Modeling the migration of foraging animals: A short review

Friedrich Lenz[1,2] Thomas Ings[3] Aleksei V. Chechkin[4]
Holger Kantz[1] Lars Chittka[3] Rainer Klages[2]

[1]Max Planck Institute for the Physics of Complex Systems, Dresden

[2]Queen Mary University of London, School of Mathematical Sciences

[3]Queen Mary University of London, Biological and Chemical Sciences

[4]Institute for Theoretical Physics NSC KIPT, Kharkov, Ukraine

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Outline

Purpose of this talk

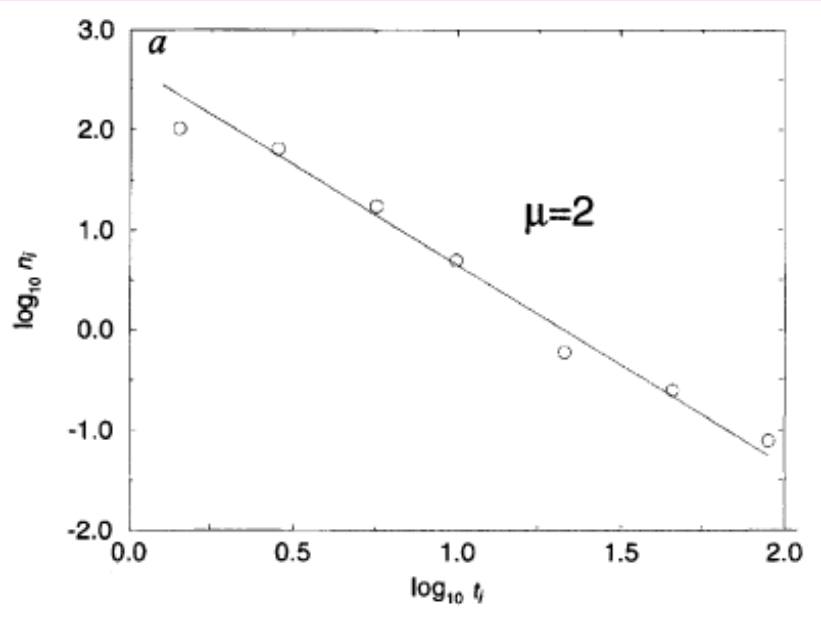
motivate the following two talks by relating them to the first one:

1. problem of modeling the migration and the search strategies of foraging animals → now
2. motivates to statistically analyze the dynamics of foraging bumblebees in Tom's experiment → F.Lenz
3. theoretical framework: hypothesis of Lévy flights as an optimal foraging strategy → A.V.Chechkin

Lévy flight search patterns of wandering albatrosses

Viswanathan et al., Nature **381**, 413 (1996):

- flight times of albatrosses foraging in the South Atlantic recorded
- distribution of flight times fitted with a Lévy flight model (power law):



Lévy flights in a nutshell

Lévy flights have well-defined mathematical properties: stochastic process

- with probability distribution function of flight lengths $\rho(\ell) \sim \ell^{-\alpha}$ with $1 < \alpha < 3$ *(power law)*,
- it is *scale invariant*,
- satisfies a *generalized central limit theorem* and
- has *infinite variance*

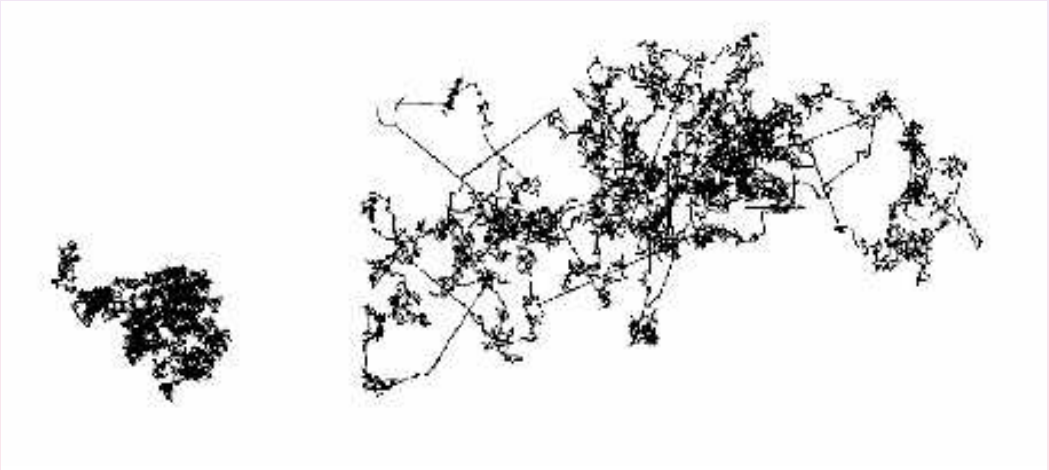
see → Chechkin for a short introduction

(also outline by Shlesinger at al., Nature **363**, 31 (1993))

Optimizing the success of random searches

Viswanathan et al., Nature **401**, 911 (1999):

- question posed about *"best statistical strategy to adapt in order to search efficiently for randomly located objects"*
- (computer) model proposed which predicts that Lèvy flights are optimal for *sparse and revisitable* targets



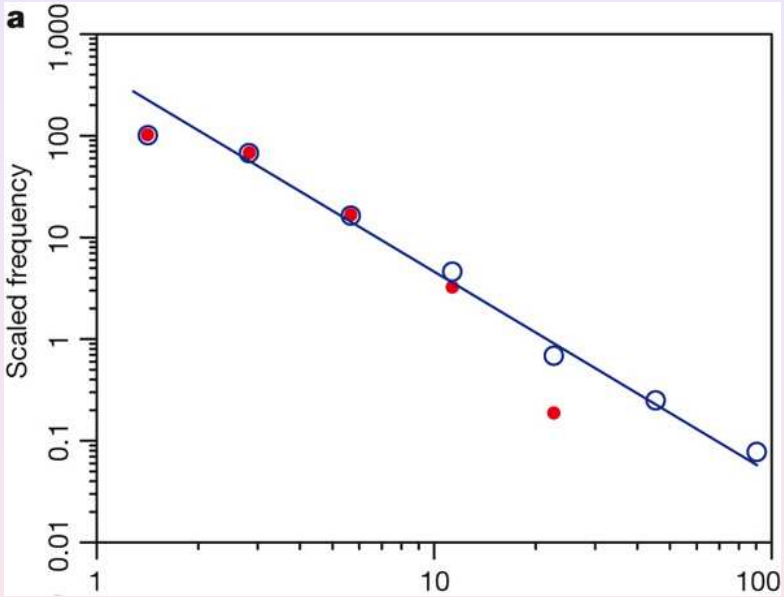
Brownian motion (left), **Lévy flights** (right)

- theory applied to bumblebee, deer and albatross data: argued that all perform Lévy flights under above conditions

Revisiting Lévy flight search patterns

Edwards et al., Nature **449**, 1044 (2007):

- Viswanathan et al. results revisited by correcting the old data:

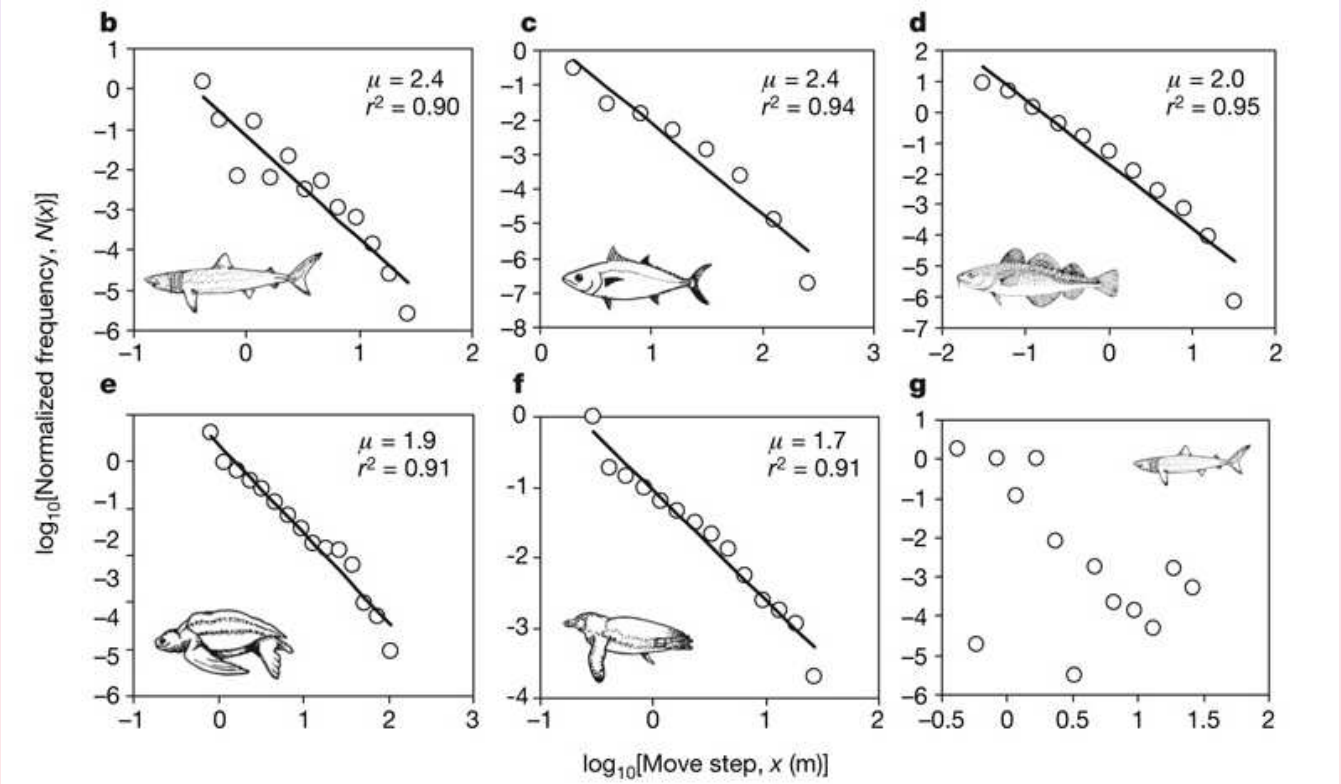


- Lévy flight behavior clearly ruled out. On the basis of new, more precise data some other (gamma distributed) stochastic process revealed
- refined data analysis yields no evidence for Lévy flights in bumblebee and deer data either

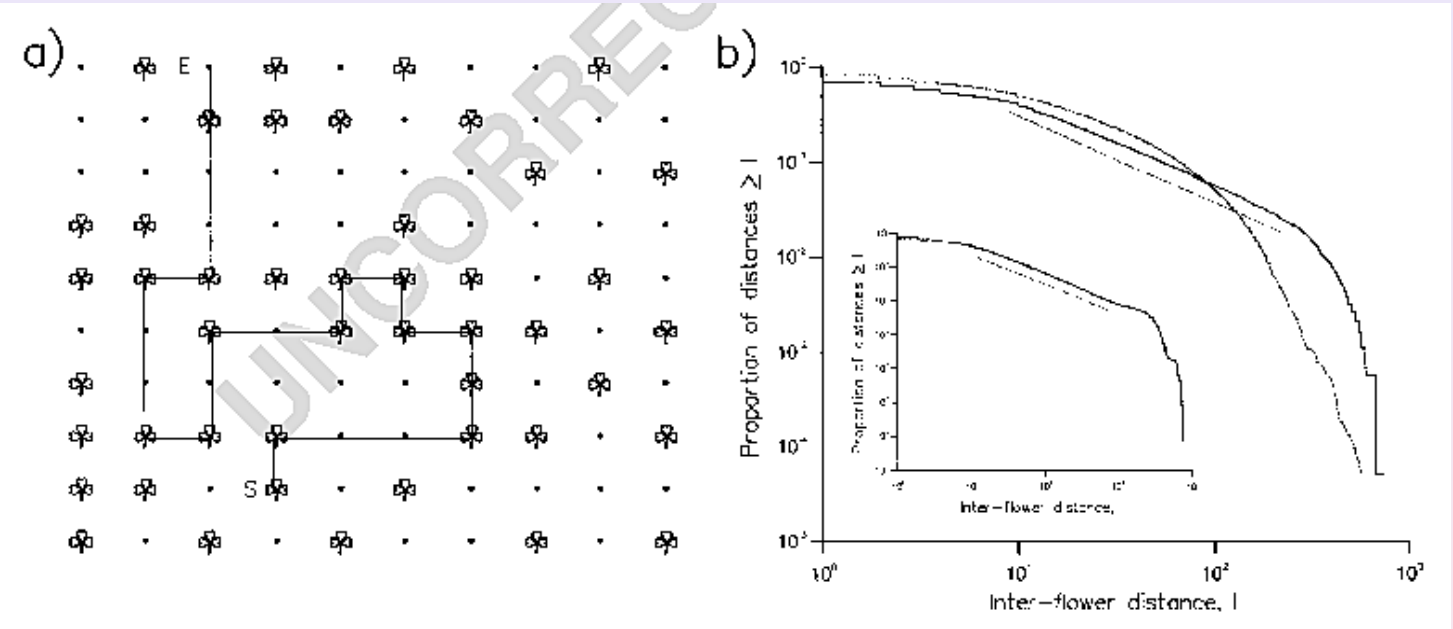
Lévy or not Lévy?

Lévy paradigm studied in series of research:

- Sims et al., Nature **451**, 1098 (2008): many marine predators are **Lévy**; prey distributions also display Lévy-like patterns: preditor-prey interaction studied



- Reynolds, Behav.Ecol.Sociobiol., in press: model proposed for bumblebee foraging in a patch of flowers; numerical analysis predicts **Lévy flights**



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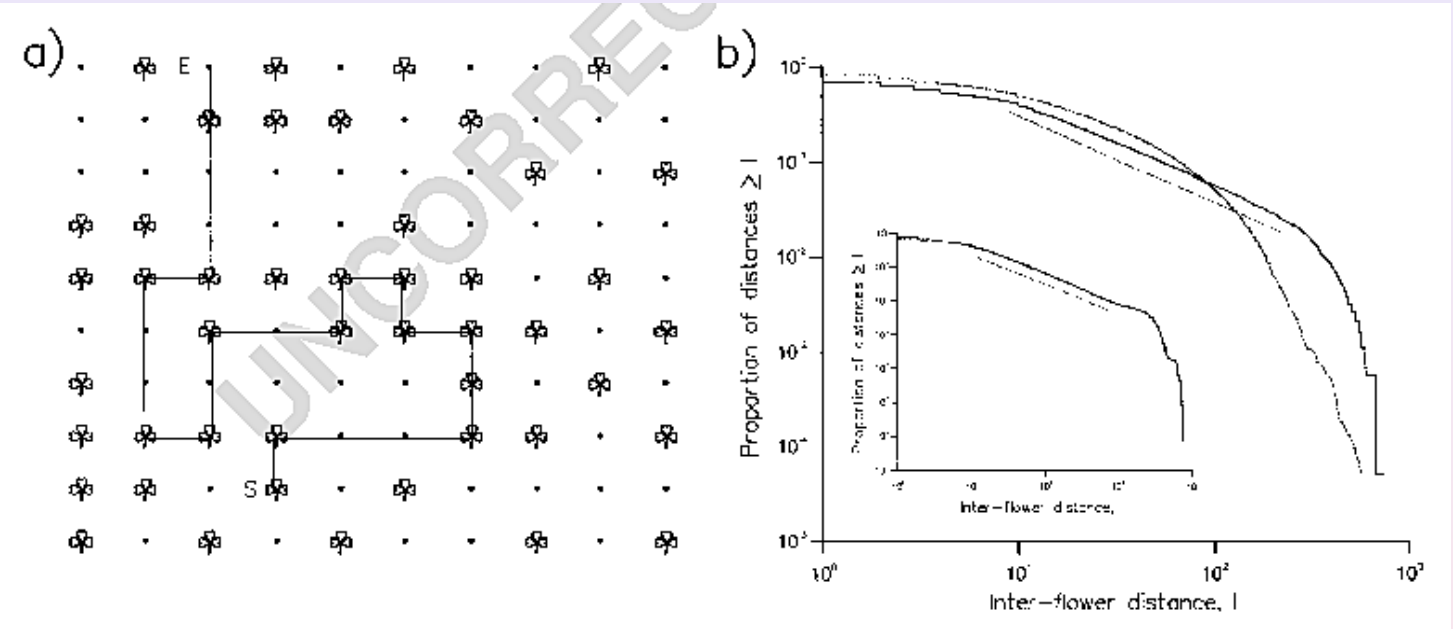


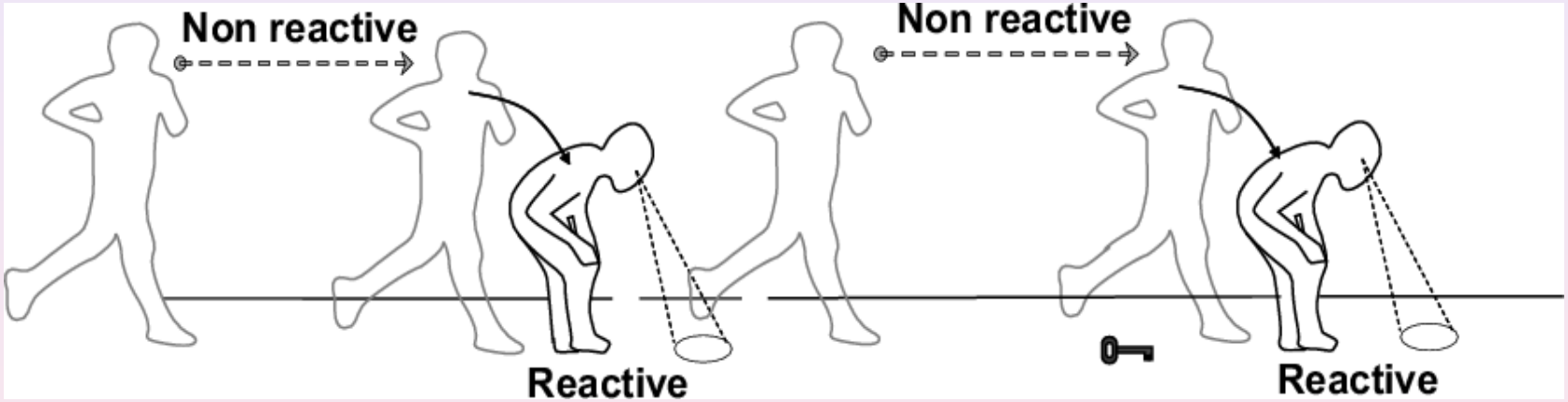
- Dieterich et al., PNAS **105**, 459 (2008): migrating biological cells are **not Lévy**; more complicated "intermittent" motion observed

etc. ...

An alternative to Lévy flight search strategies

Bénichou et al., Phys. Rev. E **74**, 020102(R) (2006):

- for non-revisitable targets *intermittent* search strategies minimize the search time, which are not necessarily Lévy



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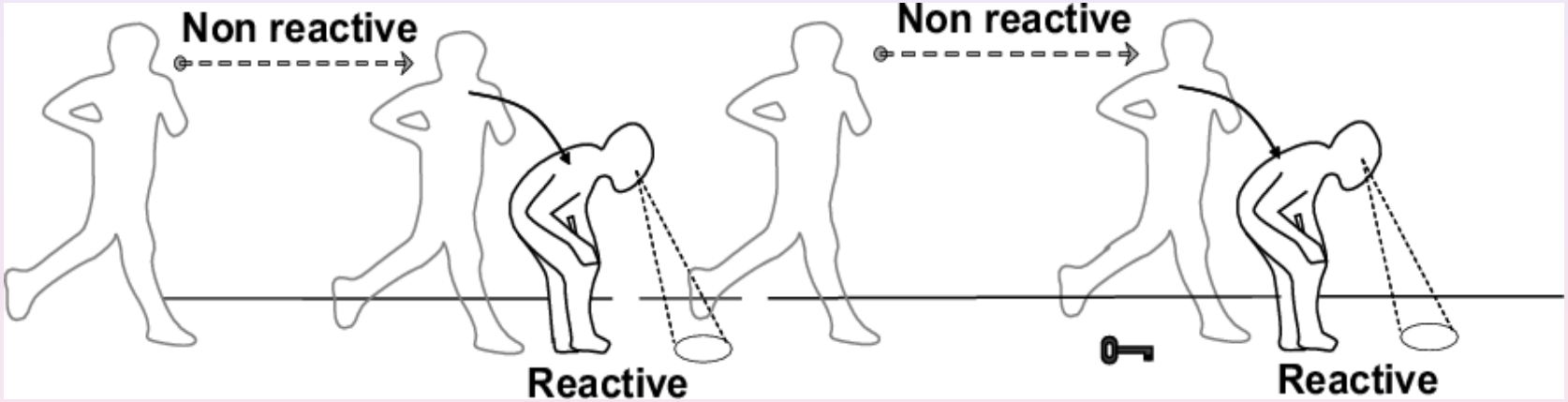

- popular account of this work in Shlesinger, Nature **443**, 281 (2006): “How to hunt a submarine?”
- approach extended by Lomholt et al., PNAS **105**, 11055 (2008) to intermittent search with Lévy relocations for rare revisitable targets

Summary and open questions

Understanding the migration of foraging animals:

- new analytical tools and better/larger data sets needed to critically check the Lévy flight paradigm
- study the relation between the type of foraging and biological conditions like
  - food source distribution
  - memory of animals
  - sensory mechanisms of animals
  - “individual personalities” of different animals

$\Rightarrow$ interplay between *statistical analysis* and *biological interpretation* of the results