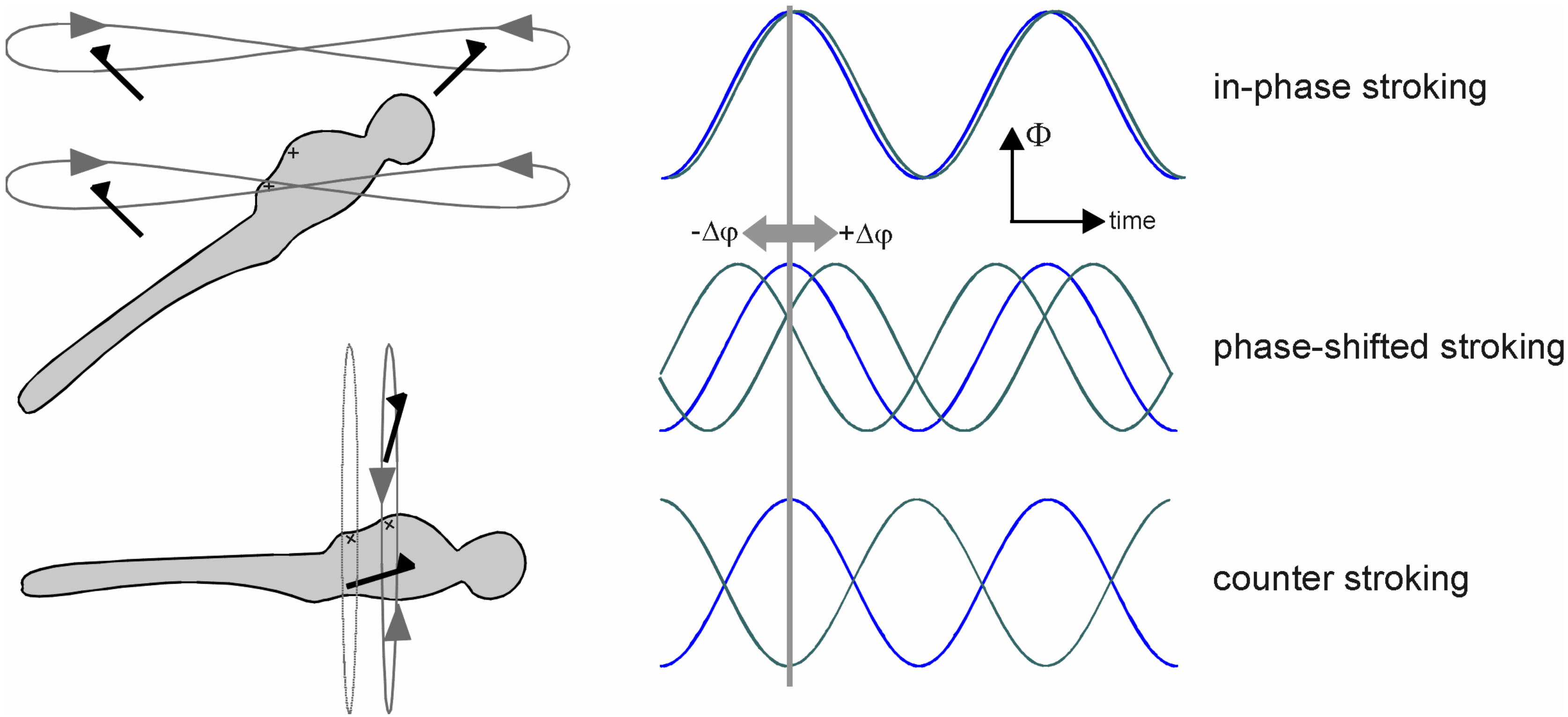
Lift enhancement and velocity differential image (2-D DPIV, 2-1 wing)



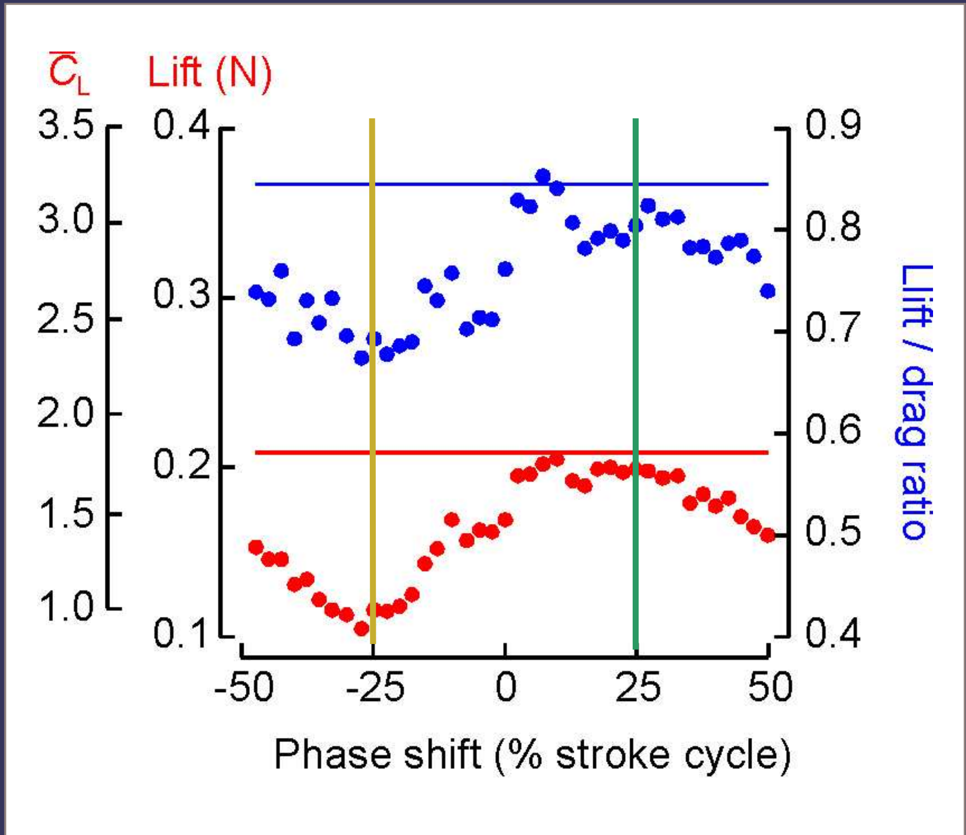
Ispilateral tandem wing-wake interaction

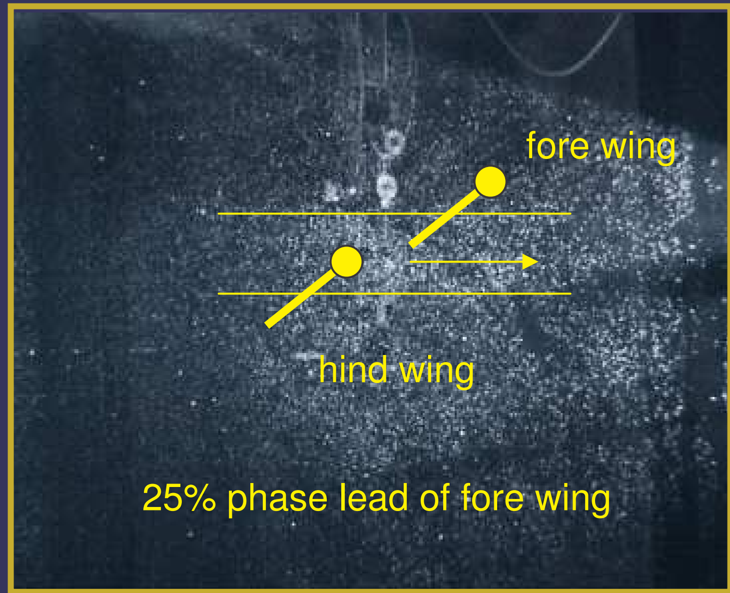
II. „force control without changes in kinematics“

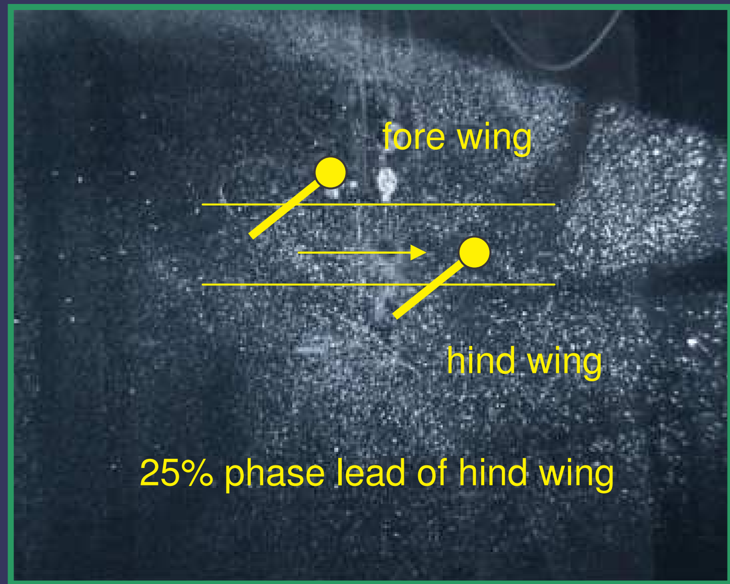
Stroke kinematics in four winged insects (dragon and damsel flies)



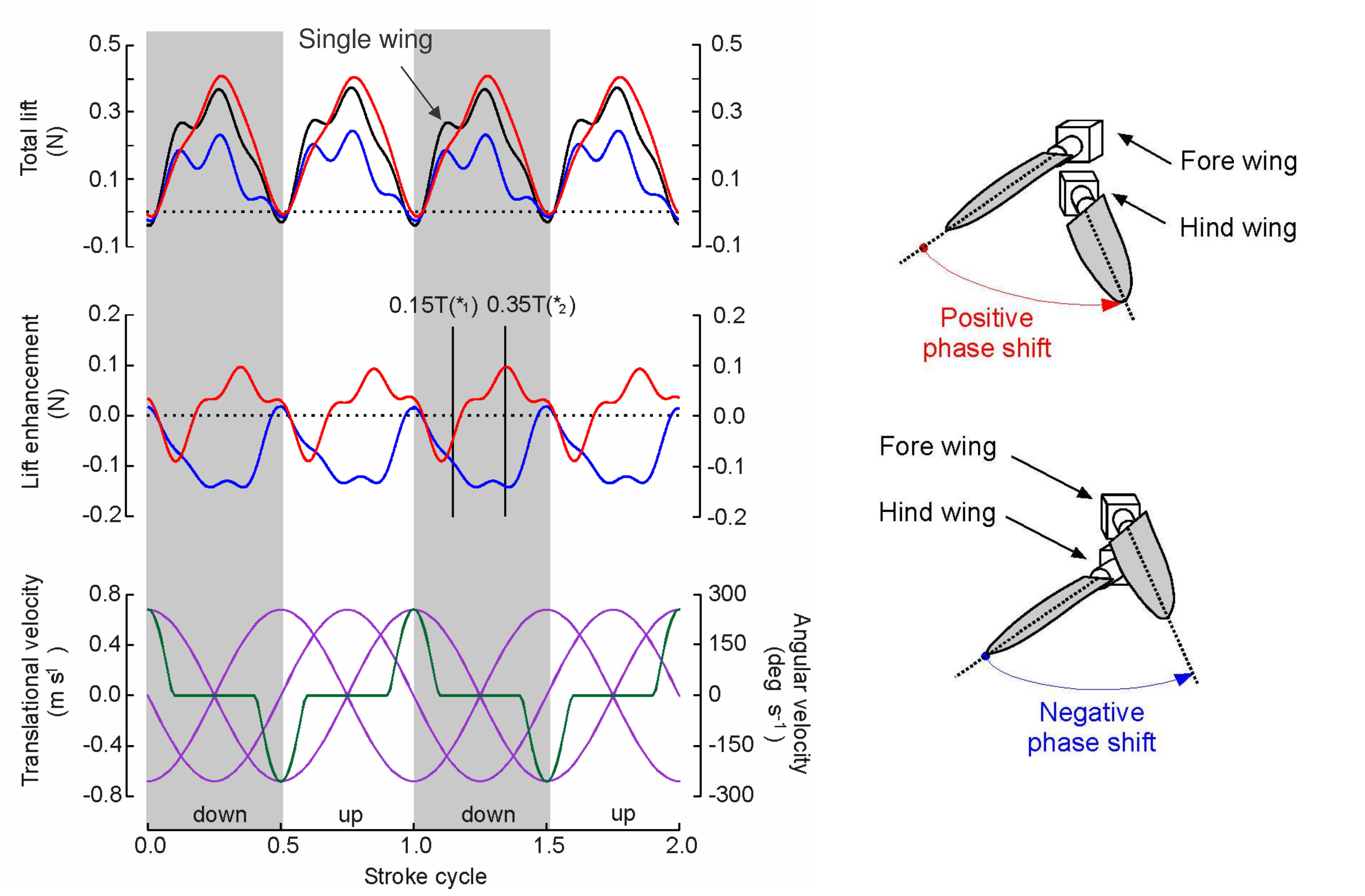
Wing-wake interaction in tandem wings: Hindwing lift



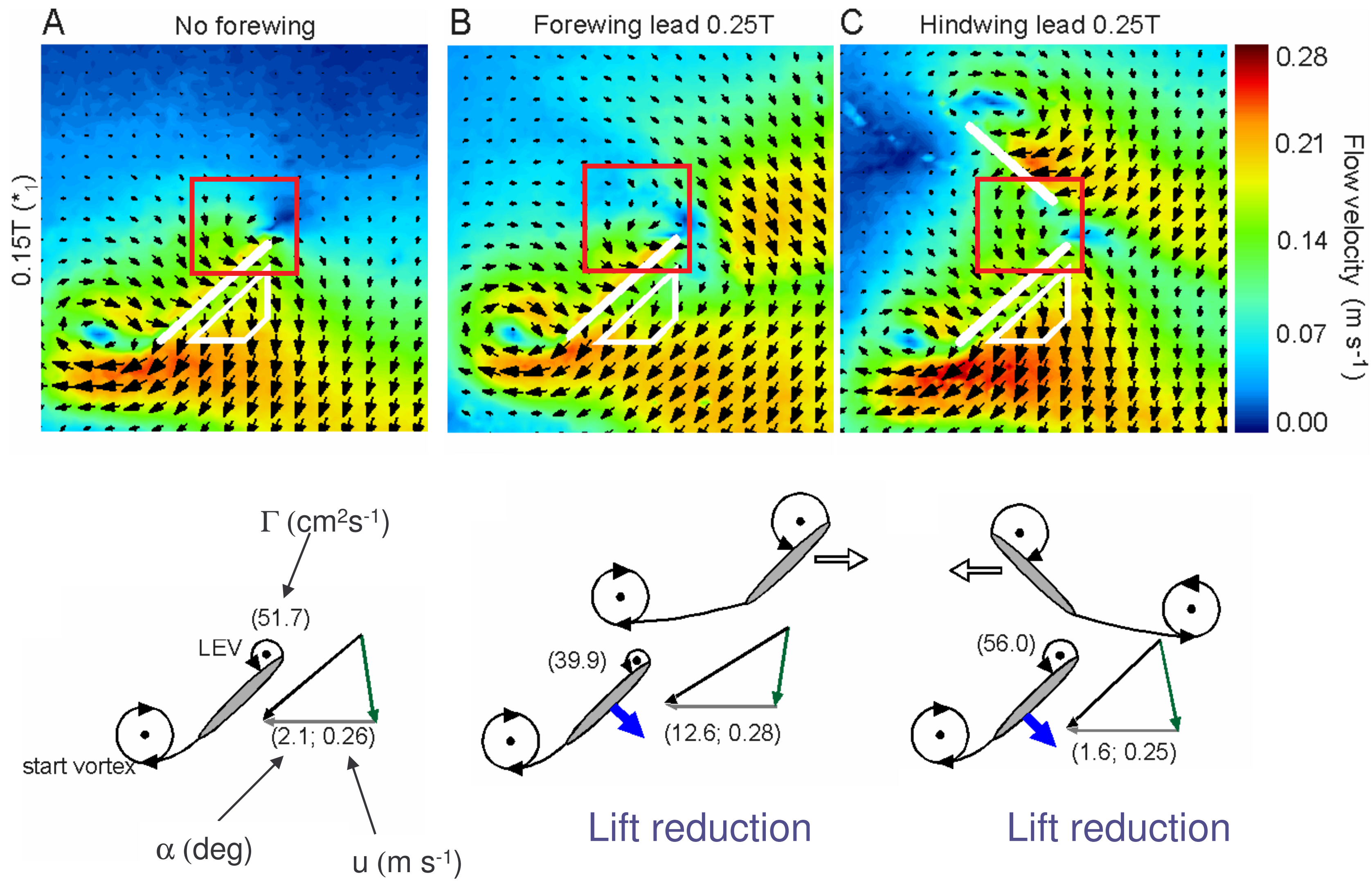




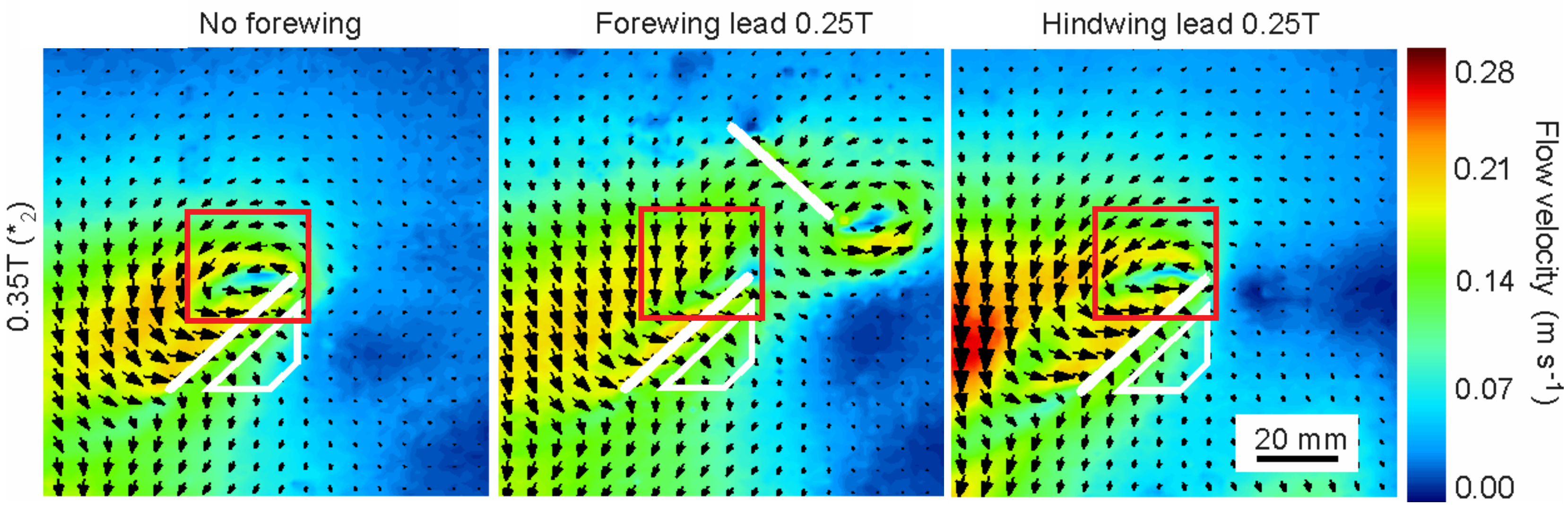
Hind wing force production and lift enhancement

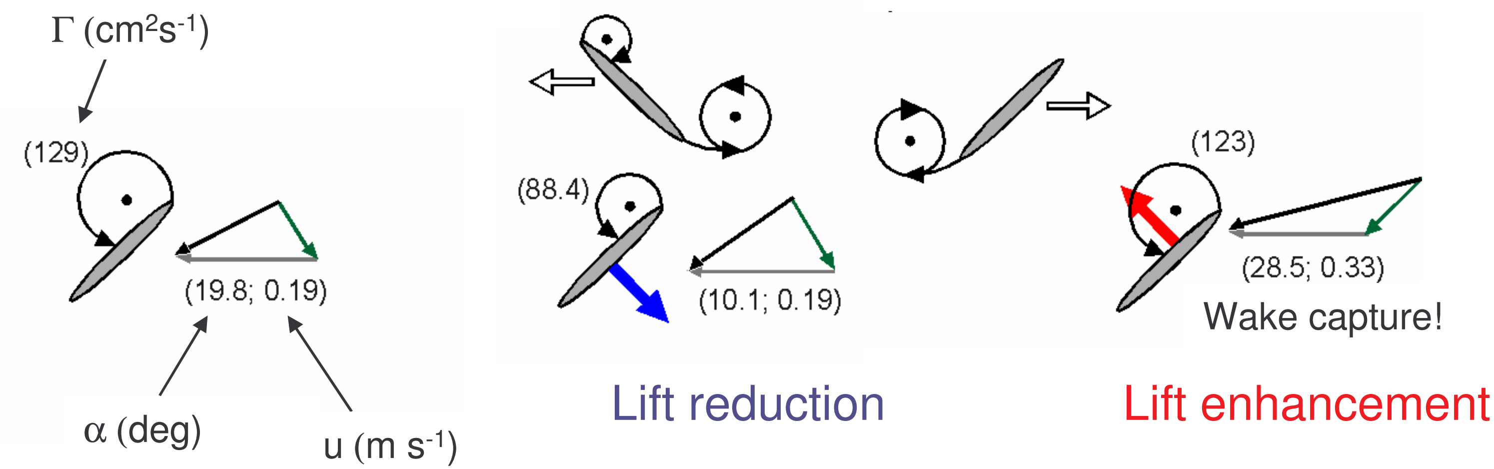


DPIV measures of hindwing LEV and local flow at 15 and 65% stroke cycle



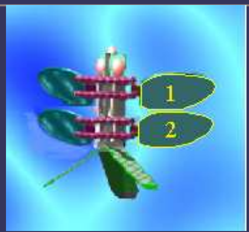
DPIV measures of hindwing LEV and local flow at 35 and 85% stroke cycle



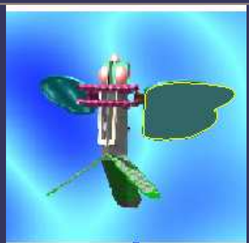


... what did we learn from these results for the construction of hovering biomimetic MAVs based on flapping wing motion ....

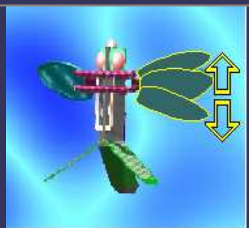
Biomimetic MAVs: Design strategies derived from aerodynamic analysis



- *Wing hinge design:*
  Tandem wing MAV simplifies implementation of control



- *Wing shape:*
  Tubby low aspect ratio wings: High C_L, low inertial costs



- *Kinematics:*
  Gross pattern depends on task and desired clap/fling effect

- *Flight control:*
  1. Kinematic phase shift (no changes in rotational timing, angle of attack, stroke amplitude required)
  2. Rotational control provides enhanced maneuverability
  3. Clap and fling: Pitch control and burst performance


‚Macro‘-air-vehicle anno
1829