Spatio-temporal dynamics of bumblebees foraging under predation risk

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Motivation

bumblebee foraging – two very practical problems:

1. find food (nectar, pollen) in complex landscapes


2. try to avoid **predators**

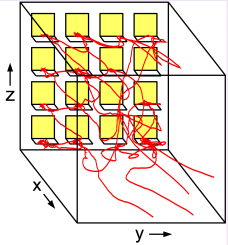
What type of motion?

Study bumblebee foraging in a *laboratory experiment*.

The bumblebee experiment

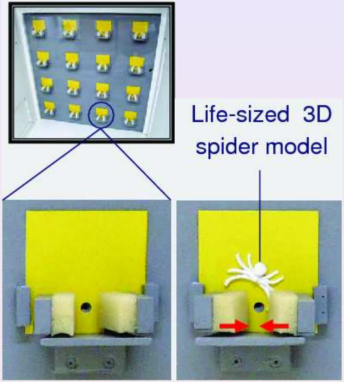
Ings, Chittka, Current Biology **18**, 1520 (2008):
bumblebee foraging in a cube of $\simeq$ 75cm side length

- artificial yellow flowers: 4x4 grid on one wall
- two cameras track the position (50fps) of a single bumblebee *(Bombus terrestris)*



- **advantages:** systematic variation of the environment; easier than tracking bumblebees on large scales
- **disadvantage:** no ‘free flight’ of bumblebees

Variation of the environmental conditions



safe and **dangerous**
flowers

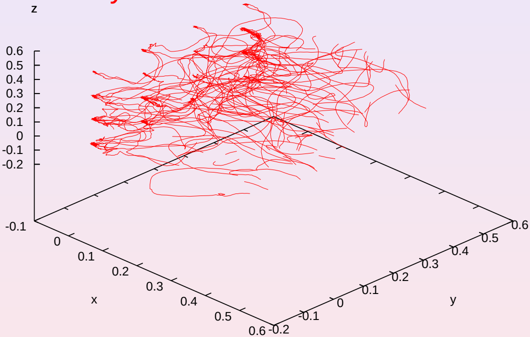
three experimental stages:

1. spider-free foraging
2. foraging under predation risk
3. memory test 1 day later

#bumblebees=30 , #data per bumblebee for each stage $\approx$ 7000

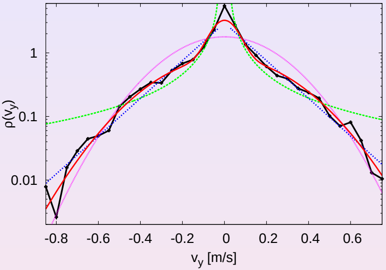
Bumblebee experiment: two main questions

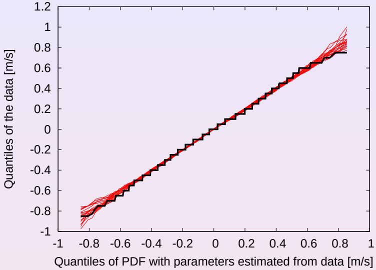
1. What type of motion do the bumblebees perform in terms of stochastic dynamics?



2. Are there changes of the dynamics under variation of the environmental conditions?

Velocity distributions: analysis





left: experimental **pdf of v_y-velocities** of a single bumblebee in the spider-free stage (black crosses) with max. likelihood fits of mixture of 2 Gaussians; exponential; power law; single Gaussian

right: **quantile-quantile plot** of a Gaussian mixture against the experimental data (black) plus surrogate data

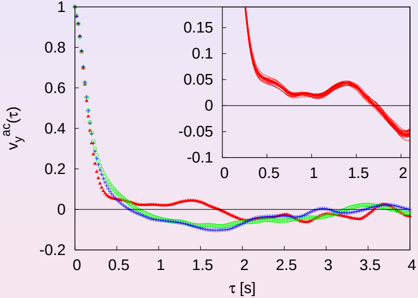
Velocity distributions: interpretation

- **best fit** to the data by a mixture of two Gaussians with different variances (quantified by information criteria with resp. weights)
- **biological explanation:** models spatially different flight modes near the flower vs. far away, cf. intermittent dynamics

big surprise: no difference in pdf's between different stages under variation of environmental conditions!

Velocity autocorrelation function $\parallel$ to the wall

$V_y^{AC}(\tau) = \frac{\langle (v_y(t)-\mu)(v_y(t+\tau)-\mu)\rangle}{\sigma^2}$ with average over all bees:

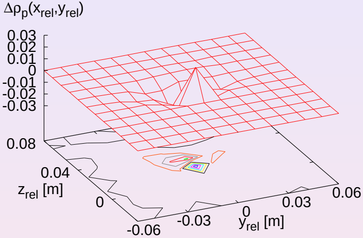


- plot: spider-free stage, predation thread, memory test
- **correlations change** from positive (spider-free) to negative (spiders)

$\Rightarrow$ $\boxed{\text{all } \textbf{changes} \text{ are in the } \textbf{velocity correlations}, \textit{not} \text{ in pdf's!}}$

Predator avoidance and a simple model

predator avoidance as difference in position pdfs spider / no spider from data:



positive spike: *hovering*; negative region: *avoidance*

modeling by the Langevin equation

$$\frac{dv_y}{dt}(t) = -\eta v_y(t) - \frac{\partial U}{\partial y}(y(t)) + \xi(t)$$

η: friction coefficient, ξ: Gaussian white noise
U: repulsive interaction potential bumblebee - spider that reproduces the change in the velocity correlations

Summary: Clever bumblebees!

- mixture of **two Gaussian velocity distributions** reflects spatial adjustment of bumblebee dynamics to flower carpet
- all changes to predation thread are contained in the **velocity autocorrelation functions**, which exhibit highly non-trivial temporal behaviour

  (nb: Lévy hypothesis suggests that all relevant foraging information is contained in pdf's)
- change of correlation decay in the presence of spiders due to **experimentally extracted repulsive force** as reproduced by generalized Langevin dynamics

Reference

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