

# Surprising Range of Signal Detection by Amoebae

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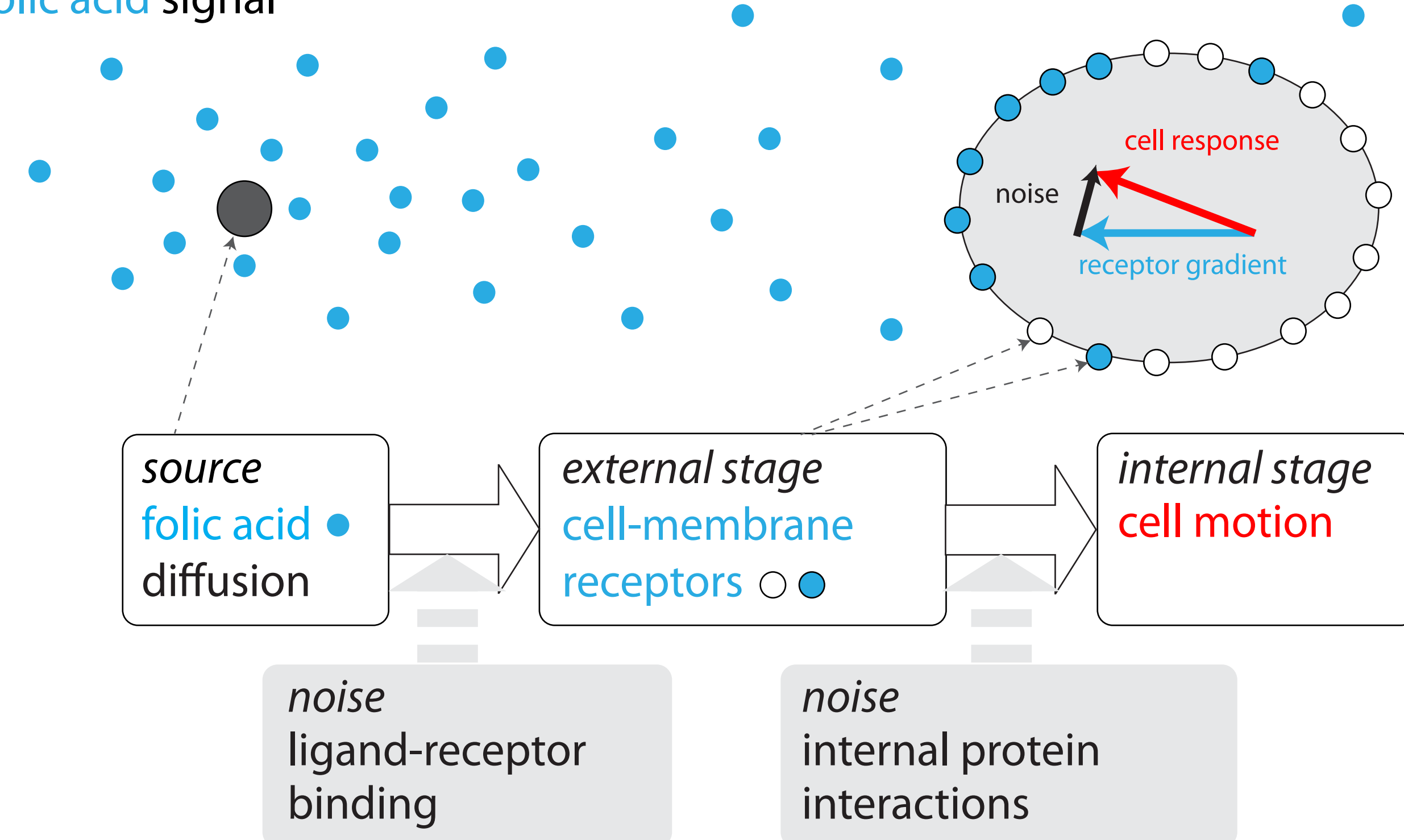
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## Summary

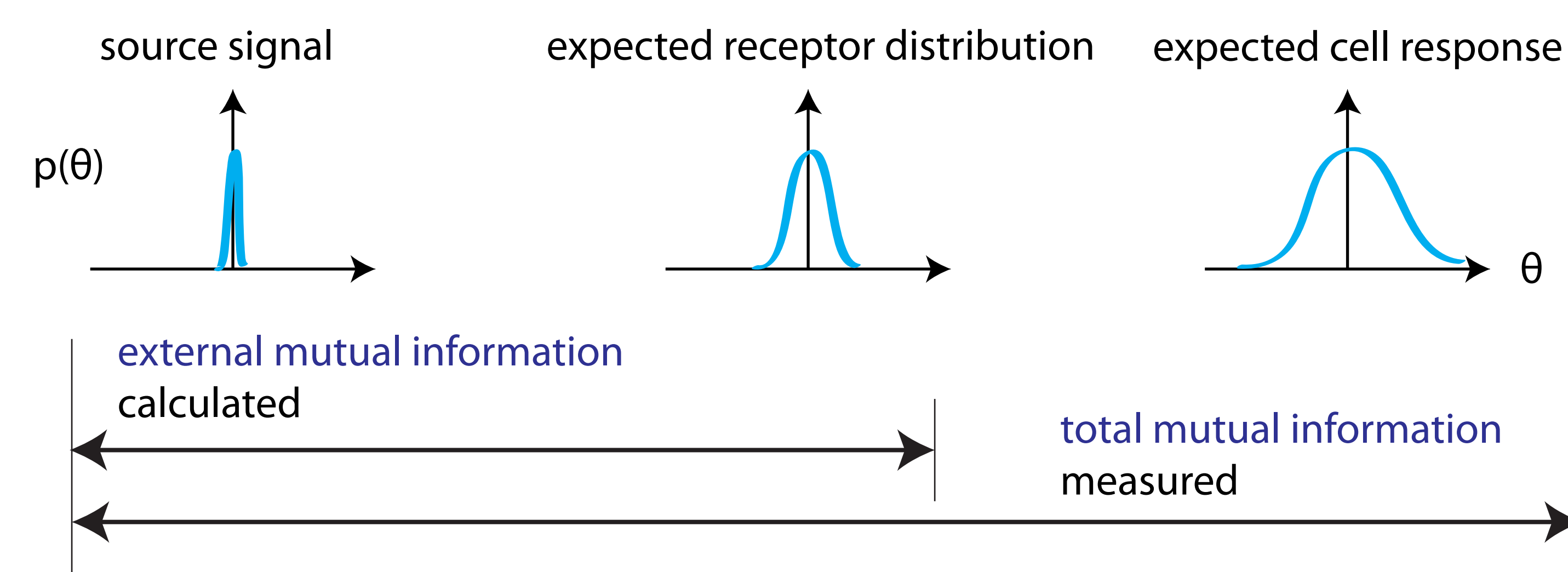
- » We investigated the range of folic acid sensing by *Dictyostelium discoideum* (Dicty) amoebae.
- » System was viewed as a Shannon's noisy communication channel, with two noise sources considered here:
  - » external noise due to receptor-ligand binding kinetics, and
  - » internal noise due to chemical reactions within the cell.
- » The response was in the regime where, theoretically, the signal should be buried by external receptor-binding fluctuations alone.

## Introduction

- » We studied directed cell motion in chemical gradients (chemotaxis) in the case of Dicty amoebae inspired by the natural chemotaxis towards bacteria, following a folic acid signal

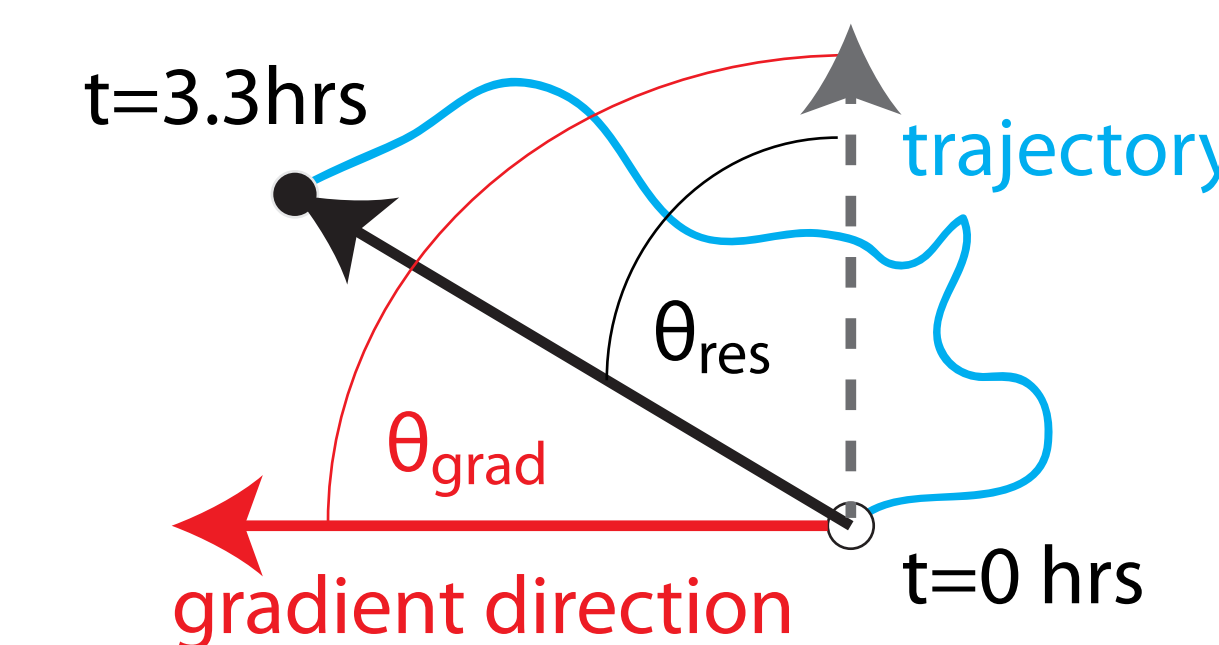
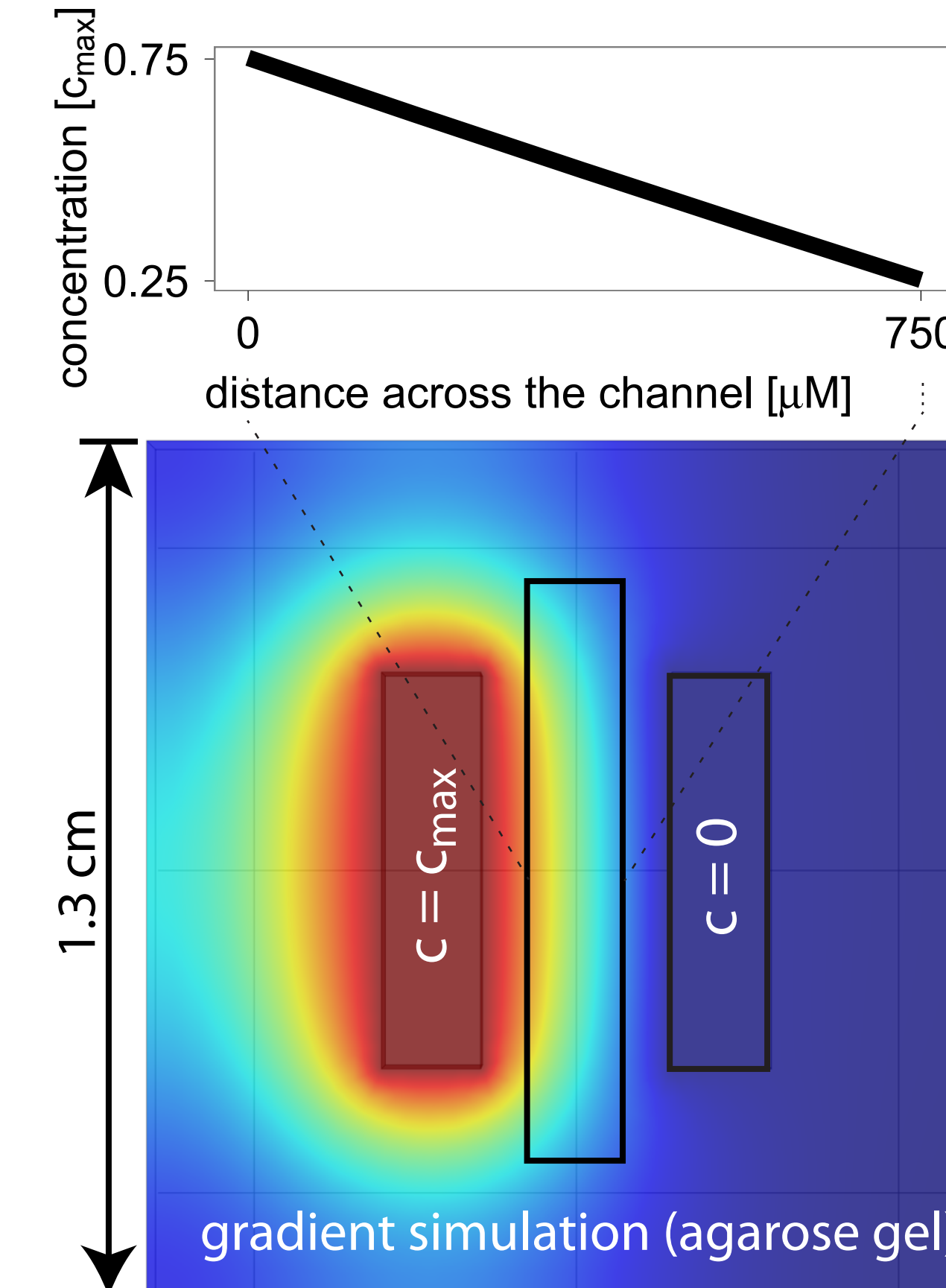


- » Gradient detection was recast in the context of Shannon's information theory
  - noise between the source and external stage was quantified using external mutual information calculated according to [Fuller; 2010]
  - noise between the source and internal stage was quantified using total mutual information which was measured [see Methods]



## Methods

- » Static gradient was achieved using an agarose-based microfluidic device with two reservoirs held at constant concentrations [Cheng; 2007]
- » Linear gradient was established in the middle, static channel by diffusion in steady state - this represents more realistic, natural environment - in contrast to flowing systems used for studies of cAMP signaling [Song; 2006, Fuller; 2010]
- » For each cell, we measured the angle  $\theta_{res}$  of total displacement vector during  $\Delta t = 3.3$  hours
- » The angle distribution  $p(\theta_{res})$  was used to compute total mutual information according to [Fuller; 2010]



- » Total mutual information  $I_{tot}$ : how much information one can acquire about  $\theta_{grad}$  by looking at the cell response,  $\theta_{res}$ :

$$I_{tot}(\theta_{res}, \theta_{grad}) = \iint p(\theta_{res}, \theta_{grad}) \log \left[ \frac{p(\theta_{res}, \theta_{grad})}{p_1(\theta_{res})p_2(\theta_{grad})} \right] d\theta_{res} d\theta_{grad}$$

- » External mutual information  $I_{ext}$ : how much information one can acquire about  $\theta_{grad}$  by knowing a distribution of receptor occupancy  $\theta_{rec}$ .

## Results and Discussion

FIGURE 1.

Comparison of:

- »  $I_{tot}$  (measured): information transferred from the source to the internal stage
  - »  $I_{ext}$  (calculated): information transferred from the source to the external stage.
- It depends on the local FA concentration which varies by a factor of 3 in the experiment: this is represented by the spread.  $K_d = 150$  nM, cell radius =  $5 \mu m$

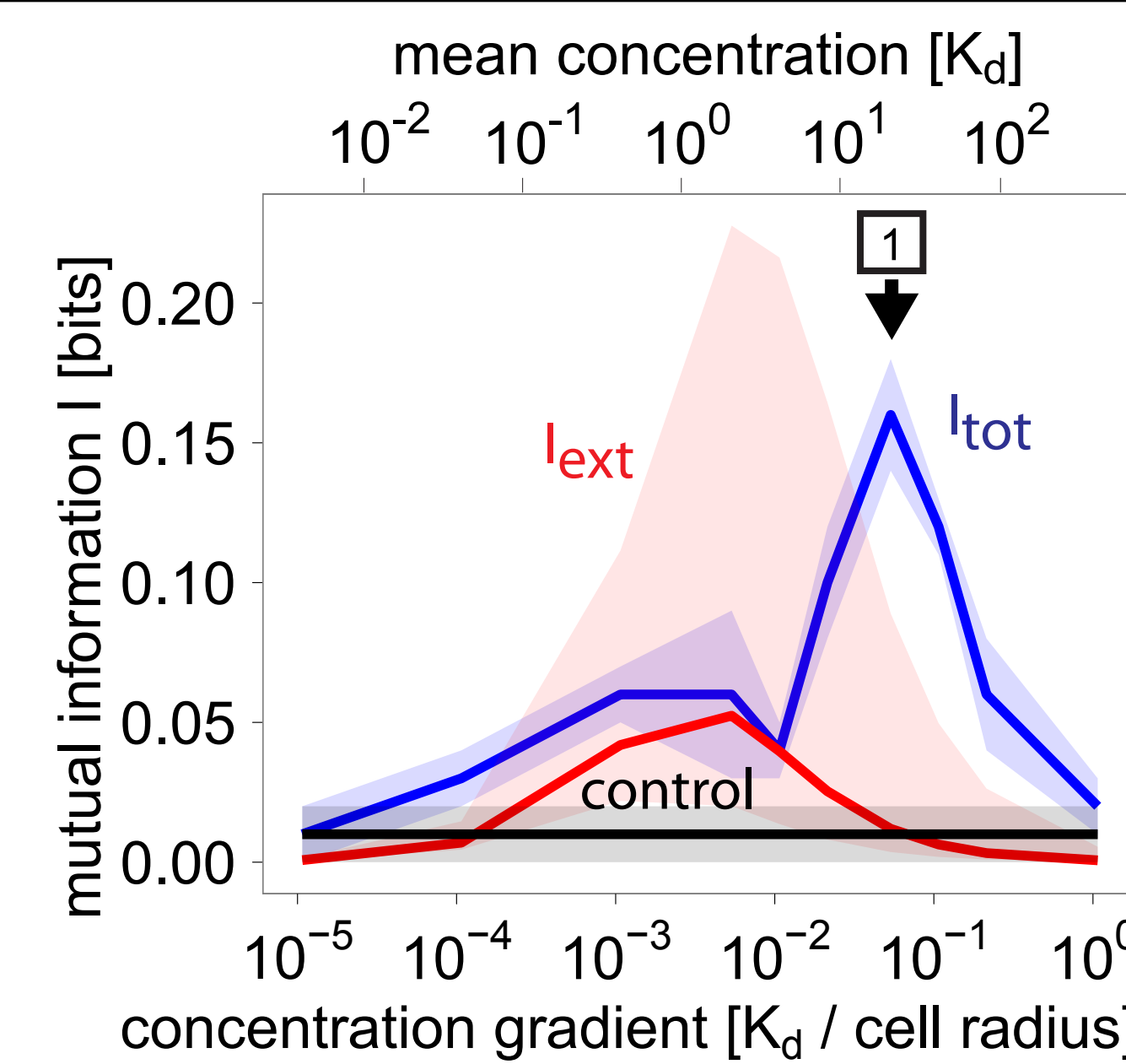
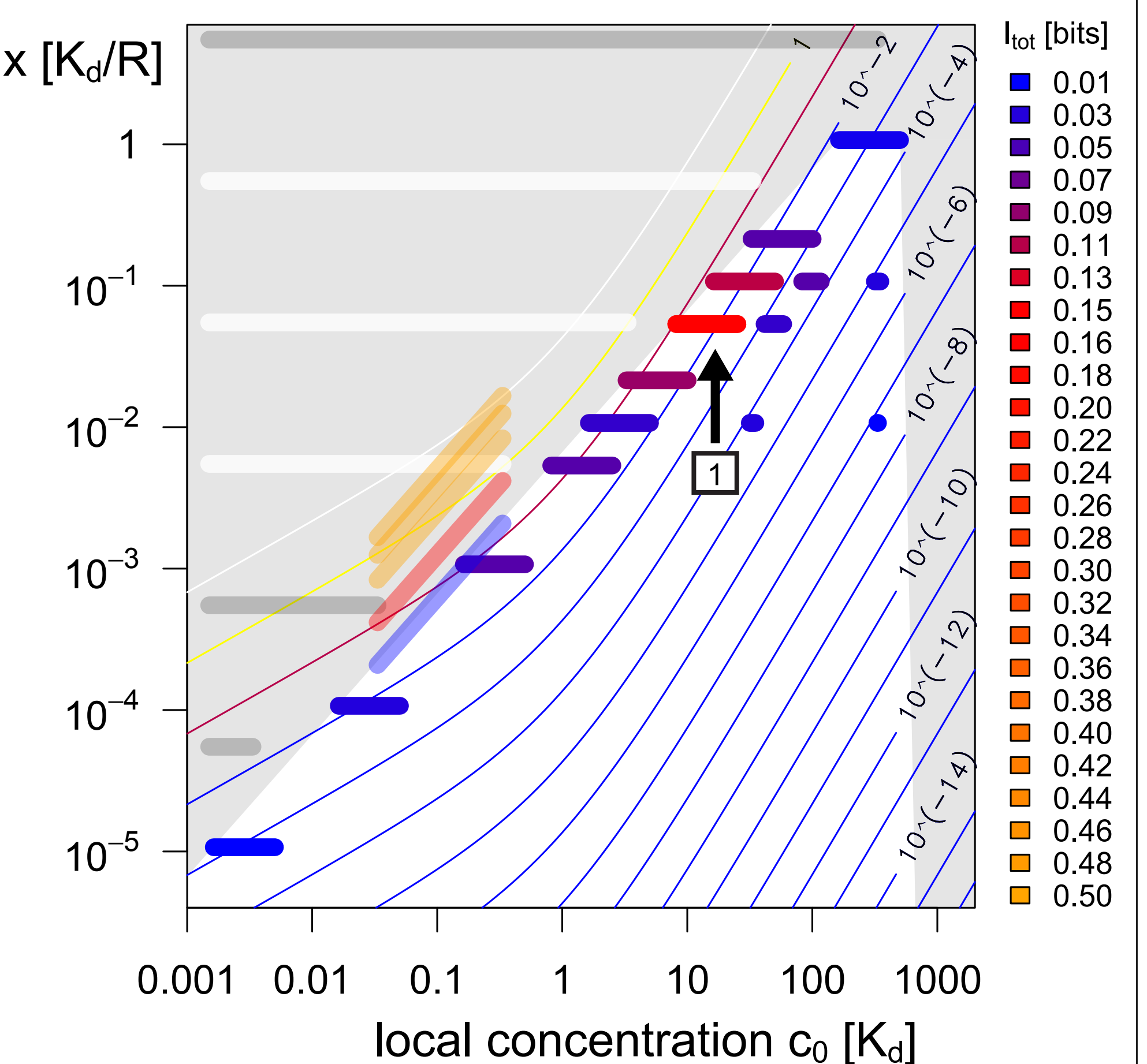


FIGURE 2.

Comparison of:

- »  $I_{ext}$ : contours; theory
  - »  $I_{tot}$ : colored bars; three different experiments:
    - blue-red: FA static experiments [this work]
    - red-orange: cAMP flowing experiments [Fuller; 2010]
    - gray-white: cAMP flowing experiments [Song; 2006]
- Shaded area: inaccessible region in our experiment.



## Conclusions

We found:

- » Response across a range of 4 orders of magnitude.
- » Surprising response at high local concentrations in saturating regime
- » Apparent violation of Jensen's inequality  $I_{tot} > I_{ext}$ : the observed response is better than what it ought to be, by considering the receptor-ligand binding as the only source of noise in signal transmission. [1]
- » Explanations: Very high membrane-bound or extracellular deaminase (degradator of FA) activity? This effect was calculated to contribute to degradation of less than 0.1% of FA even for the best response. [1]

## References

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