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A multi-stable gravitational approach to fixational eye movements

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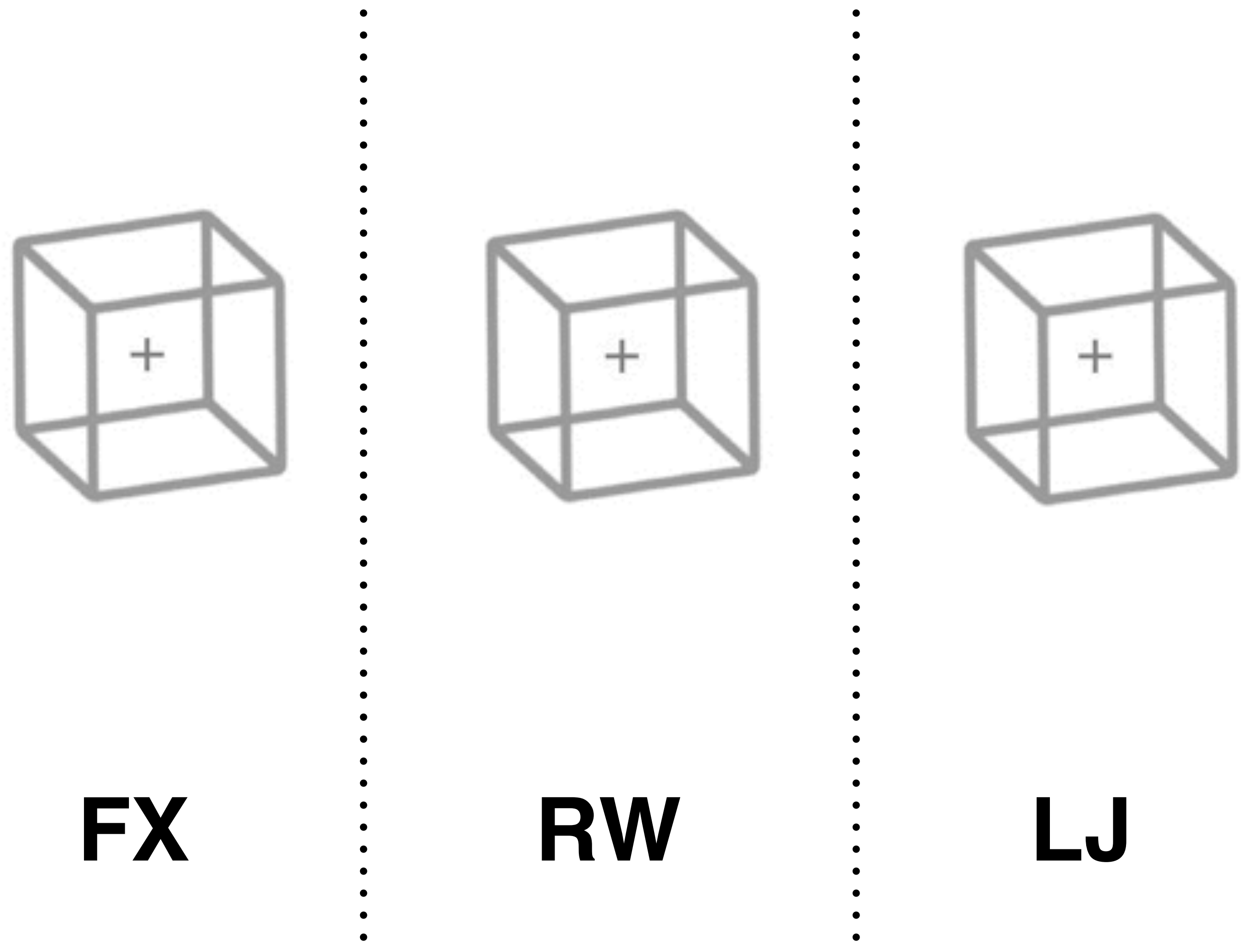
Agenda

- Context:
  - Experimental work on bi-stability
  - Observations of micro-pursuits
  - Current models of Fixational Eye Movements (FEM)
- Model description
- Perceptual multi-stability perspectives

Context

Motion on a Necker cube



Manipulate perceptual reversal dynamics of bi-stability (Necker cube) using retinal image motion:

FX: no stimulus motion (fixed)

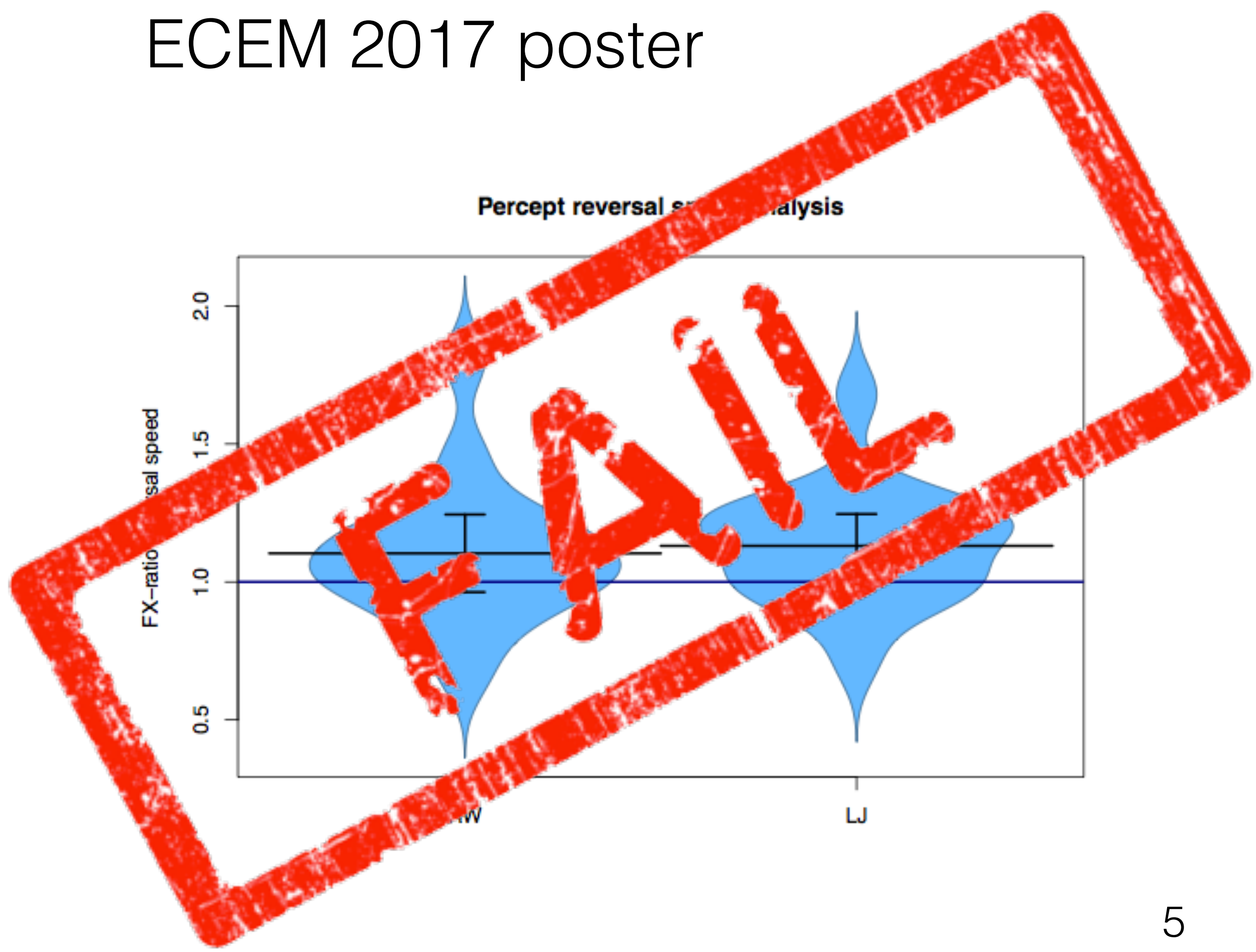
RW: unpredictable pseudo-random movement (random walk)

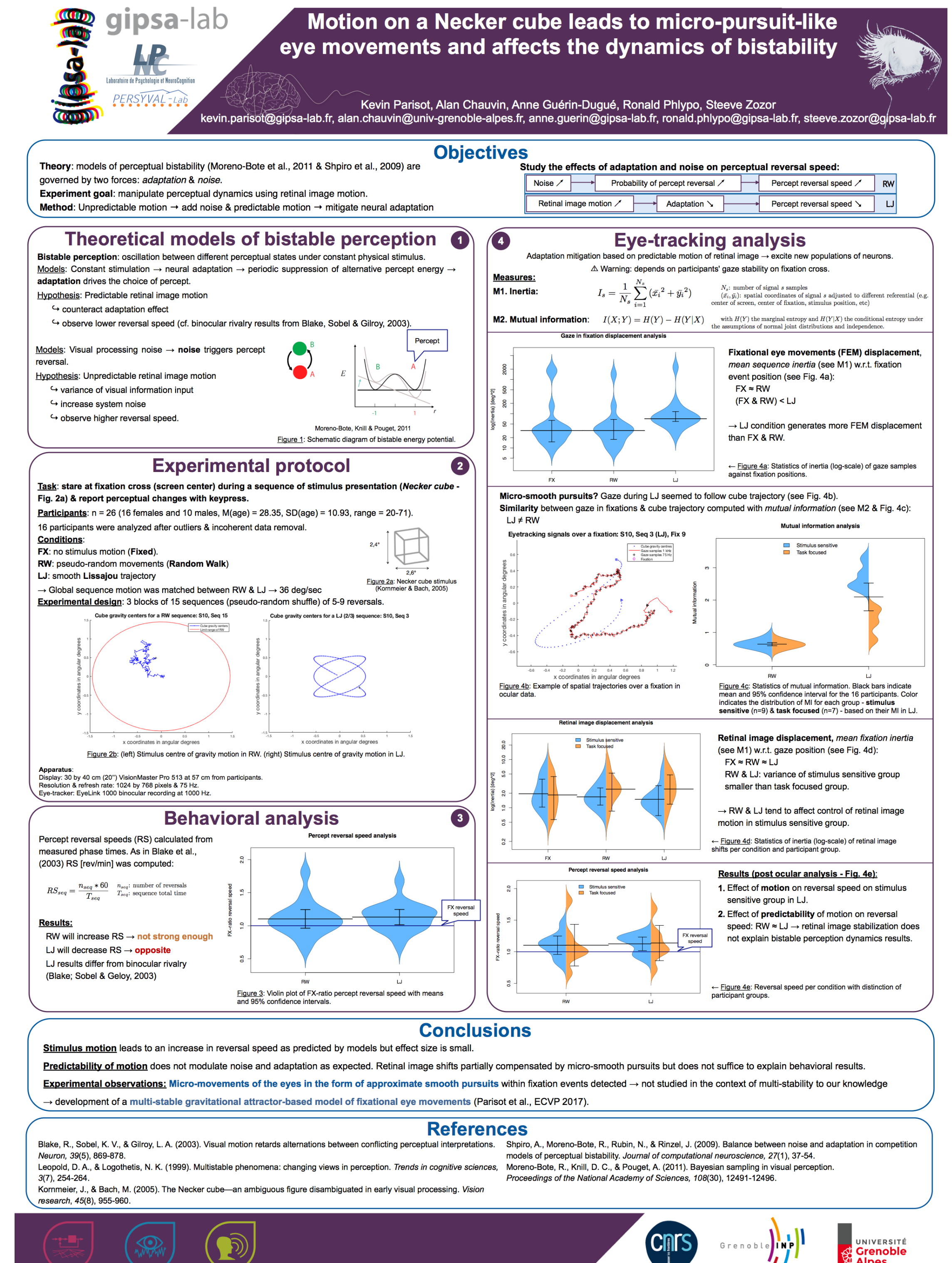
LJ: predictable smooth Lissajou trajectory

Experimental results

Perceptual dynamics results did not agree with hypotheses driven from bi-stability models

We investigated for a possible explanation in **ocular data**; ECEM 2017 poster

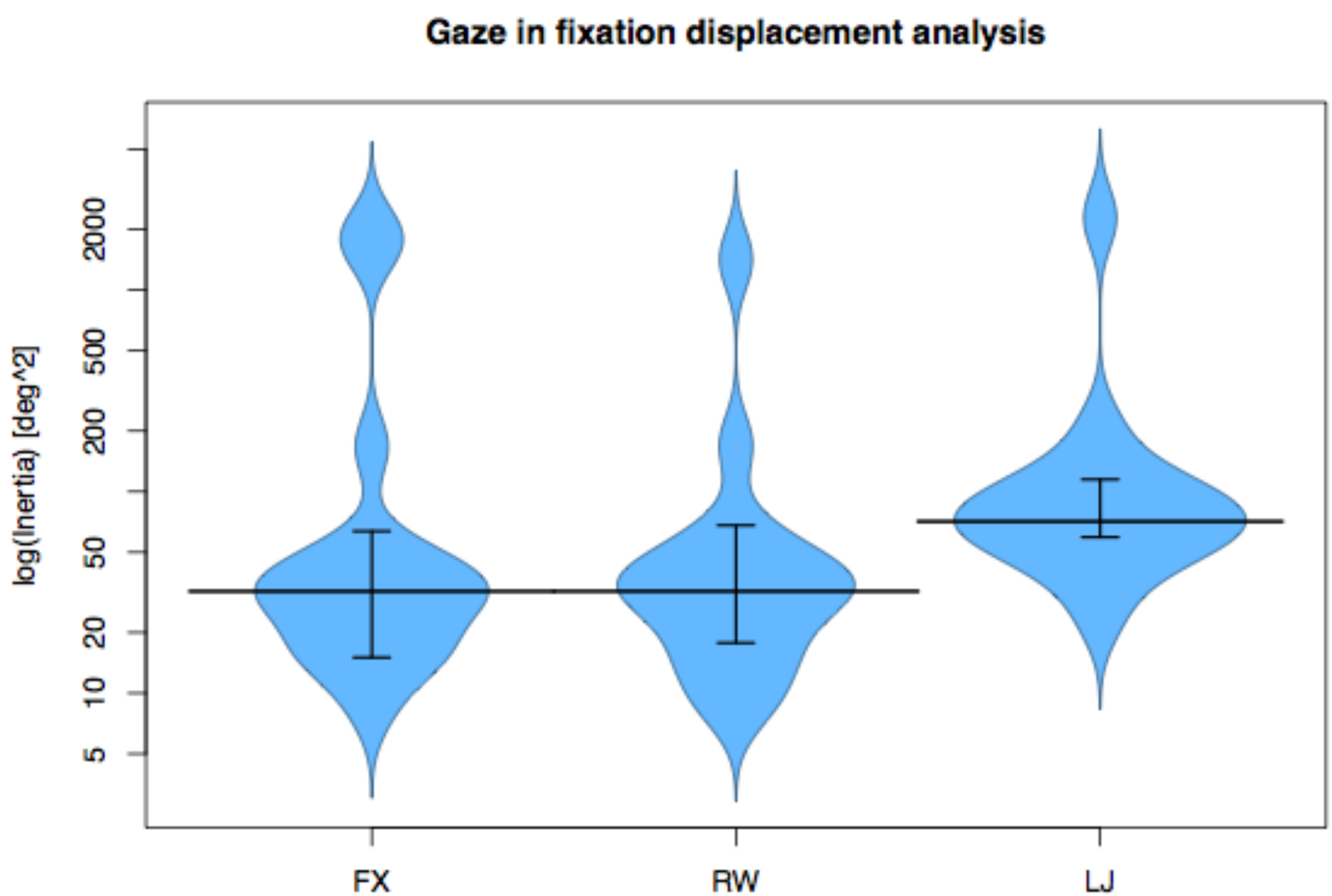




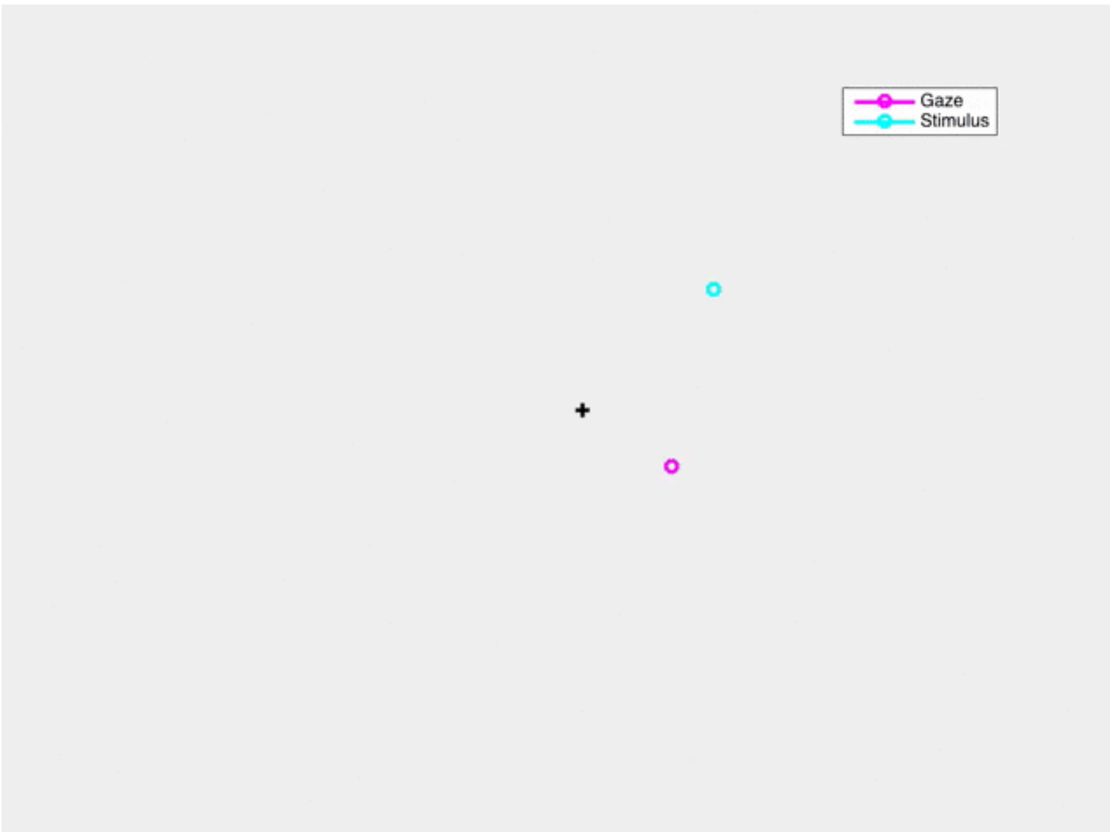
Fixational Eye Movements

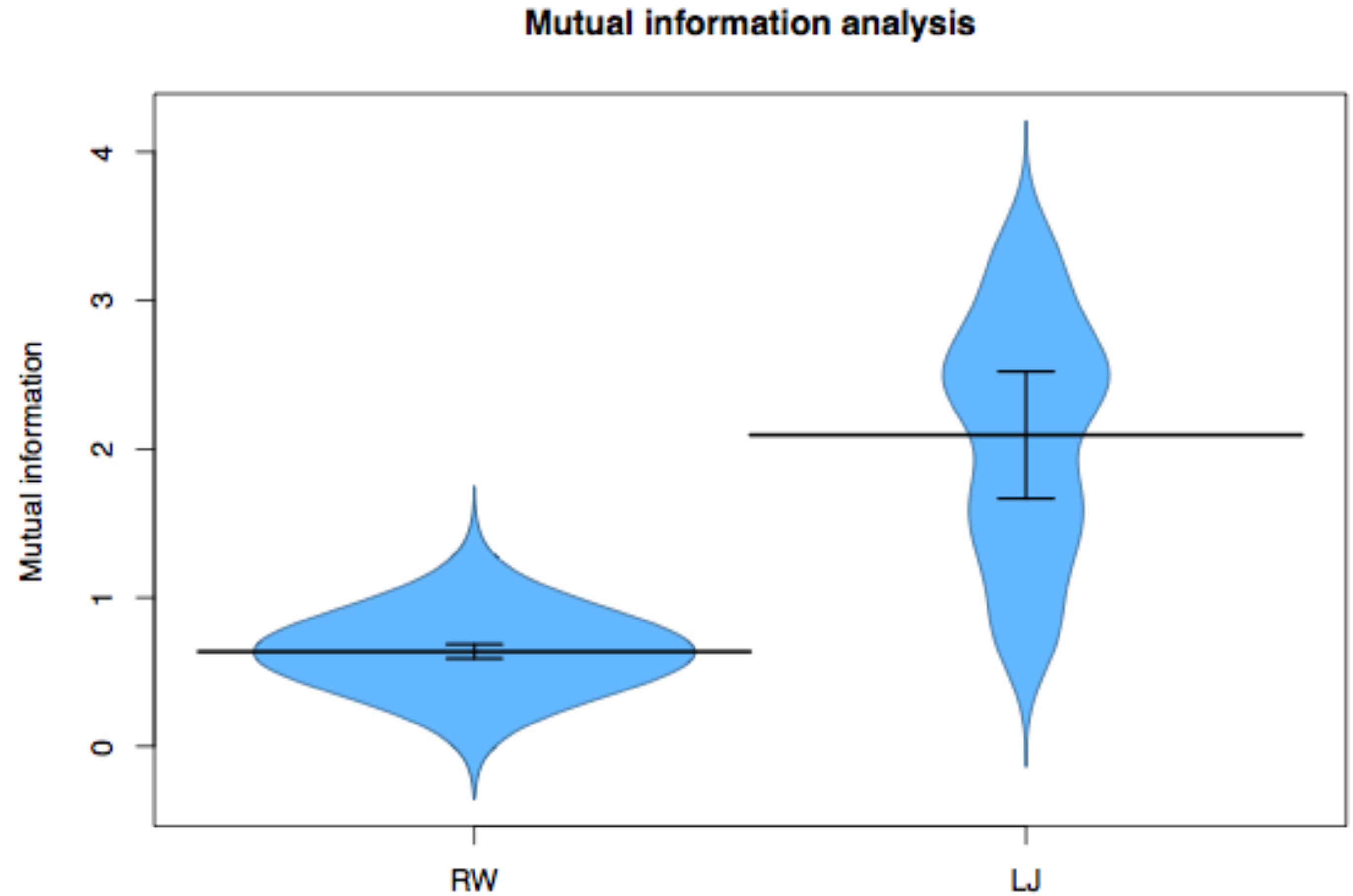
Investigation of Fixational Eye Movements (FEM) displacement

Predictable condition (LJ) had higher gaze motion w.r.t. center of fixation than other conditions



Micro-pursuit eye movements





Observation of **small amplitude smooth pursuit-like fixational eye movements** (FEM < 1°):

Mutual information used as a measure of similarity between Gaze and Stimulus

Only observed once before: Martins, A. J., Kowler, E., & Palmer, C. (1985). *JOSA*

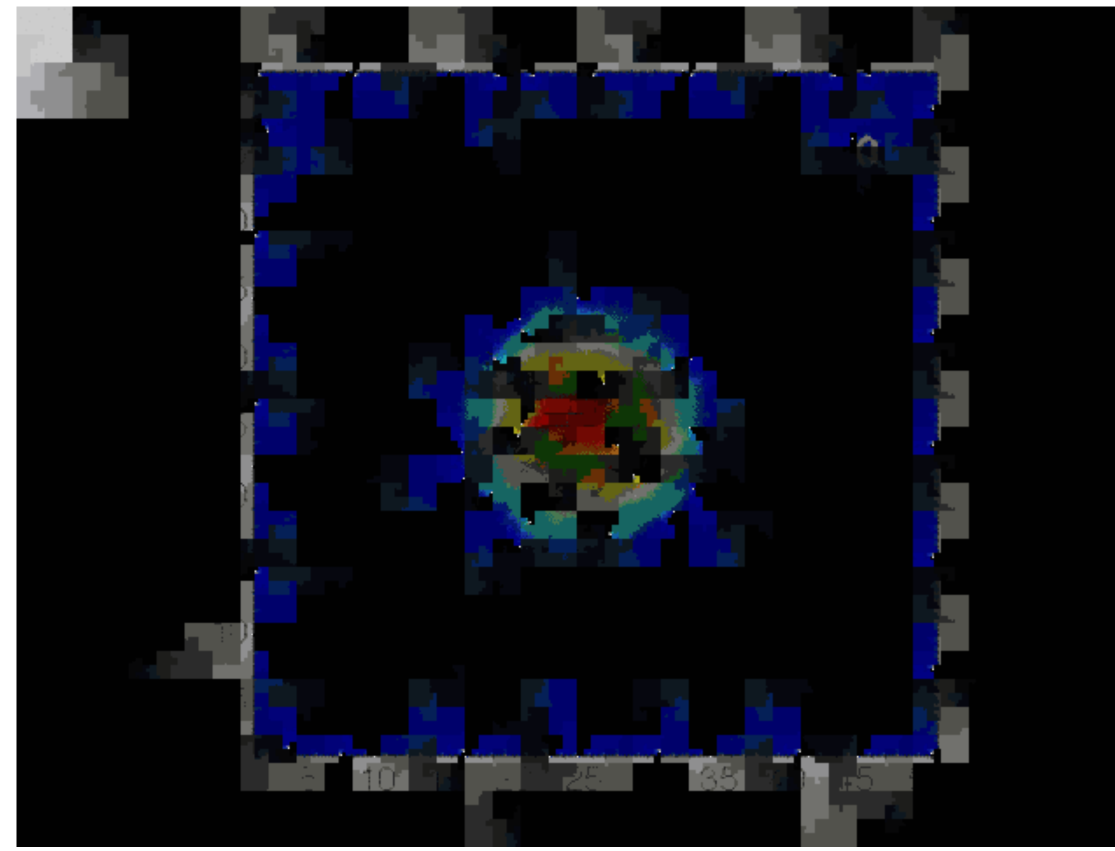
Fixational Eye Movements models

Compatibility with micro-pursuit eye movements?

Current generative model:

- Integration of micro-saccades, small amplitude saccades, and other FEM
- Use of **potential fields**

To our knowledge, no model can account for micro-pursuit eye movements!



Engbert, R., Mergenthaler, K., Sinn, P., & Pikovsky, A. (2011). *PNAS*
Sinn, P., & Engbert, R. (2016). *Vision research*

Model Description

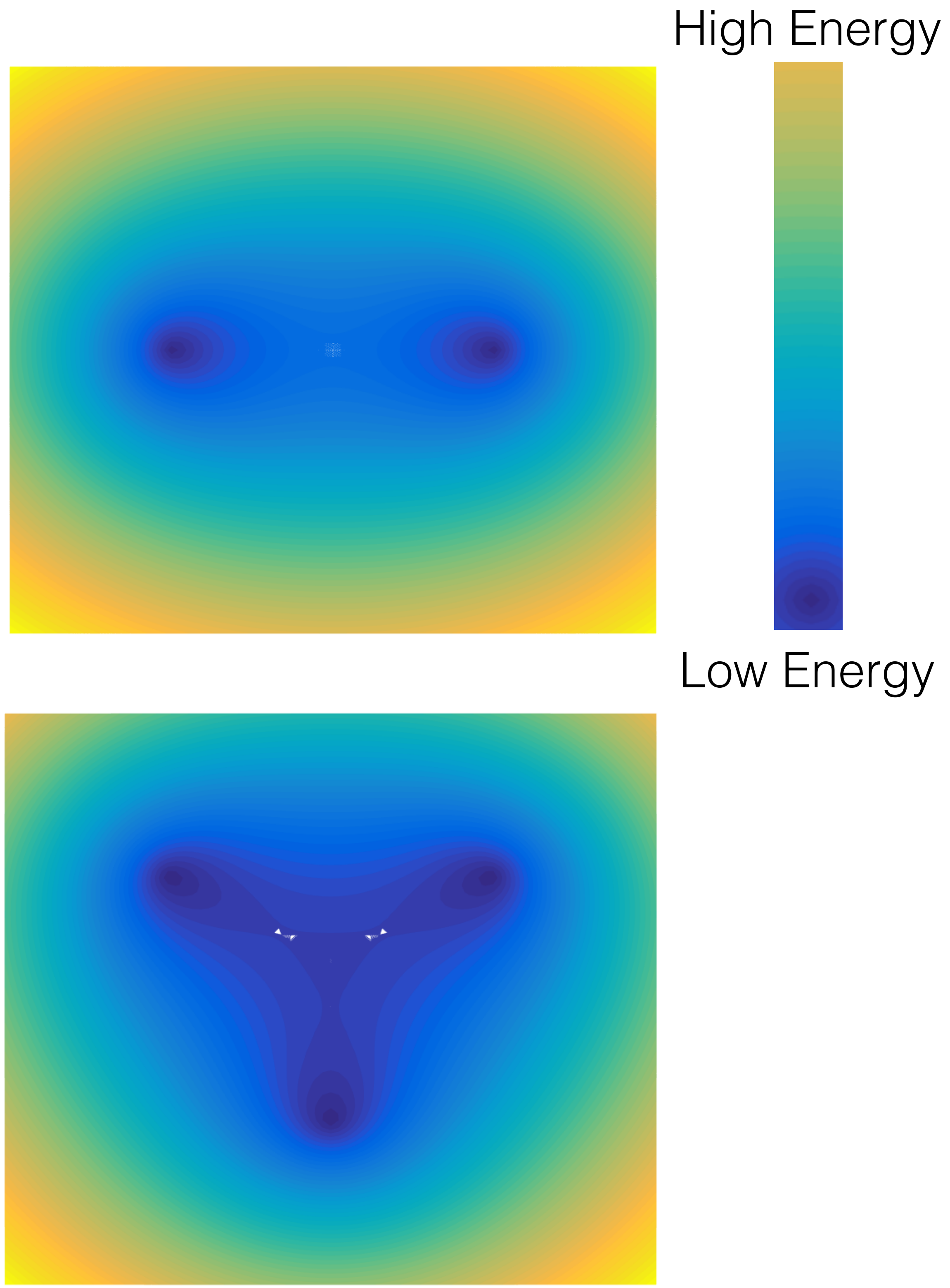
GraFEM: **Gra**vitational potential **F**ixational **E**ye **M**ovements model

Map of visual field

Gravitational energy **potential field (V)** can generate multiple **attractors**

Attractor **parameters**:

- position (x,y coordinates)
- depth (energy)
- slope

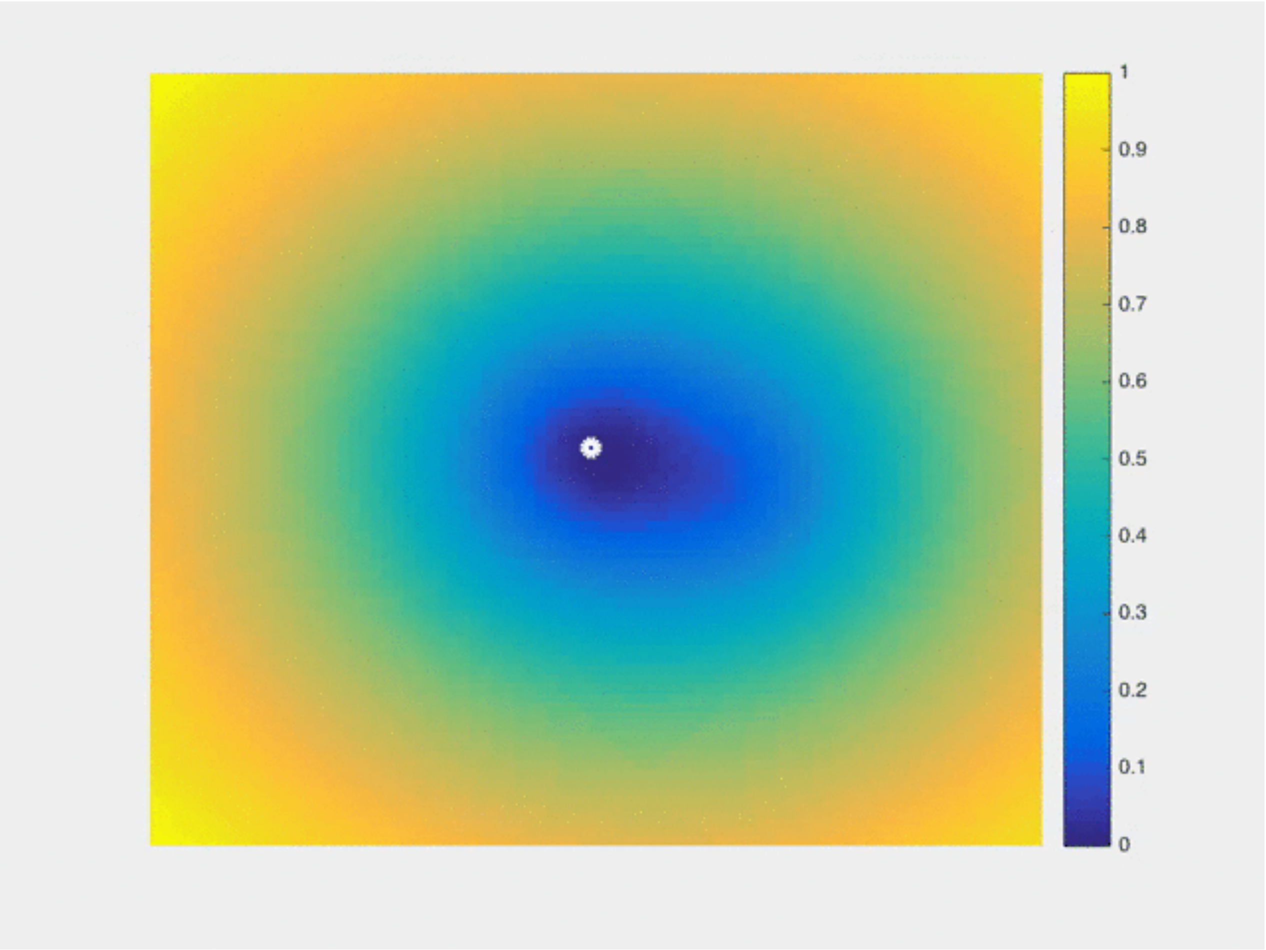


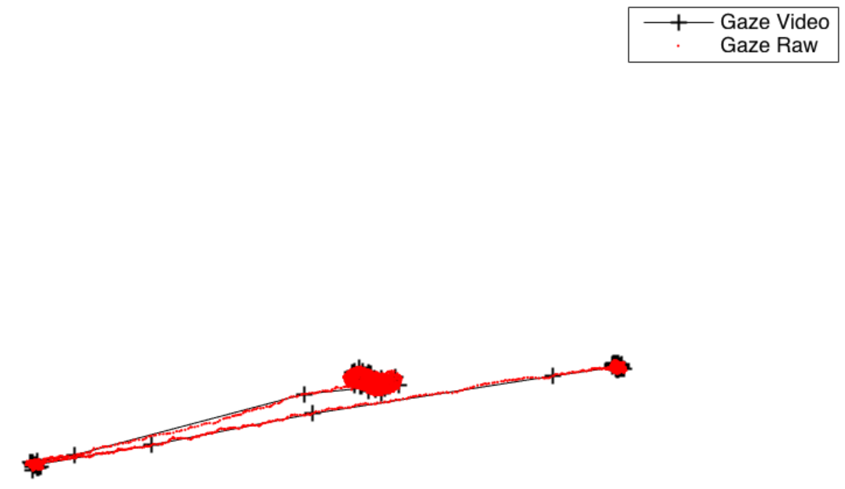
Gaze: a particle in the energy potential

Gaze-dynamic: **particule (p)** in the **potential field** and with added **noise**

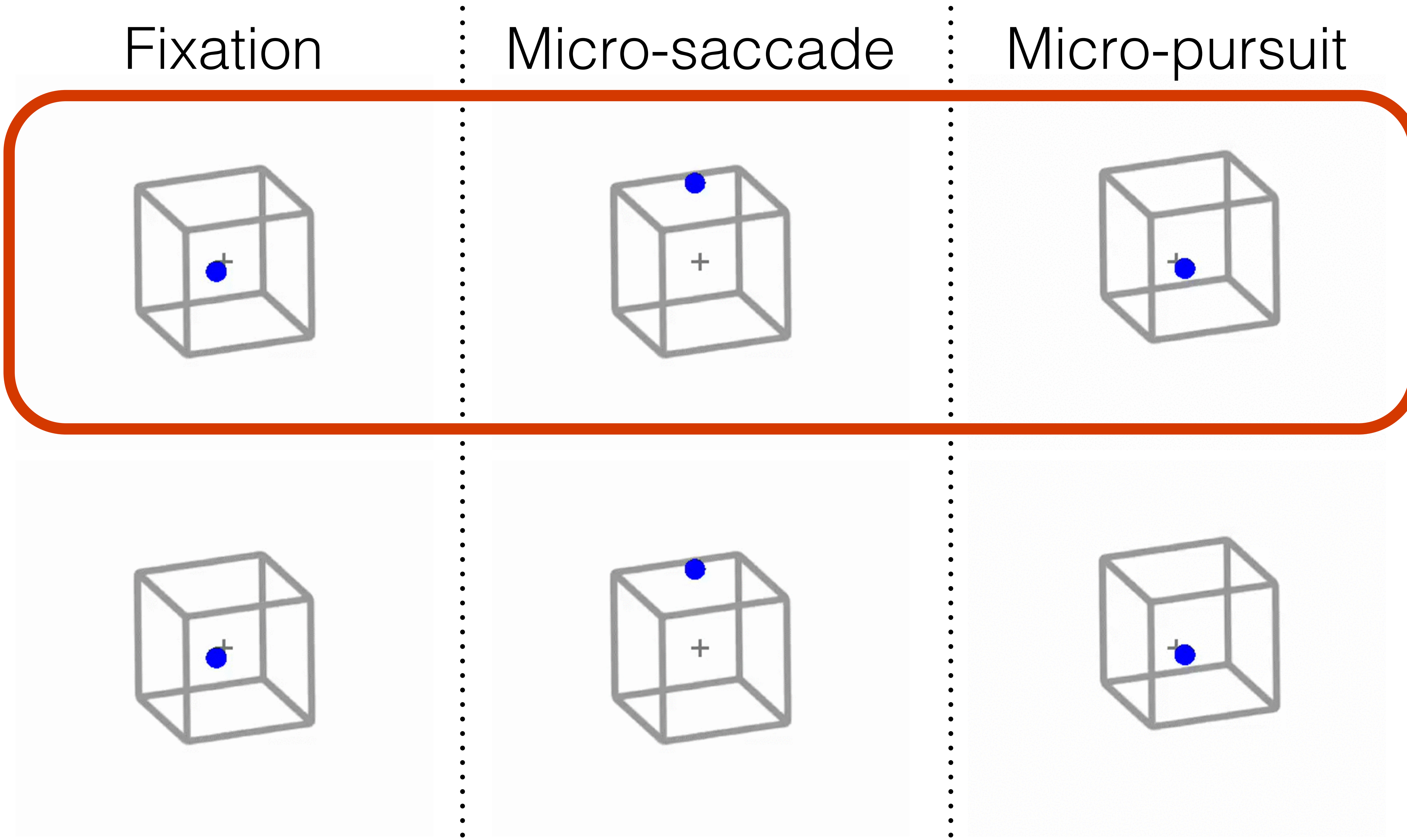
$$\dot{\vec{p}}(t) = -\nabla V(\vec{p}, t) + \xi(t)$$

Result:





FEM simulations



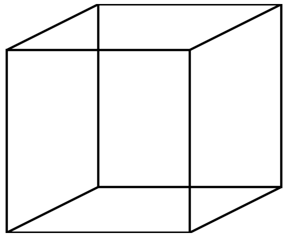
Can you differentiate the lines with simulation or data?

Perceptual multi-stability perspectives

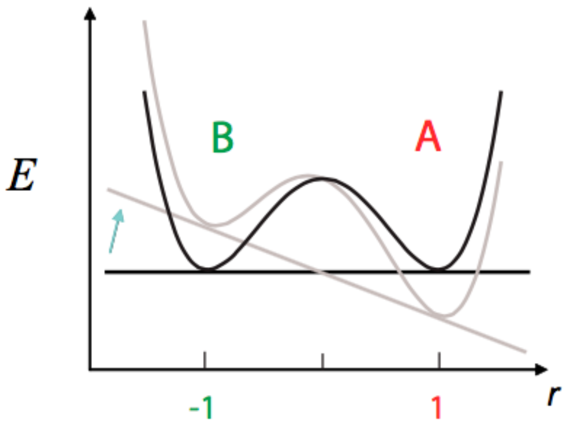
GraFEM: a multi-stable model?

GraFEM → **multi-stable** model with **spatial attractors**

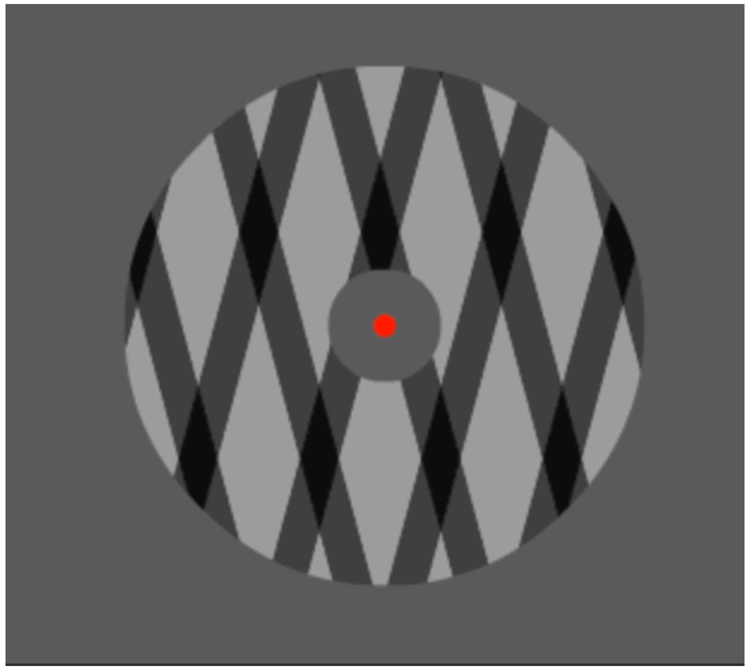
Multi-stable models → predict perceptual dynamics and behavior for ambiguous figures (e.g. bi-stability) where **attractors are perceptual states**

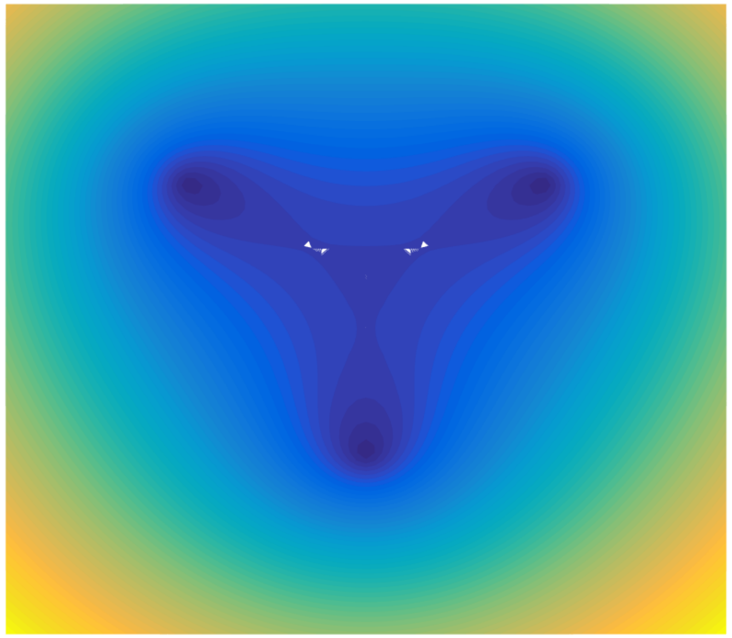


Necker cube



Bi-stability





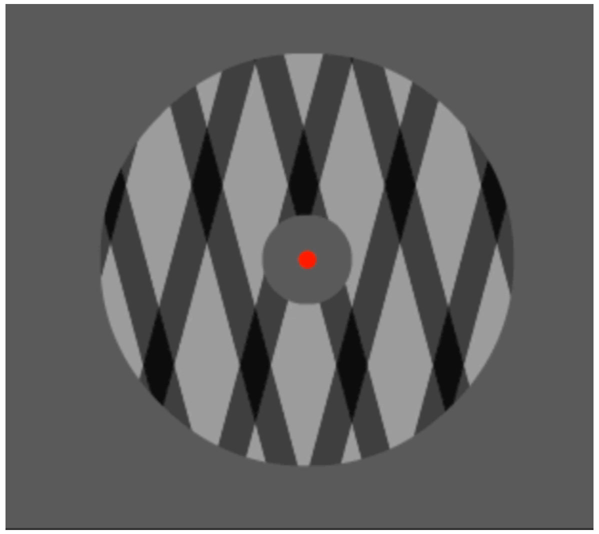
Tri-stability

Moreno-Bote, R., Rinzel, J., & Rubin, N. (2007). *Journal of neurophysiology*
Moreno-Bote, R., Knill, D. C., & Pouget, A. (2011). *PNAS*
Huguet, G., Rinzel, J., & Hupé, J. M. (2014). *Journal of vision*
http://www.cerco.ups-tlse.fr/~hupe/plaid_demo/demo_plaids.html

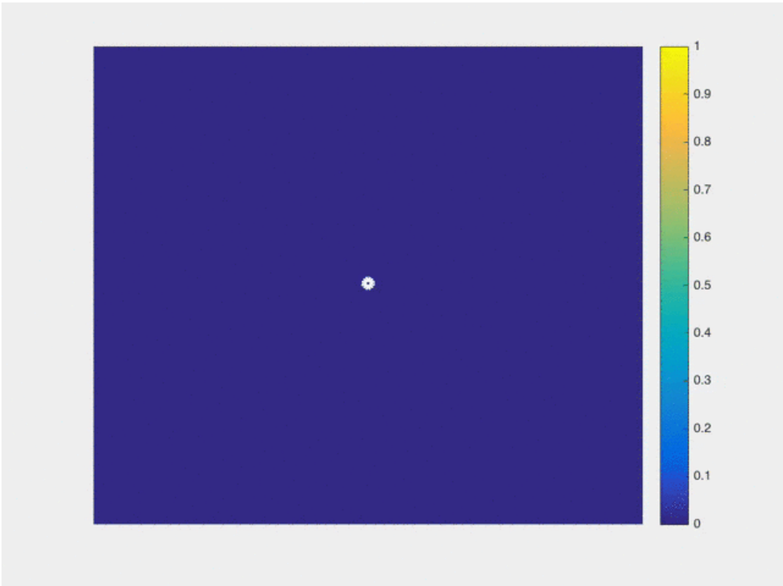
Perspectives

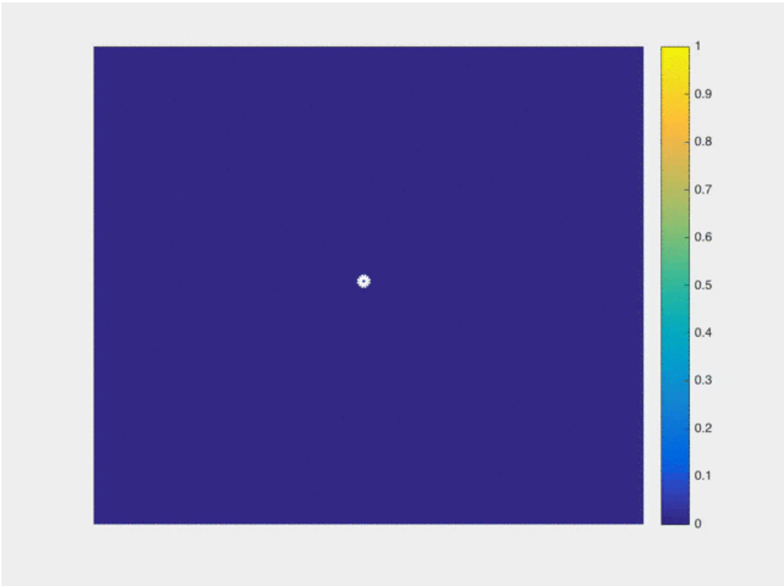
Integration of both spaces to investigate interactions between eye movements & visual perception

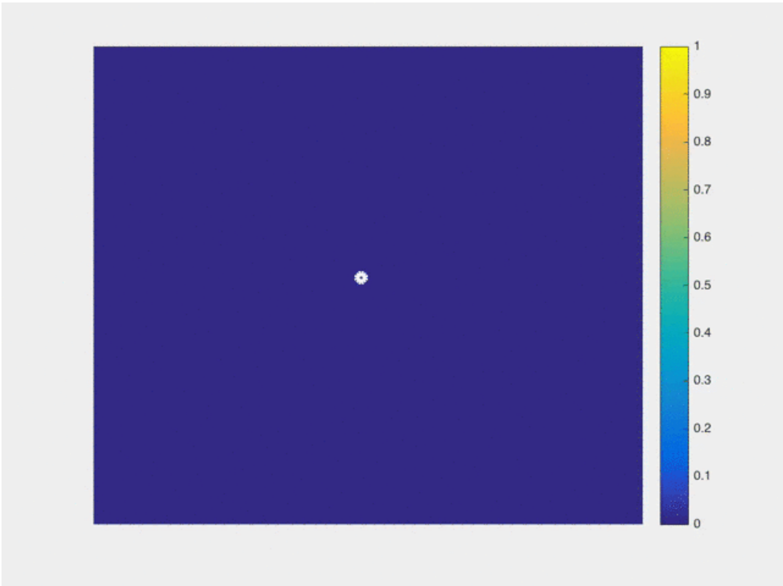
Moving plaids: first naïve approach



Eye movement **predictions** on perception?







Take home message

- Observations of **micro-pursuits** FEM: only observation since Martins, Kowler, & Palmer, (1985). *JOSA*
- Description of **GraFEM**: an FEM generative model that can be extended to **all eye movements**
- GraFEM is multi-stable w.r.t. spatial attractors
- Development of links between eye-movement and perceptual models


GraFEM
Jeremy Shaun McDonald, Cosmos