Non-equilibrium phenomena of resetting

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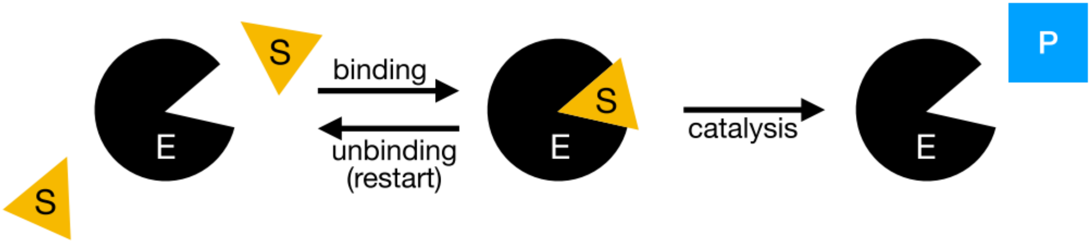
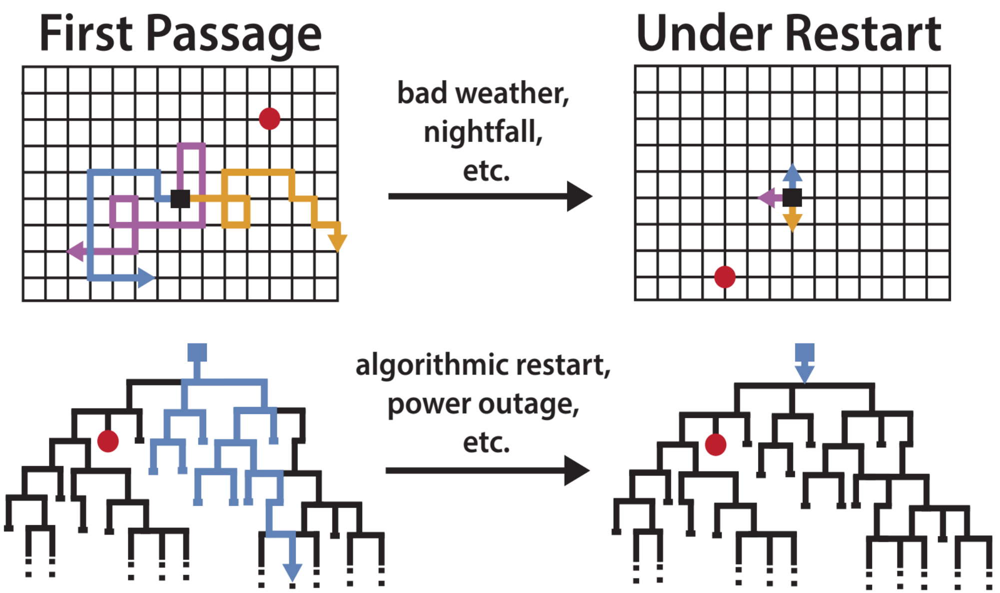
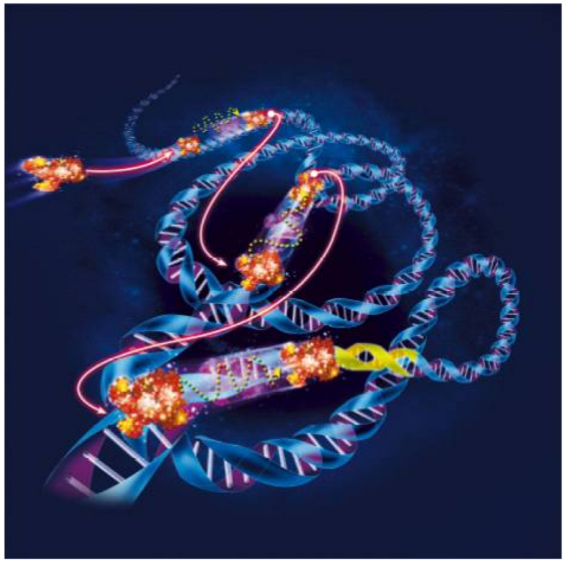
Kyoto, August 4, 2023

Prologue

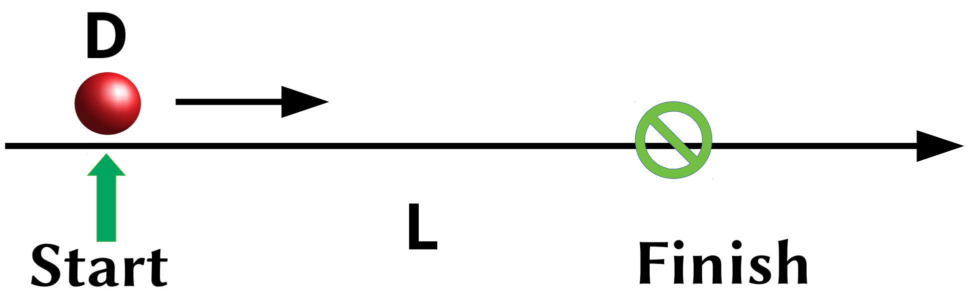






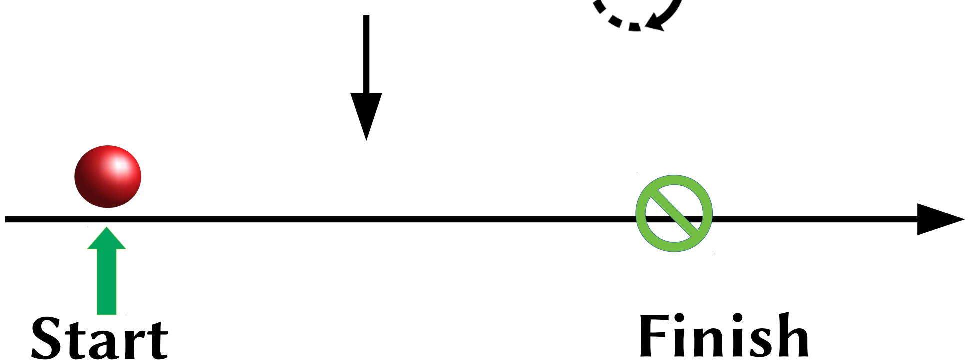
@ Virginie Denis, Pour La Science 352, February 2007

Diffusion in one dimension

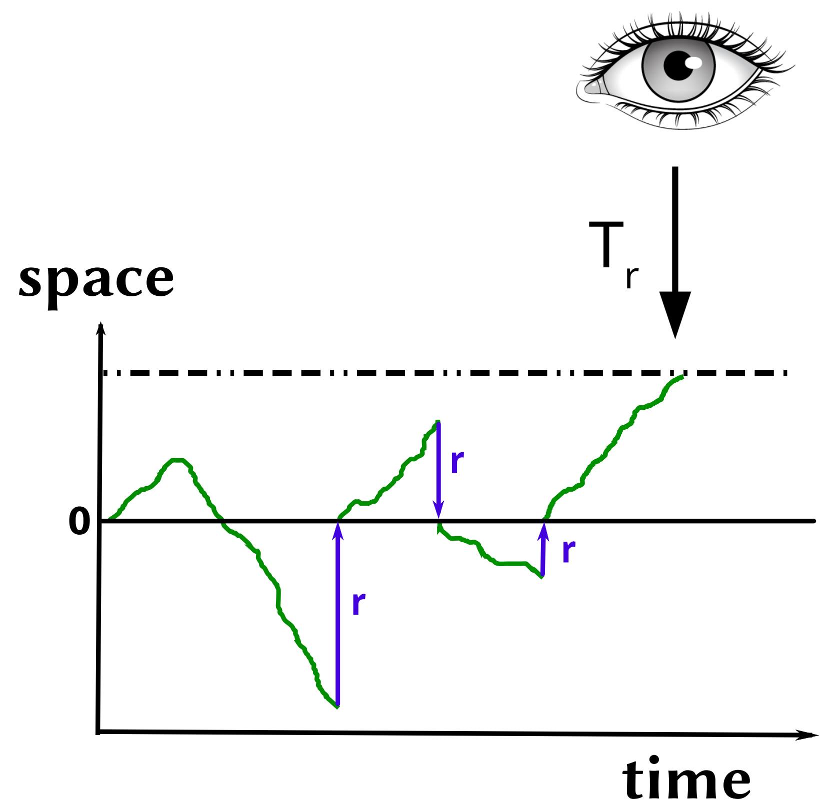


$T = \infty$ (Levy/Polya)

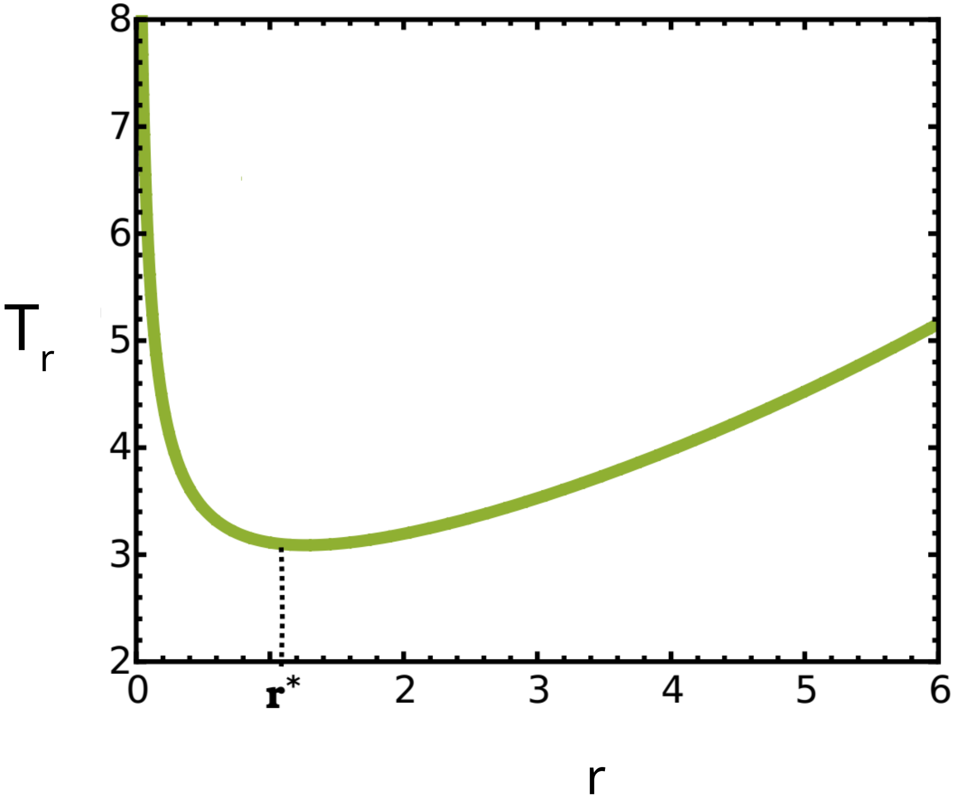
restart/reset at a rate



$T_r = ?$



Mean completion time

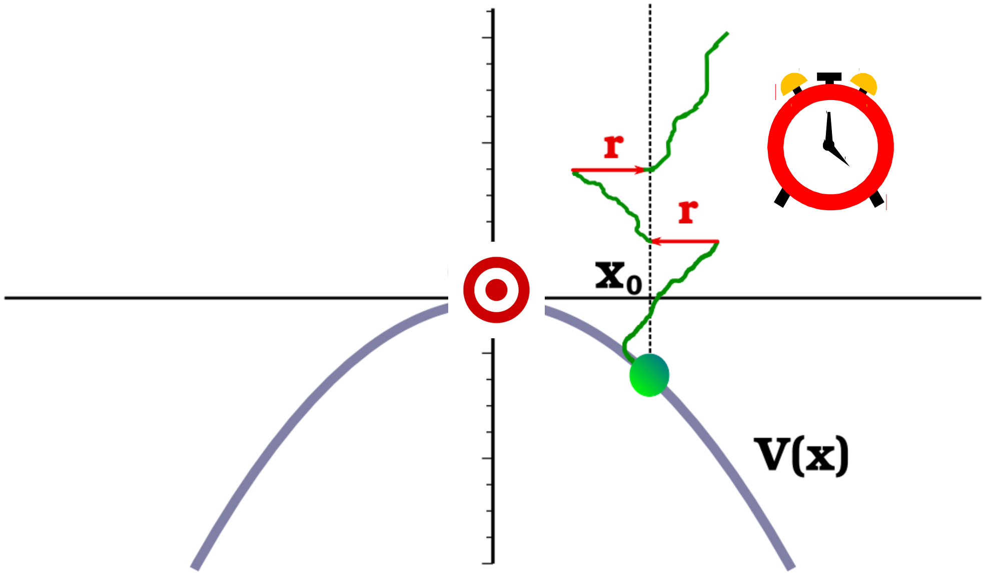


$T_r < \infty$

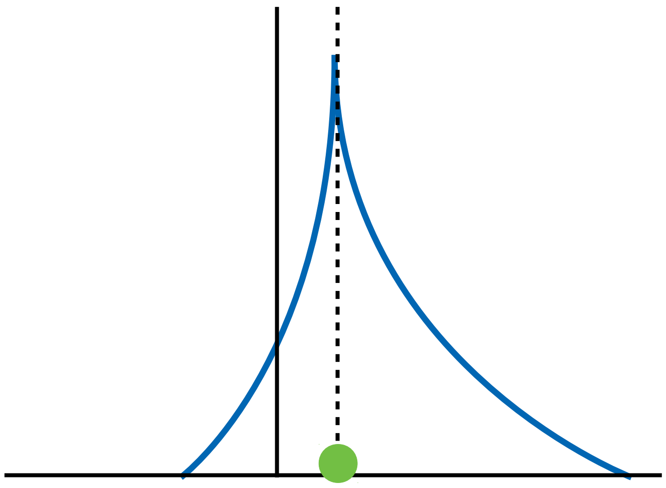
Optimal resetting rate

Evans & Majumdar PRL 106 (16) '11

Rolling downhill, searching uphill



Position density of the particle



Mean threshold reaching time = ?

$T_r < \infty$!!

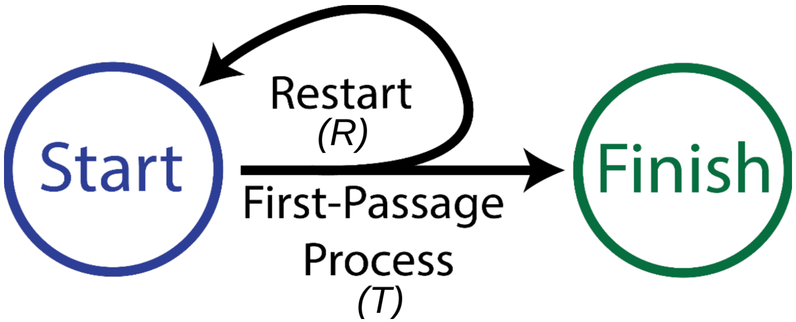
Pal PRE 91 (1) '15

Non-equilibrium-ness of resetting

- Unique non-equilibrium steady state with resetting coordinate as an attractor
- Non-zero current
- Stationary states even for the unbounded potential landscape
- An effective confinement -- Smart way of eliminating detrimental trajectories
- Expedite completion

Pal & Reuveni PRL '17; PRL '19; Evans, Majumdar & Schehr JPA review '20

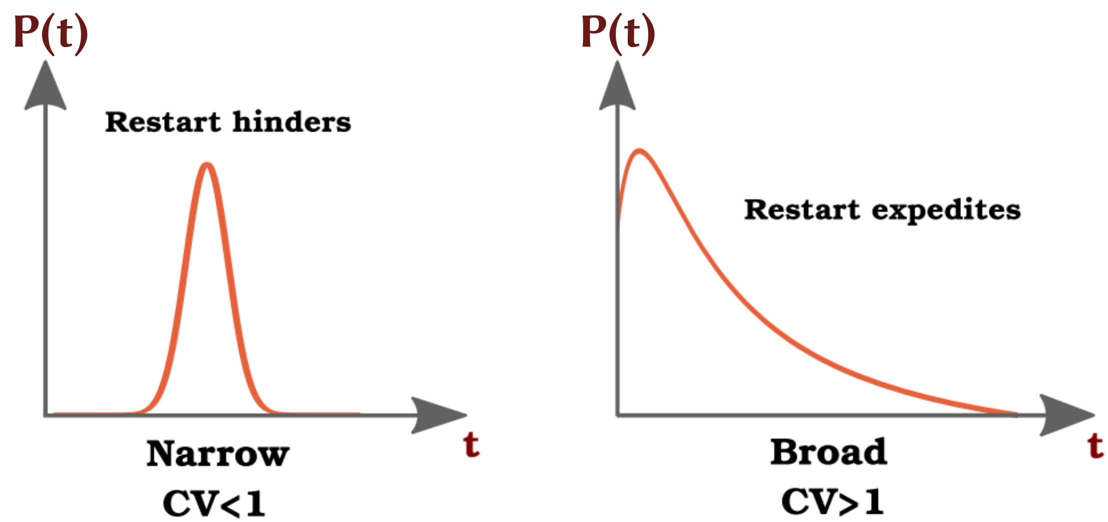
Resetting "transition"



When does resetting lower the MFPT?

$$CV \equiv \frac{\sigma(T)}{\langle T \rangle} > 1$$

Coefficient of variation
for the underlying process



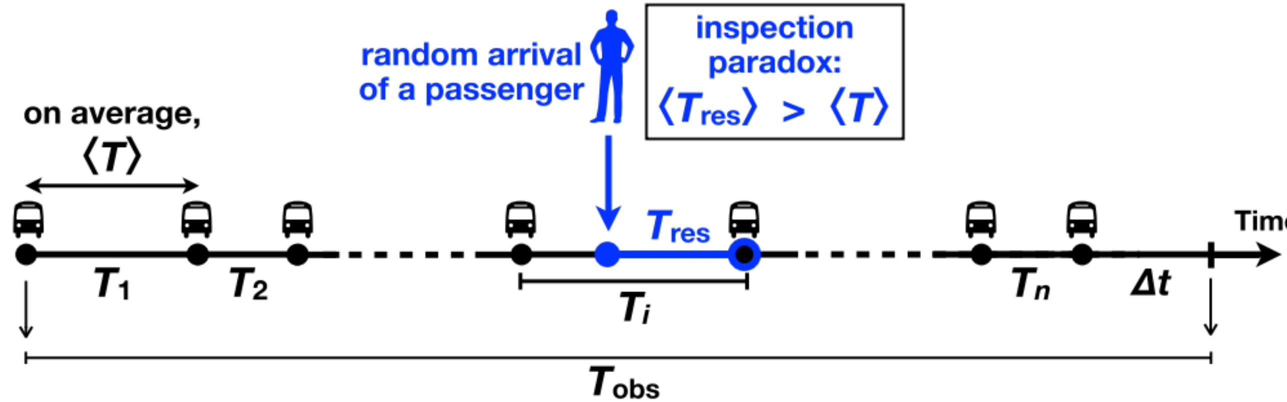
Higher uncertainty/noise is better

Pal et al PRR '19; JPA viewpoint '22; JCP '23

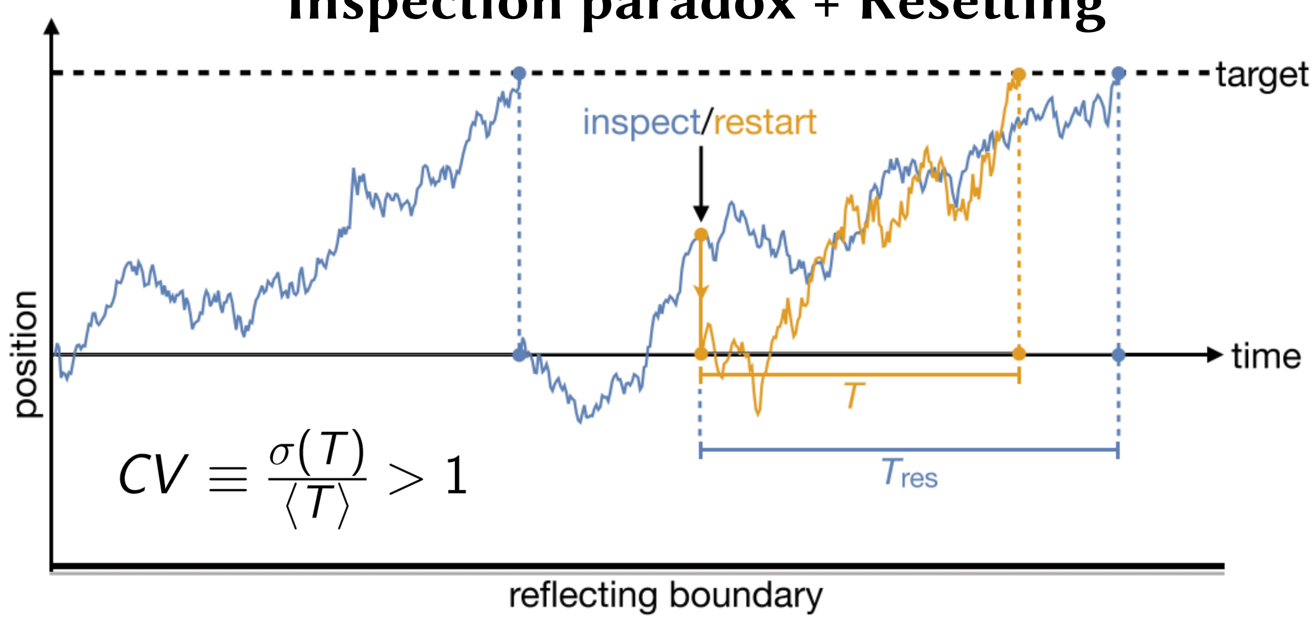
Inspection (Feller's) paradox

$$\langle T_{\rm res}\rangle = \frac{\langle T\rangle}{2}\left(1 + CV_T^2\right)$$

William Feller



Inspection paradox + Resetting

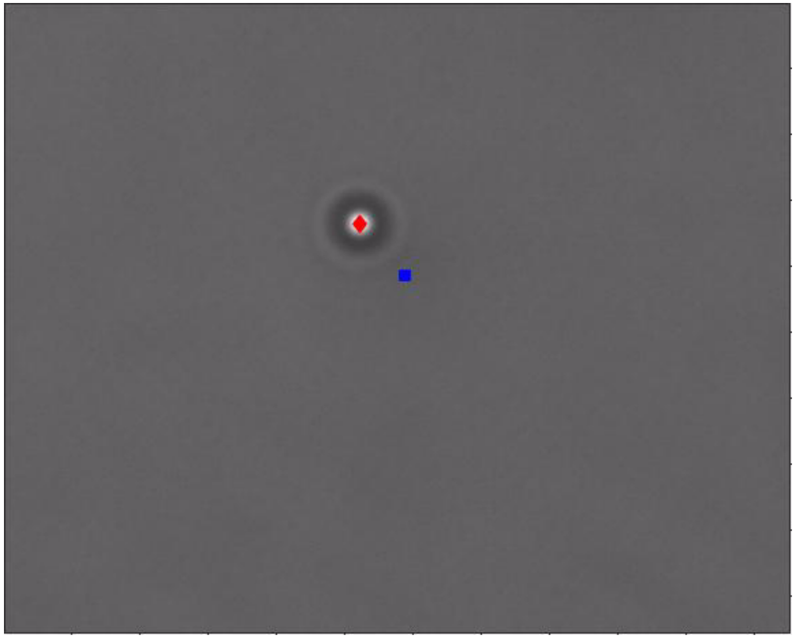


$$CV \equiv \frac{\sigma(T)}{\langle T\rangle} > 1$$

Pal et al JPA viewpoint '22 for other processes such as branching diffusion, chemical kinetics etc.

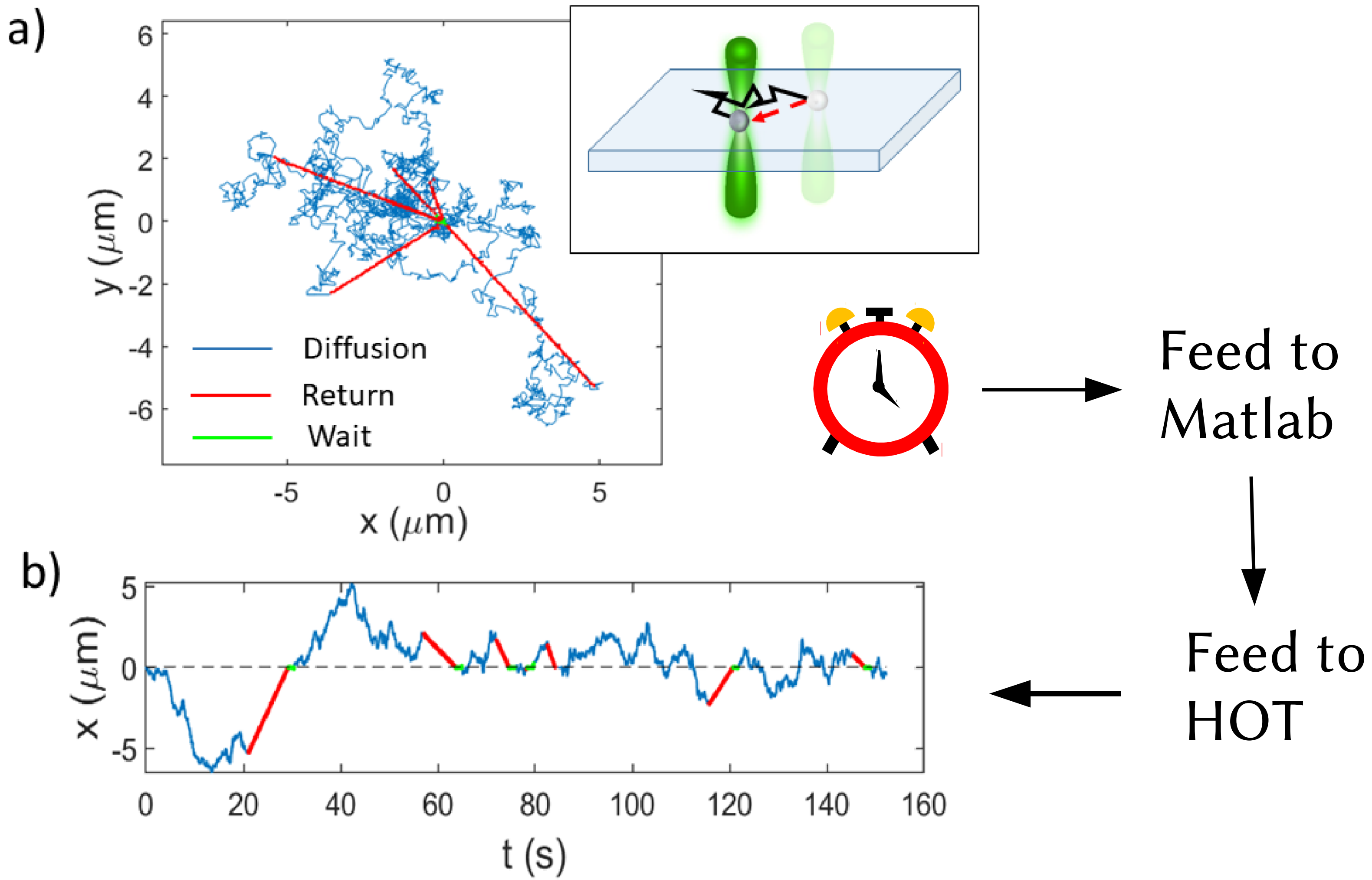
Towards realistic resetting

Resetting on a glass slide



Friedman et al, JPC Letters (2020) in collaboration with Roichman Group

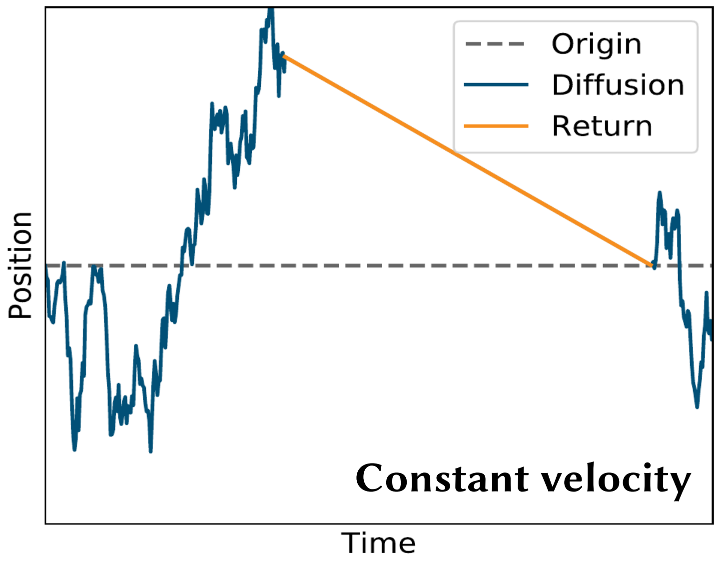
Key observations from experiments

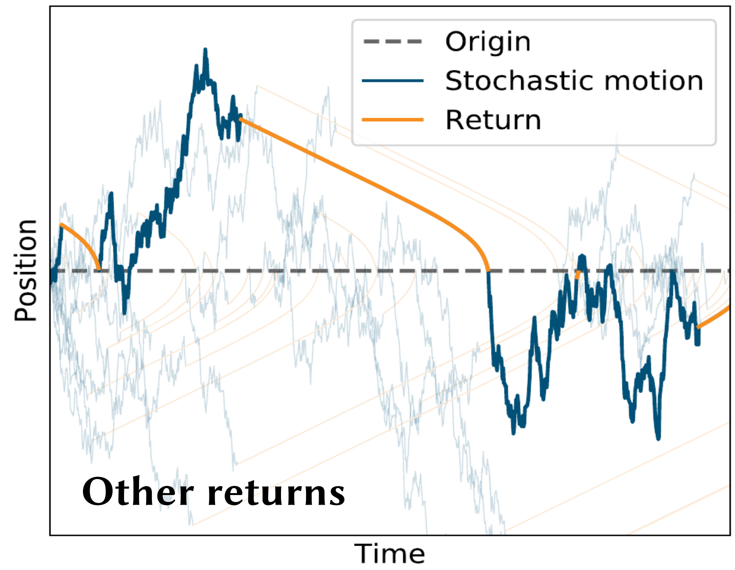


- Resetting is a **finite time** physical process
- Also a spatio-temporal process

Friedman et al, JPC Letters (2020)

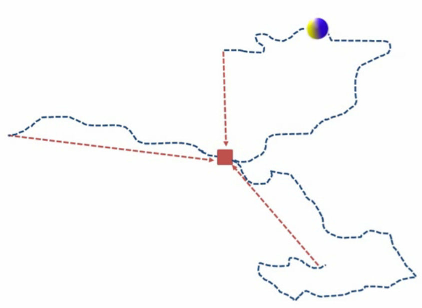
Realistic situations

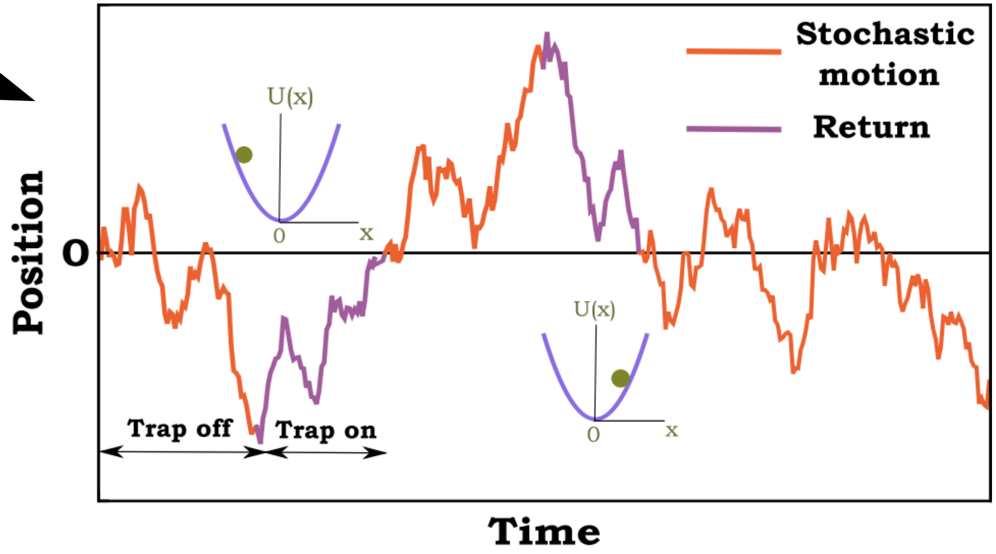




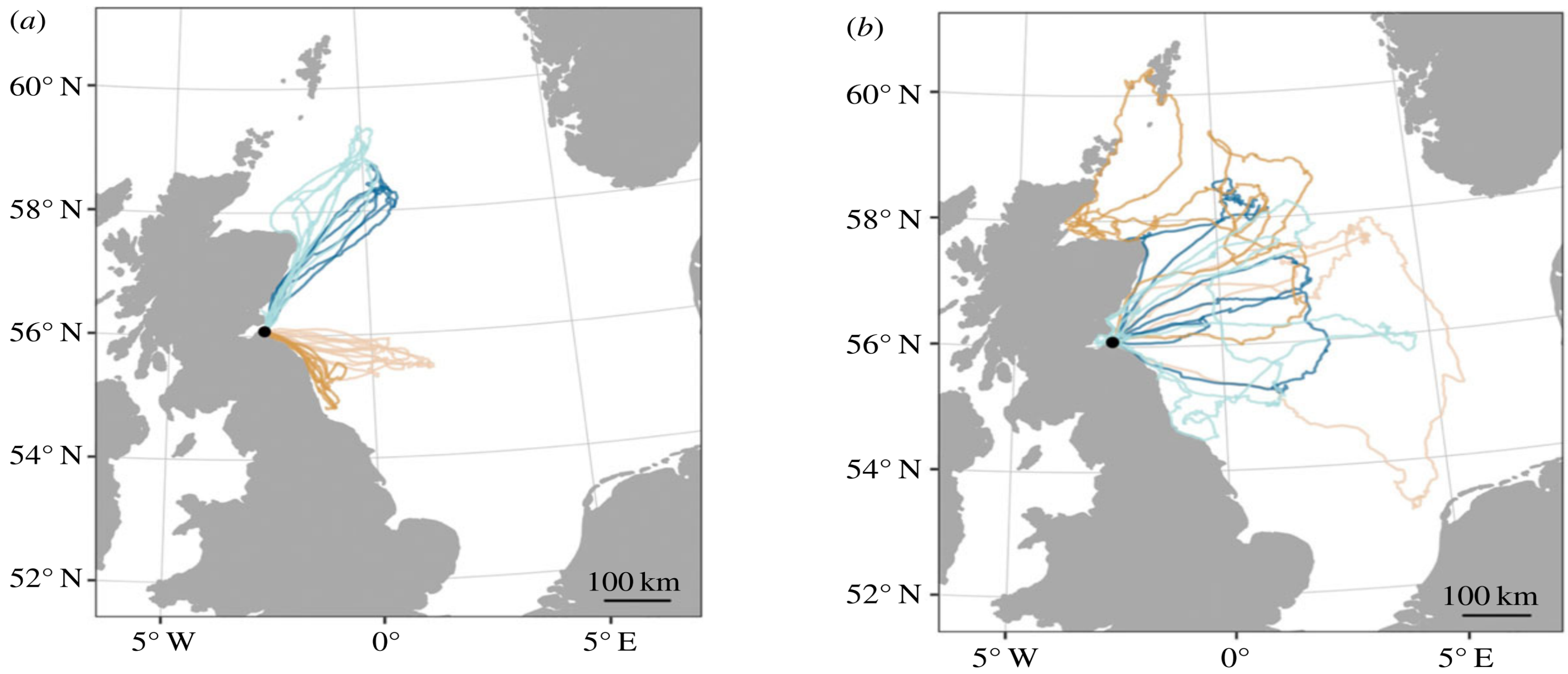
Deterministic return

Stochastic return





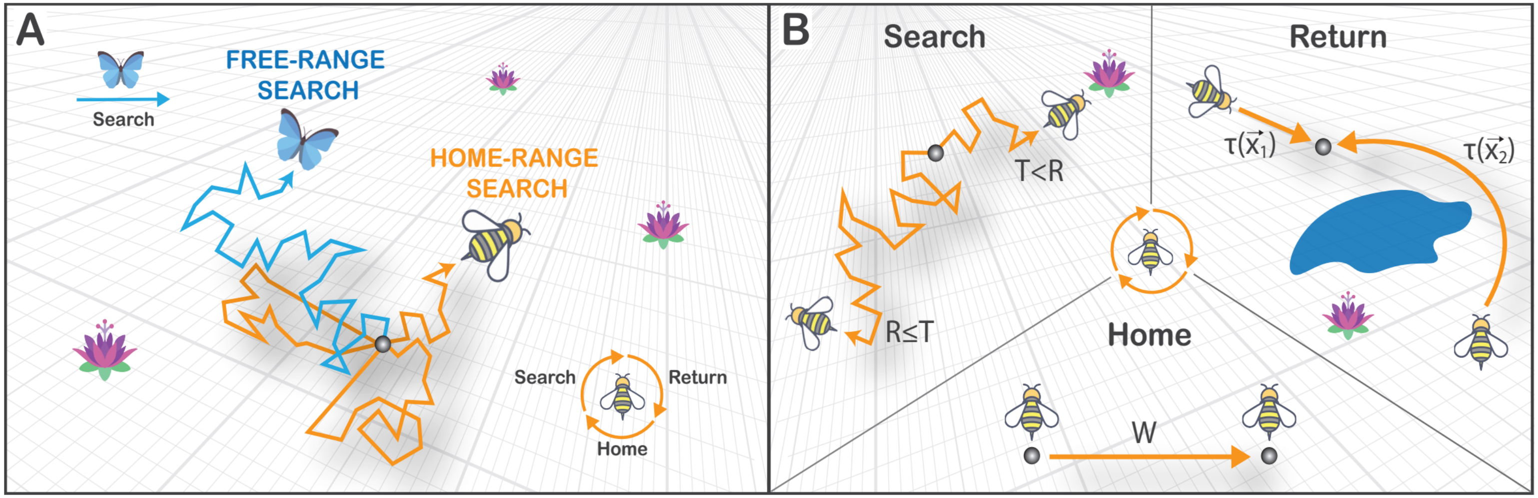
Sea bird foraging – Macroscopic search



Grecian et al, J. R. Soc. Interface '18

It maybe remarked that most animals and plants keep to their proper homes and do not needlessly wander about ; we see this even with migratory birds, which almost return to the same spot – **Darwin 1861**

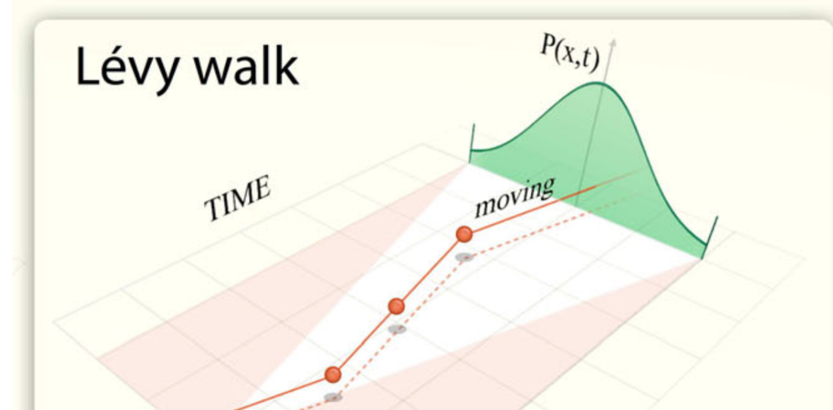
Home range search – a cyclic process

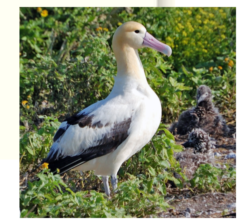


$$T_R = \begin{cases} T & \text{if} \quad T < R \\ R + \tau(\vec{x}) + W + T'_R & \text{if} \quad R \leq T \end{cases}$$

- When is the home return beneficial?
- Finite time resetting? Effect of topography? Experimental set-ups

A more general search



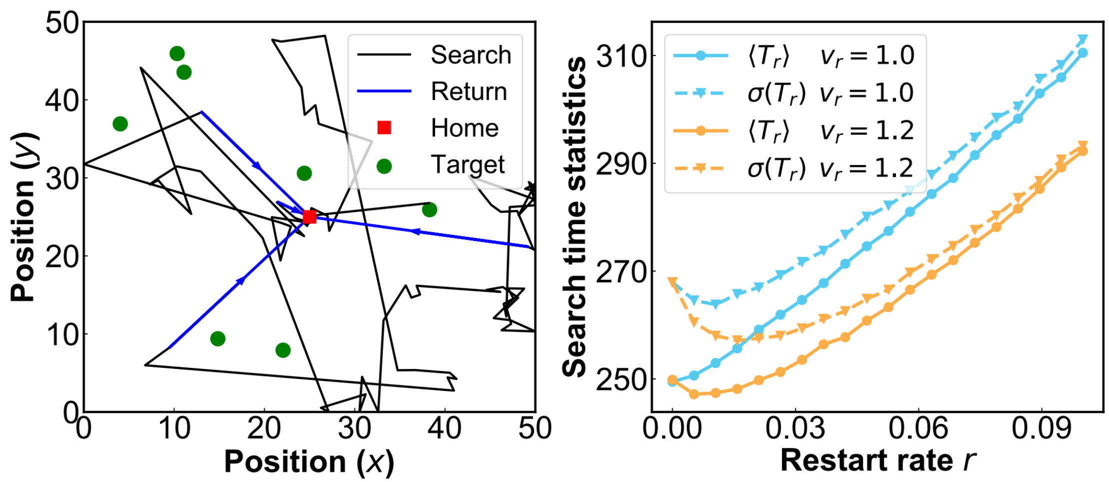


- Lévy walk search in a complex topography
- Multiple targets
- Reduction in mean search time

Viswanathan et al Nature (96), Nature (99), Physics of Life Reviews (2008); Klafter & co-workers RMP (2014)

$$\sigma(T_{r*}) < \sigma(T)$$

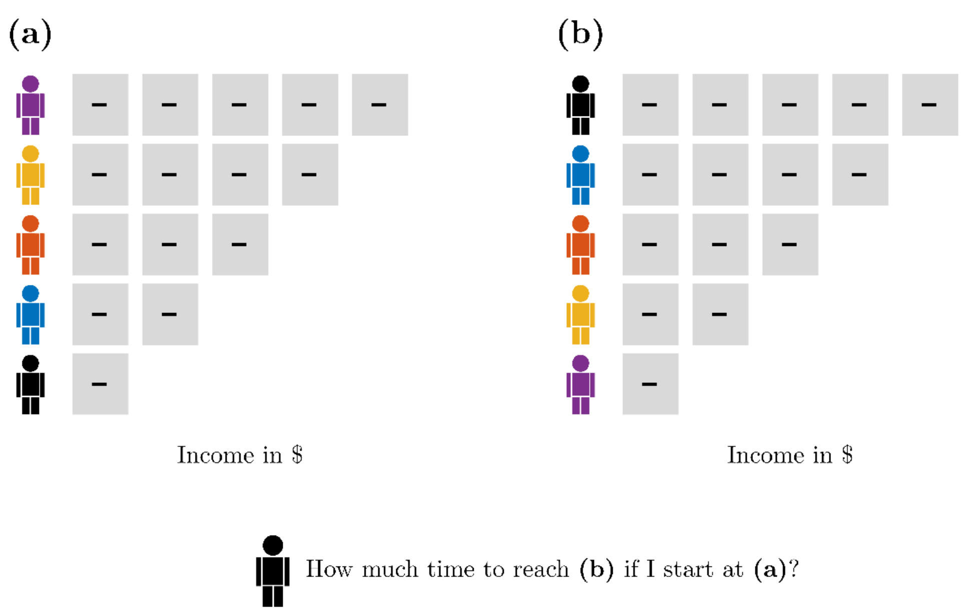
Optimal home-range search also reduces **<u>fluctuations</u>** in search time

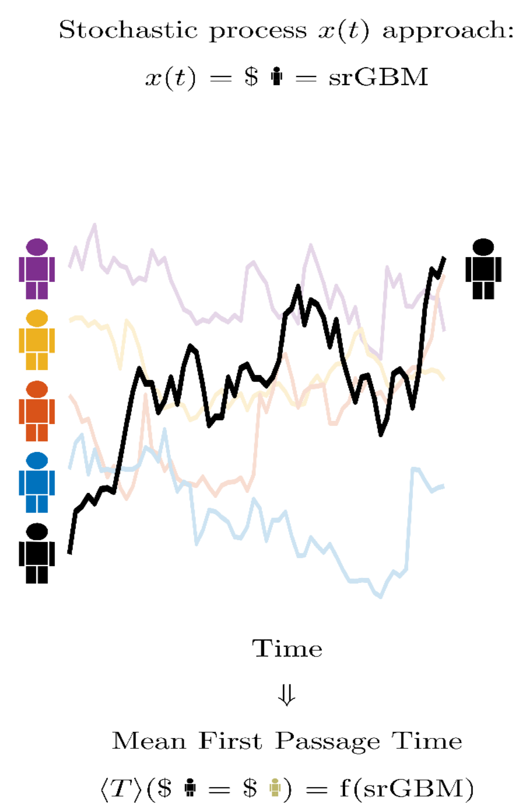


Pal et al PRR '20; Sar et al Soft Matter '23 (resetting mediated active search)

Moving forward

- Non-instantaneous resetting protocols are time consuming but realistic (experiments with colloids, robots and home range search)
- Applications to economics [Stojkoski, **Pal** et al Proceedings of Royal Society A '22; arXiv:2212.13176], record statistics and aggregation-fragmentation models [Kumar and **Pal**, PRL '23], queuing theory [Bonomo, **Pal** and Reuveni PNAS Nexus '22]

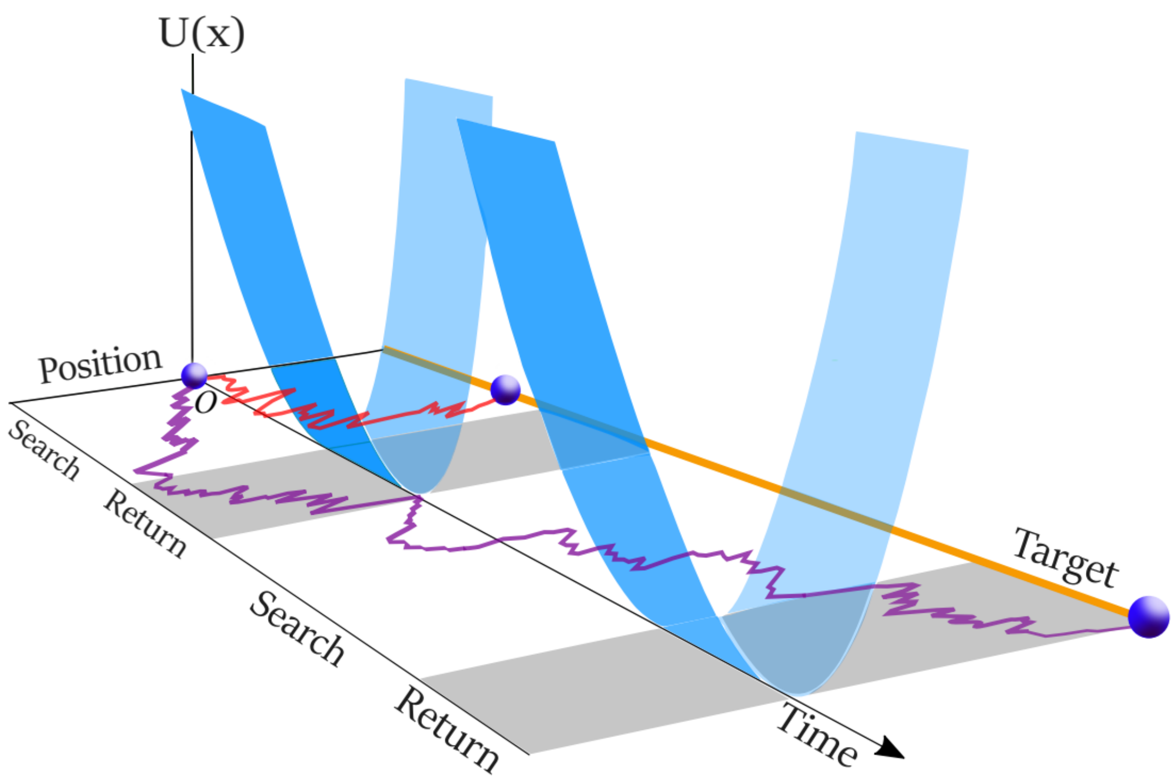




Evans, Schehr, Majumdar J Phys A (review) '20
Pal et al J Phys A (Viewpoint review) '22

Can non-inst return protocols do better than classical inst resetting?

Yes, with a searcher who makes errors in return!



arXiv: 2307.16294 led by Arup Biswas

Thank you!