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Honeybees' altitude control relies on same optical invariants as pilots

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Main question: Perceiving a complex visual environment, what optical invariant does *Apis mellifera* focus on to stabilize its altitude?



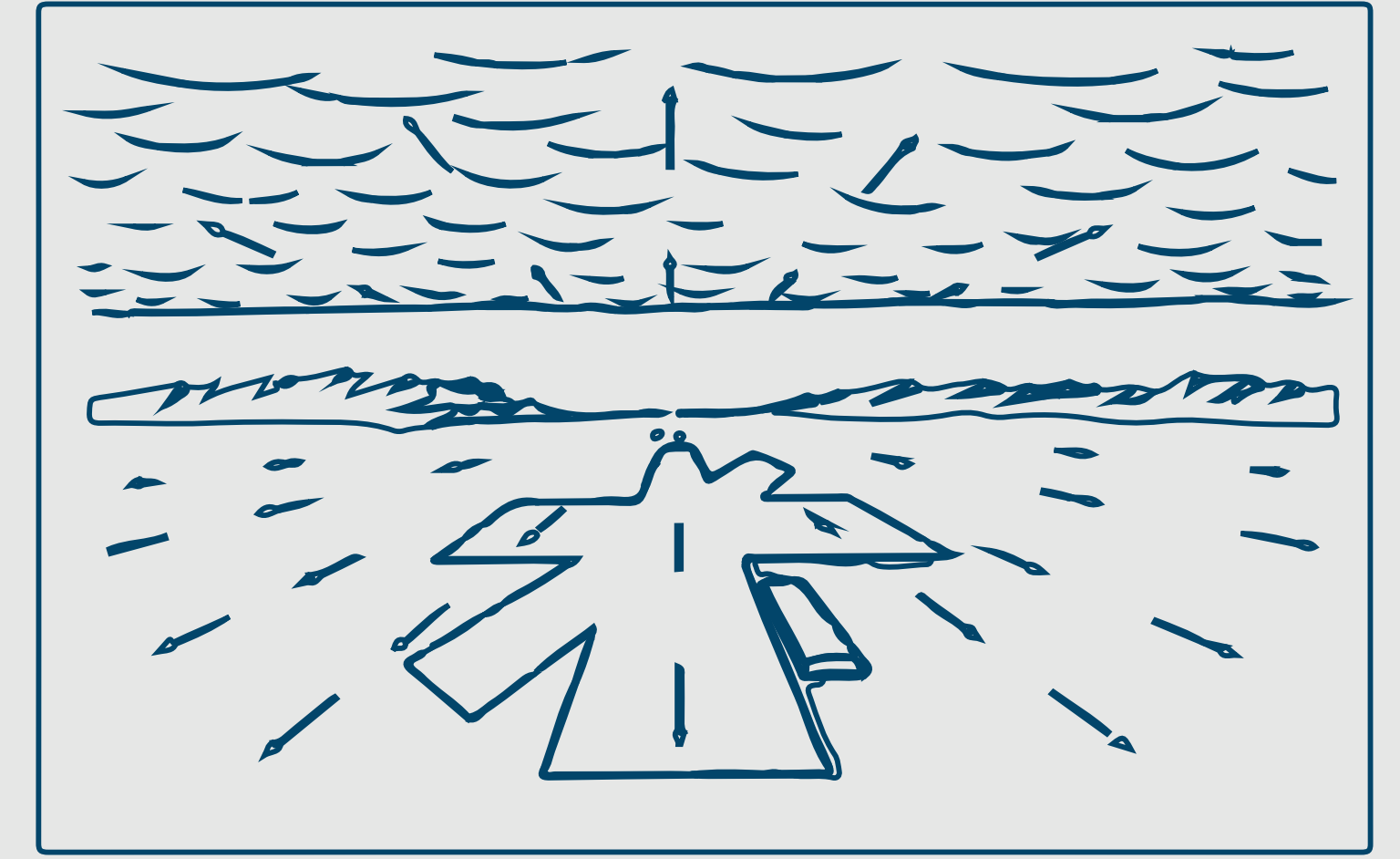
Bases and aims

Optic flow: vector field of the apparent motion of objects, surfaces, and edges in a visual scene caused by the relative motion between an agent and the scene.

Optical invariants: particular properties of the optic flow unaltered when the agent is moving. Two optical invariants are particularly relevant for a ground_following task:

- **optical speed rate of change** $\dot{\omega}$ [used by bees and pilots]
- **splay angle rate of change** \dot{s} [used by pilots]

Aims: (1) To determine if bees also use splay angle rate of change for performing ground-following tasks
(2) To set the priority and weight system by which bees use these two optical invariants to control their altitude



Optic flow field perceived by a flying agent (Gibson 1950, 1979)

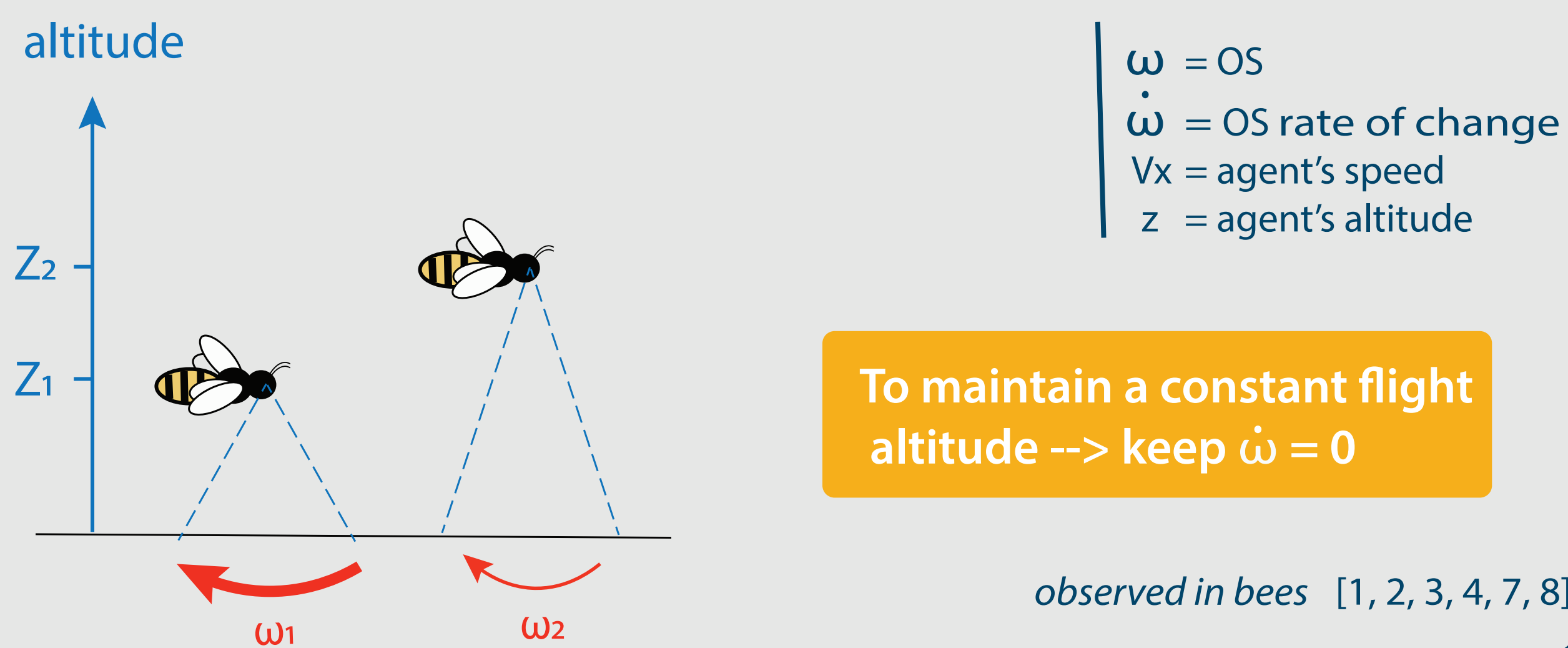


Optical speed (OS) experienced by a flying agent

OS (ω) is the speed of environment's image scrolling the retina when an agent is moving.

- OS increases for an agent going down ($\dot{\omega} > 0$)
- OS decreases for an agent going up ($\dot{\omega} < 0$)

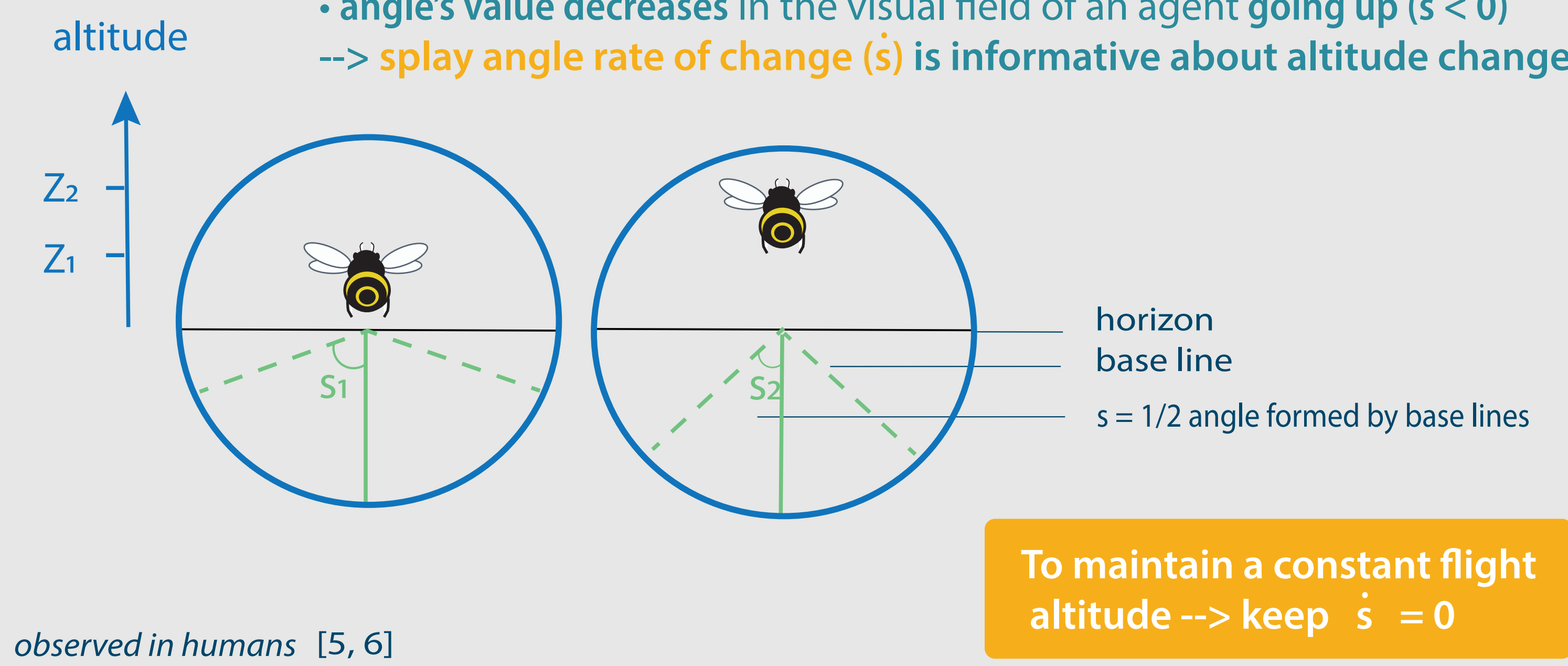
--> **optical speed rate of change** ($\dot{\omega}$) is informative about altitude change



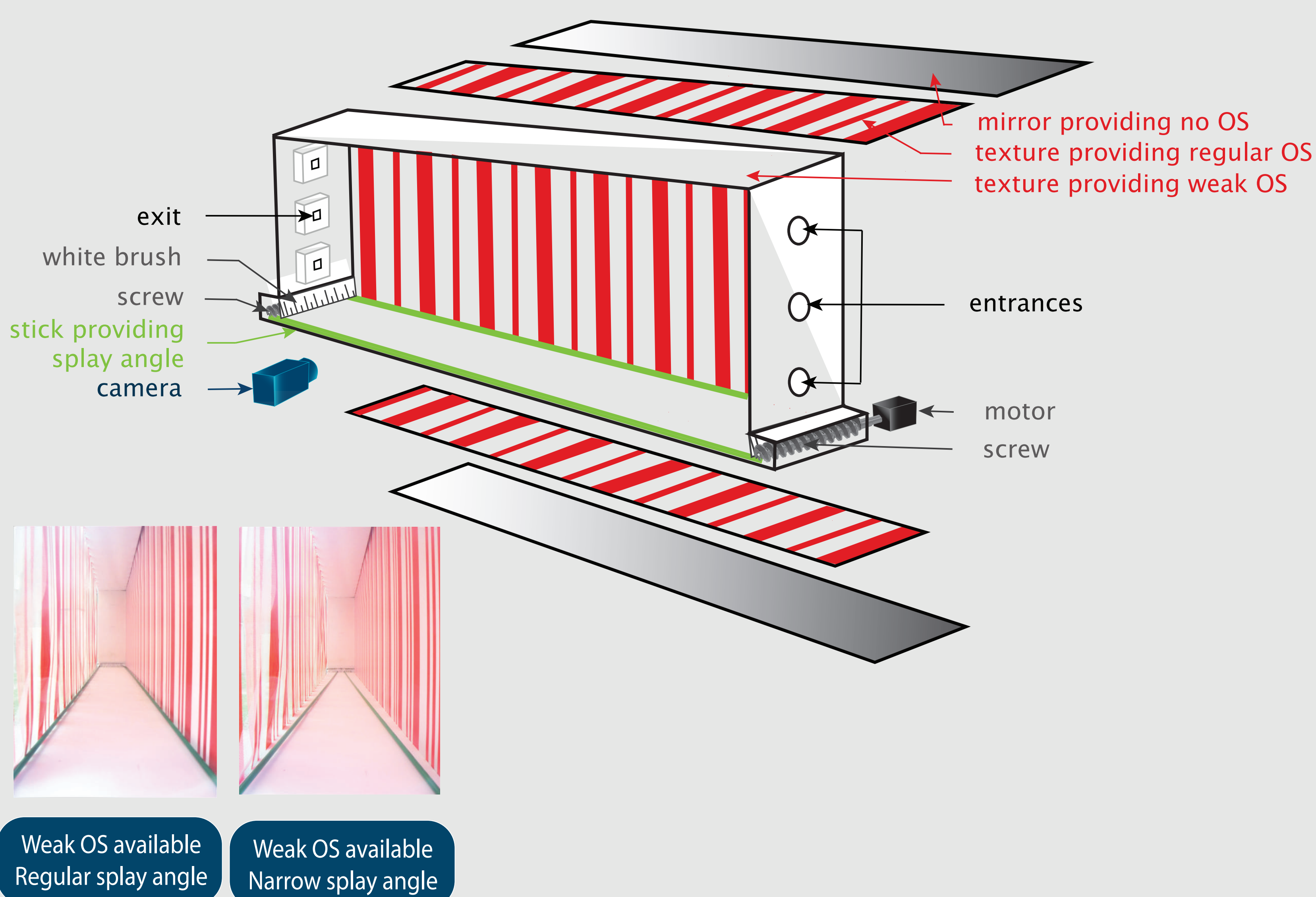
Splay angle rate of change experienced by a flying agent

Base lines join at the image's focus of expansion forming the **splay angle (s)**:

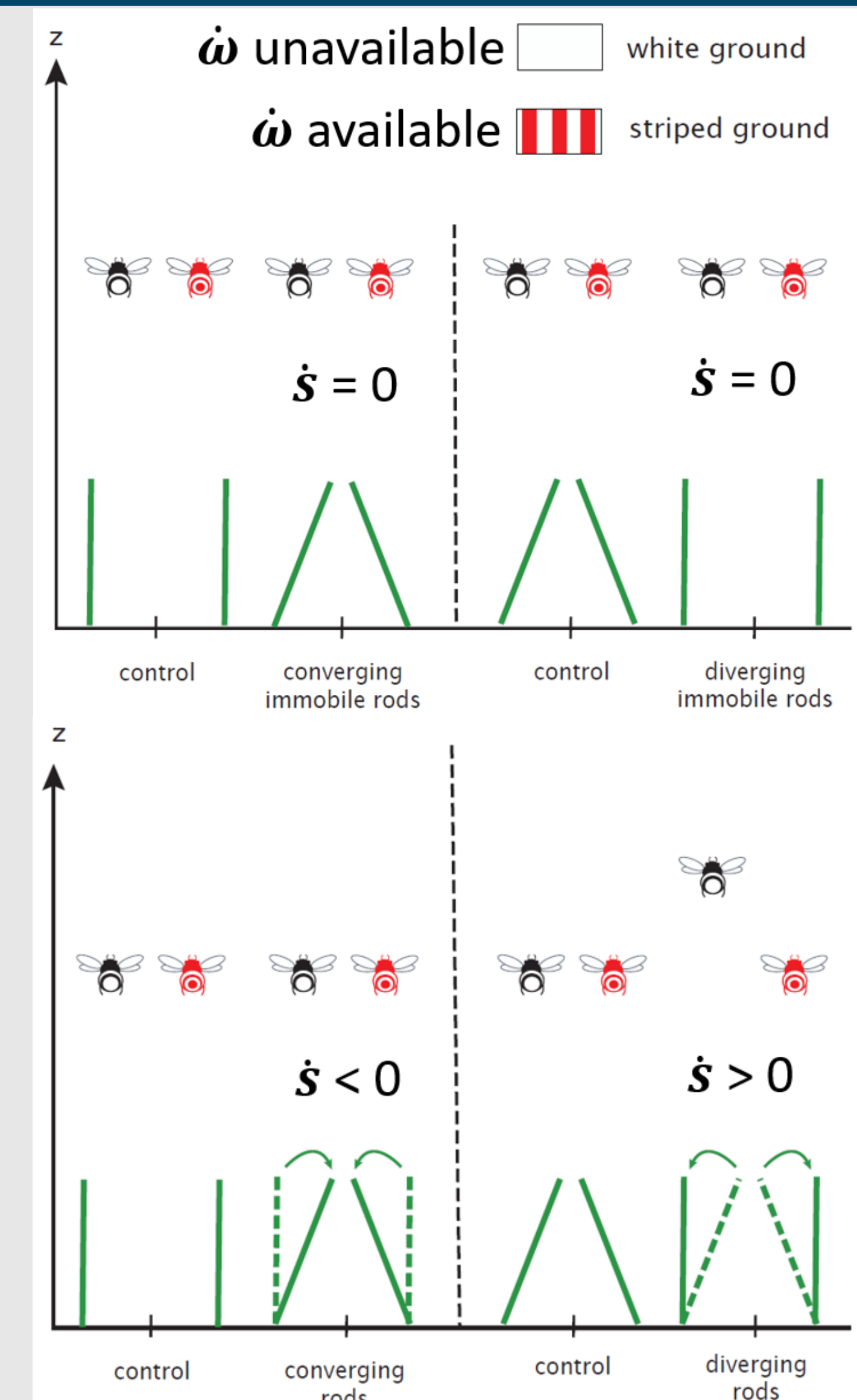
- angle's value increases in the visual field of an agent going down ($\dot{s} > 0$)
 - angle's value decreases in the visual field of an agent going up ($\dot{s} < 0$)
- > **splay angle rate of change** (\dot{s}) is informative about altitude change



Experimental setup [9]



Predictions and results [9, 10]



- A bee perceiving a **splay's enlargement** will interpret a **loss of altitude**, so it will go up to maintain a null splay angle rate of change. ✓
- A bee perceiving a **splay's narrowing** will interpret a **gain in altitude**, so it will go down to maintain a null splay angle rate of change. ✗



Highlights

- An experimental setup was designed to investigate whether the splay angle rate of change is implicated in bees' altitude control
- A flight tunnel was built enabling specific manipulations of two optical invariants
- Splay angle rate of change is used by bees to control their altitude in a ground-following task
- Splay angle rate of change is used by bees only if the optical speed rate of change is less accessible