# 20.109
# Synthetic Biology Module
# Lecture #8

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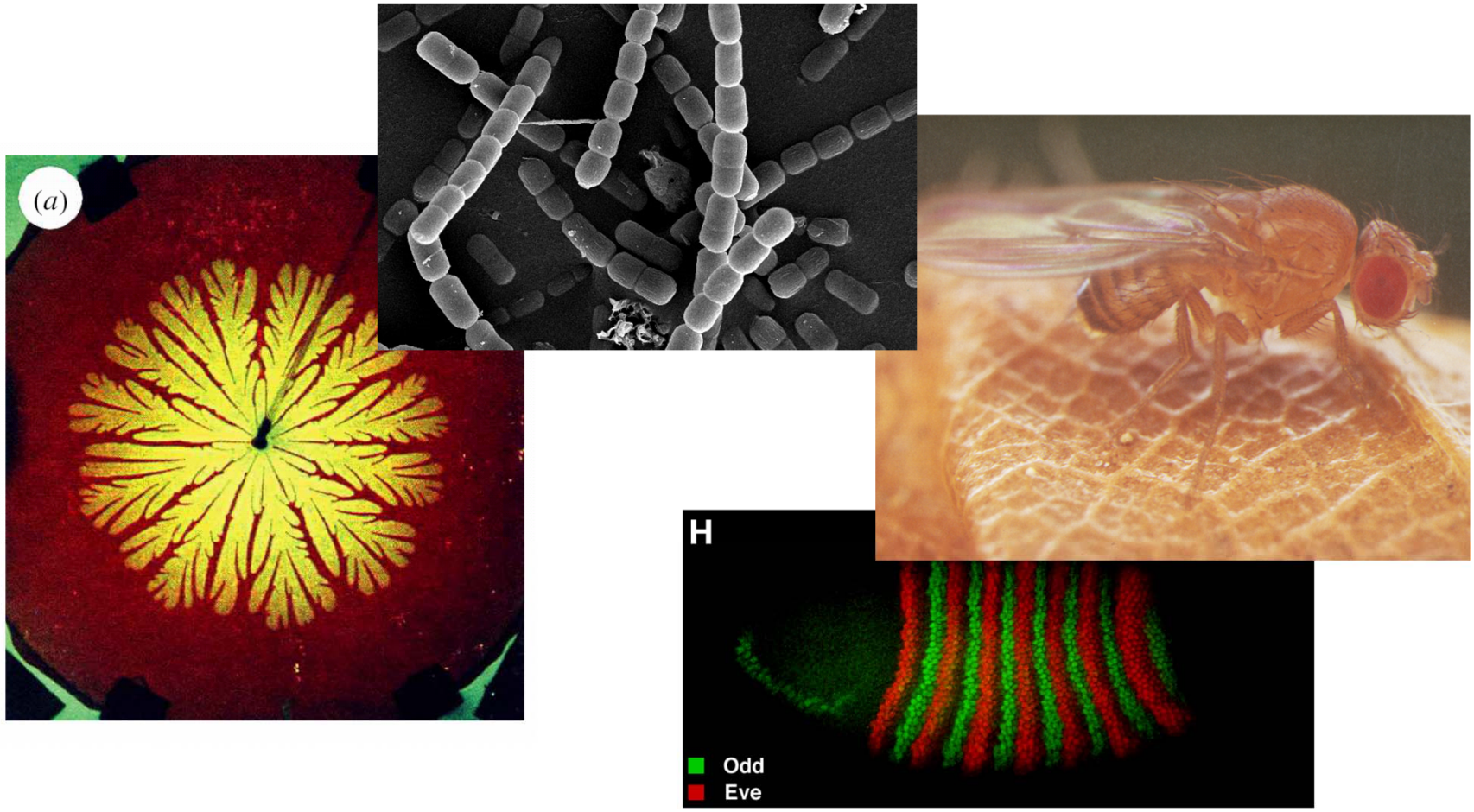
CSAIL

# Natural Pattern Formation

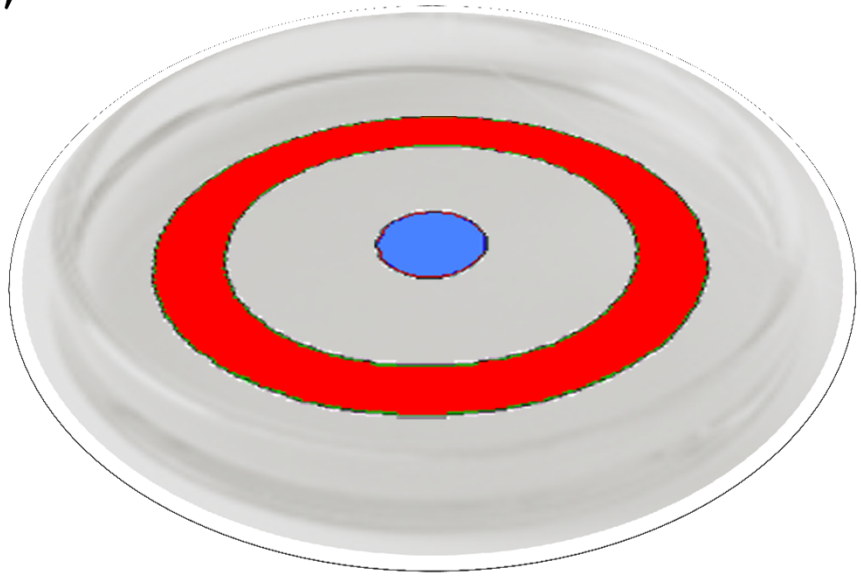



- Robust global behavior from unreliable parts
- Repeated network motifs. Same molecules used by different species, different stages of development.

# Programmed pattern formation in bacteria

High level behavior:

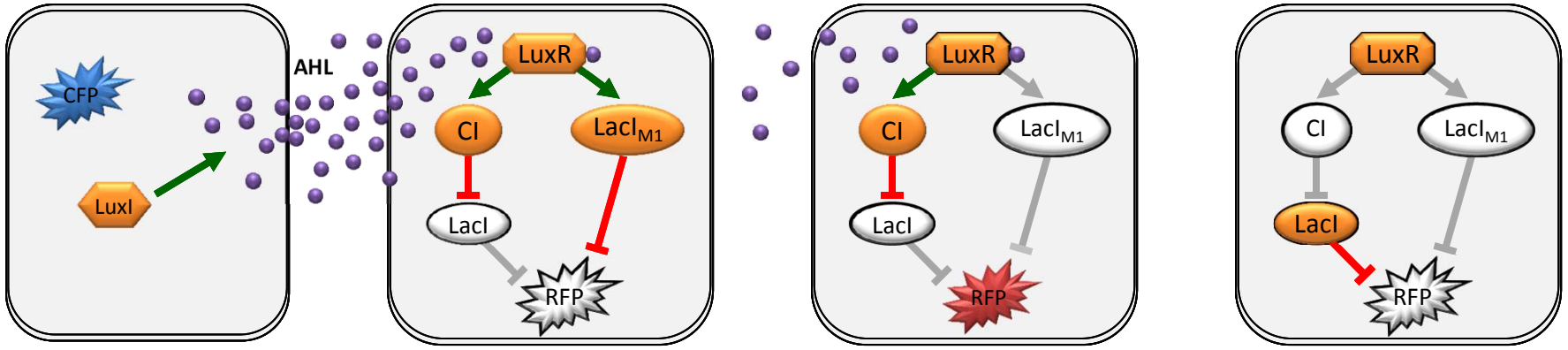
**"Ring-like spatial patterns"**



Bio-program:

- **Cell type: *sender***
  **send (AHL)**
- **Cell type: *receiver***
  **input: AHL**

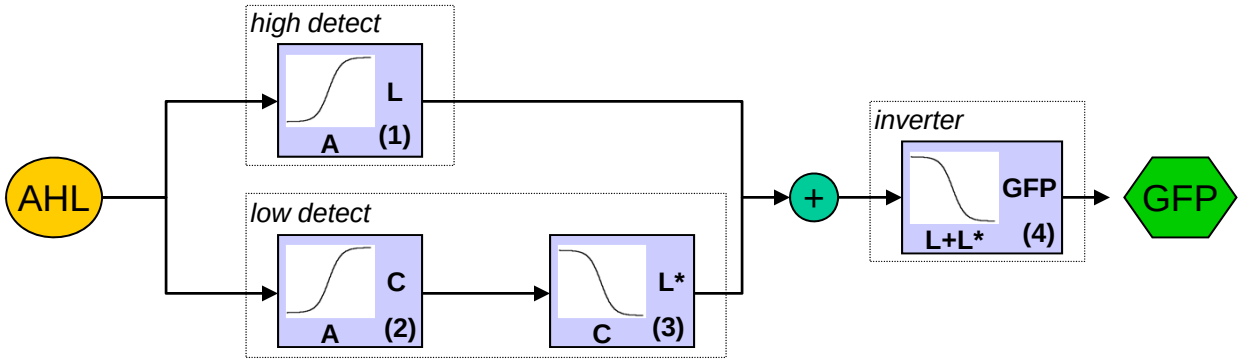
  **case (AHL)**
  **low: RFP = off**
  **med: RFP = on**
  **high: RFP = off**




***Sender*** ***Band detector*** ***Band detector*** ***Band detector***

Basu, *et al., Nature* (2005)

# Band Detect Model

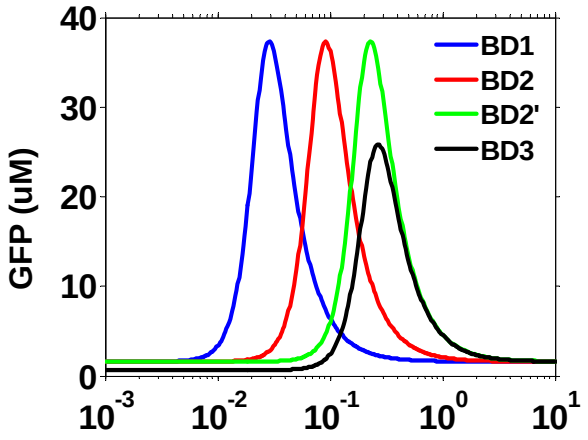


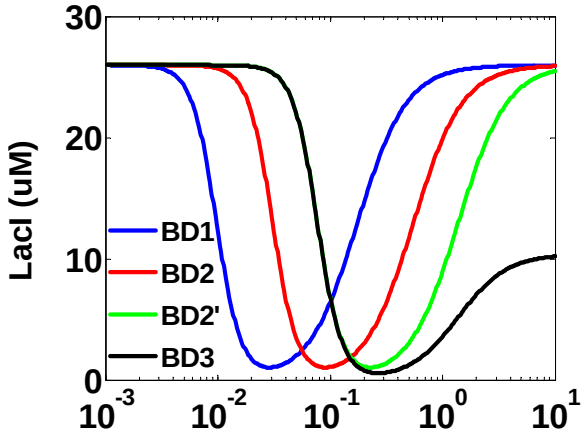

$$\frac{dL}{dt} = \frac{\alpha_L \cdot A^{\eta_A}}{A^{\eta_A} + \beta_A^{\eta_A}} - \gamma_L \cdot L$$

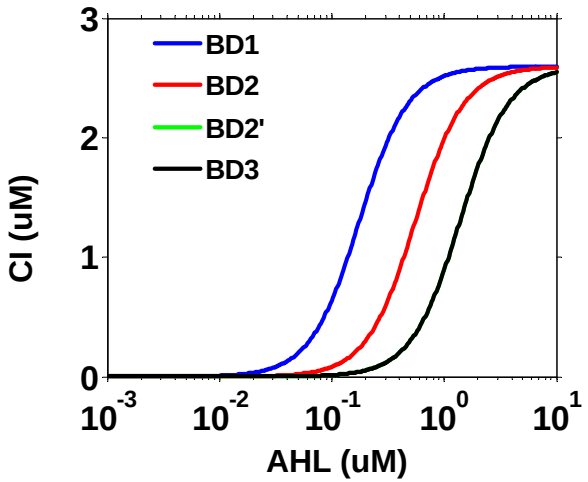
$$\frac{dC}{dt} = \frac{\alpha_C \cdot A^{\eta_A}}{A^{\eta_A} + \beta_A^{\eta_A}} - \gamma_C \cdot C$$

$$\frac{dL^*}{dt} = \frac{\alpha_L{}^* \cdot \beta_C^{\eta_C}}{\beta_C^{\eta_C} + C^{\eta_C}} - \gamma_L \cdot L^*$$

$$\frac{dG}{dt} = \frac{\alpha_G \cdot \beta_L^{\eta_L}}{\beta_L^{\eta_L} + (L + L^*)^{\eta_L}} - \gamma_G \cdot G$$

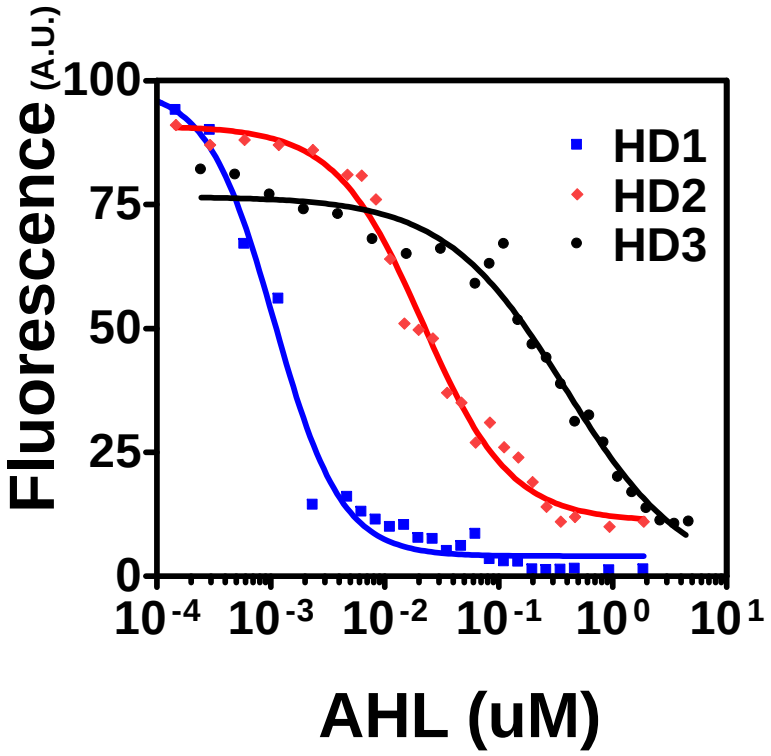


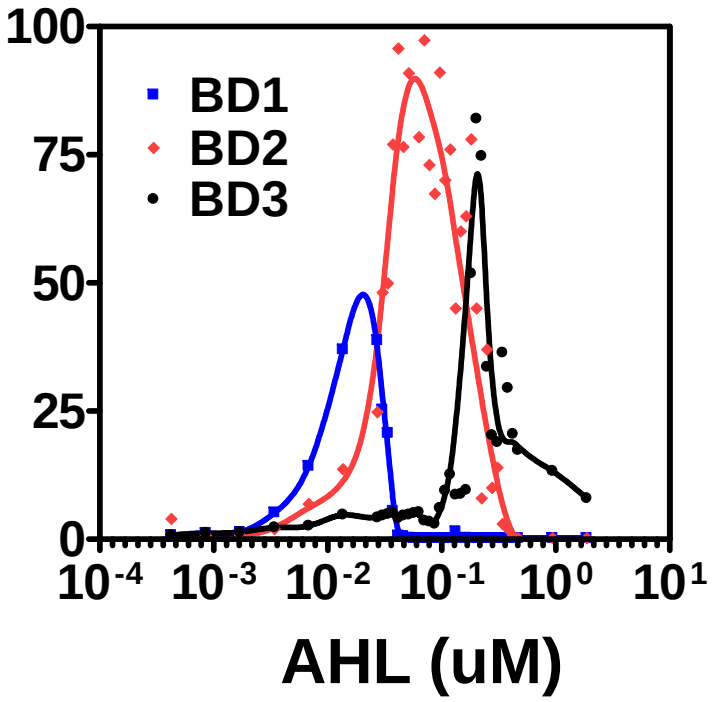



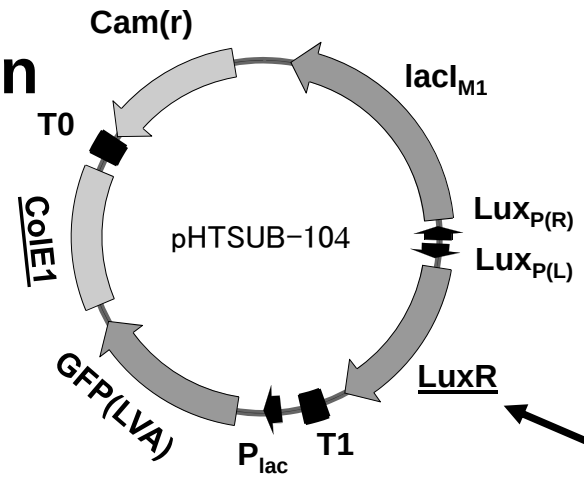

**BD1 – Hypersensitive LuxR**
**BD2 – Wildtype LuxR**
**BD2' – Reduced plasmid copy number for LuxR**
**BD3 – Reduced plasmid copy number for LuxR, $LacI_{M1}$, GFP**

# Experimental Dosage Response

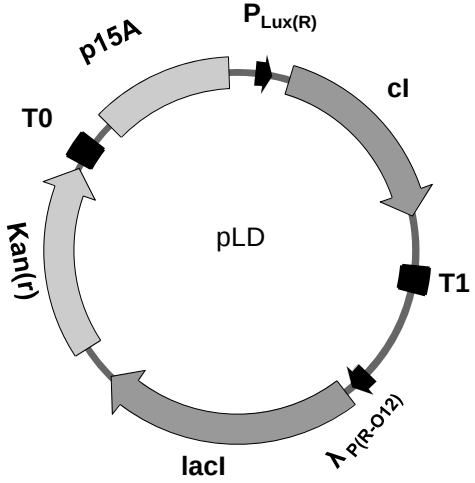


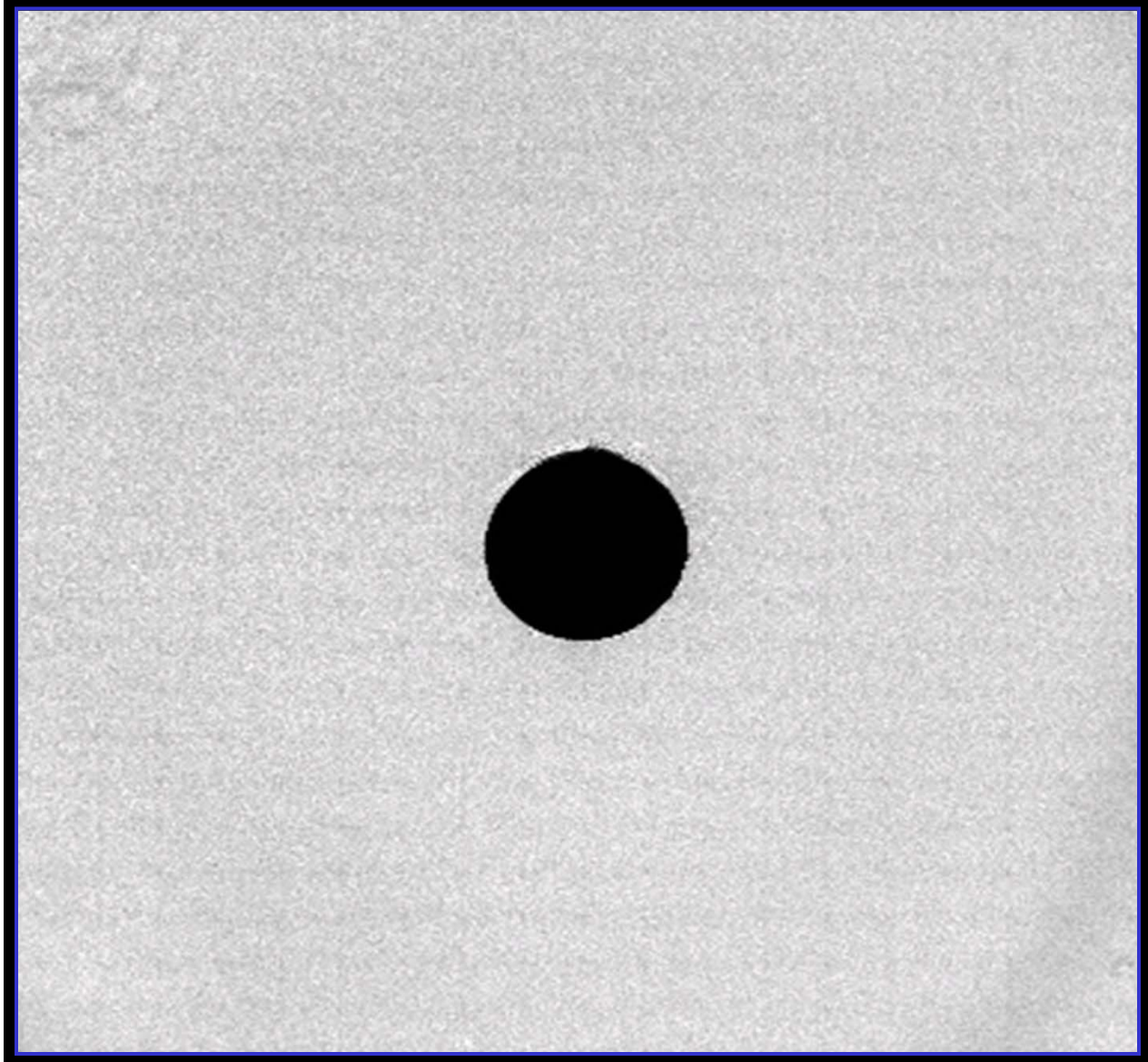

HD3 Mutation



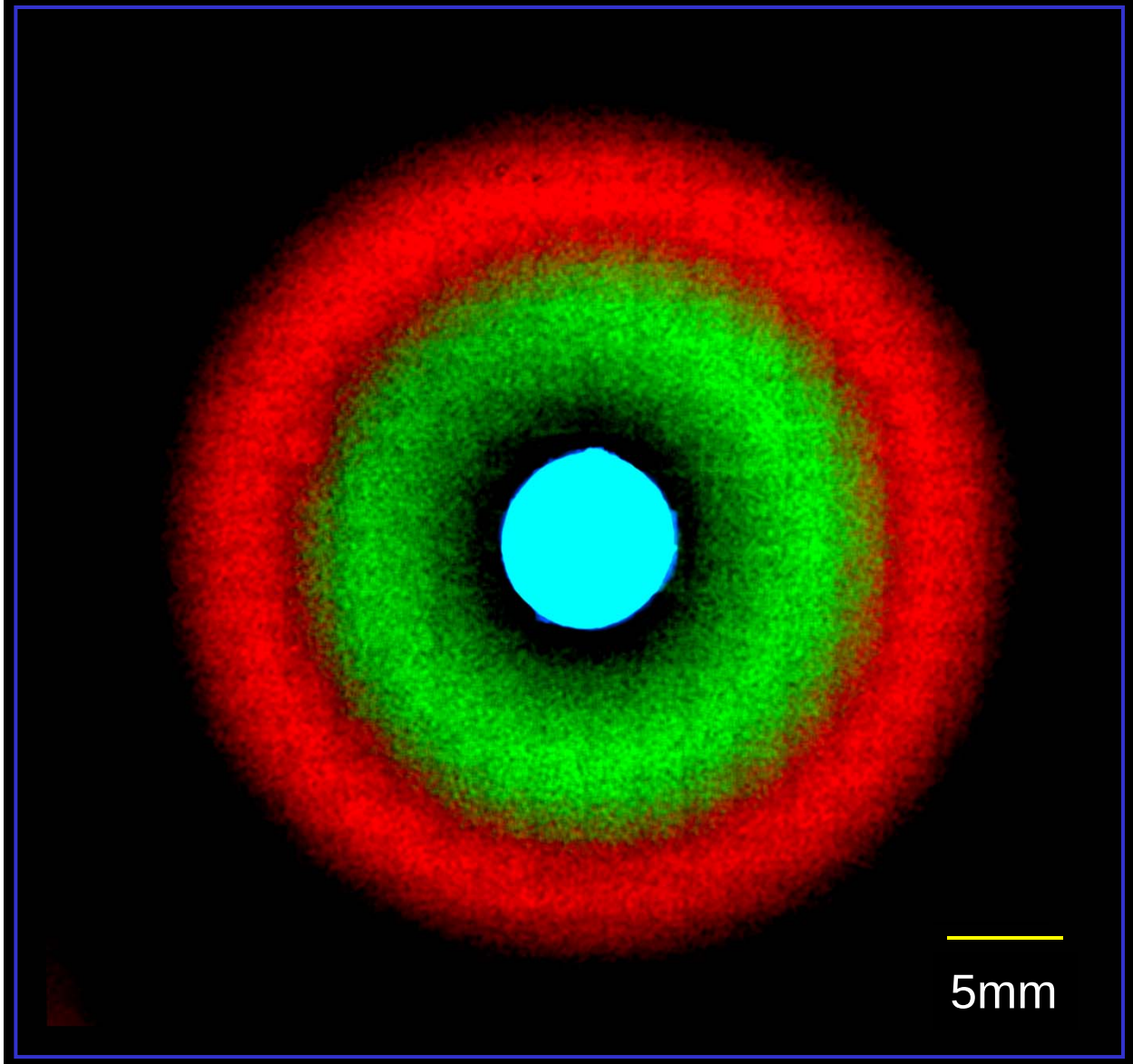

HD1 Mutation

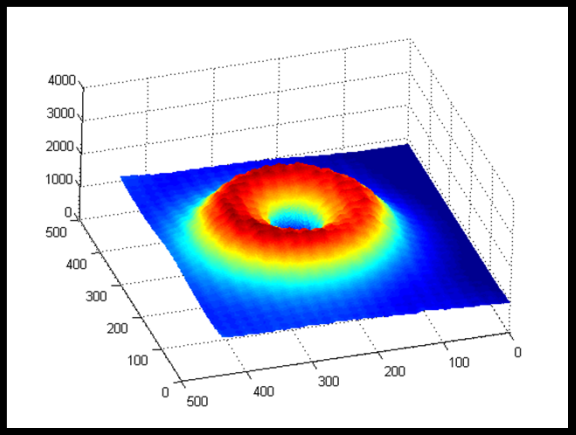


# Bullseye with BD2-Red / BD3-GFP

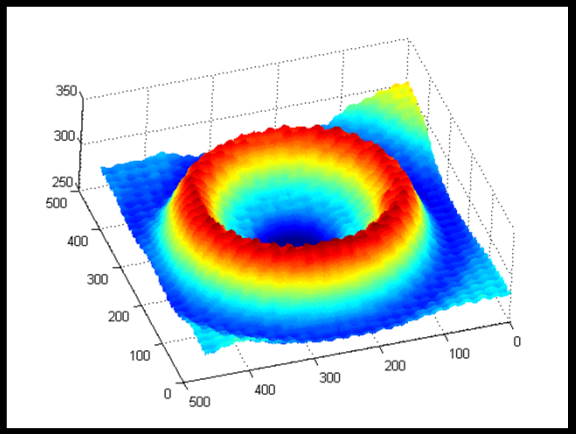


# Bullseye with BD2-Red / BD3-GFP

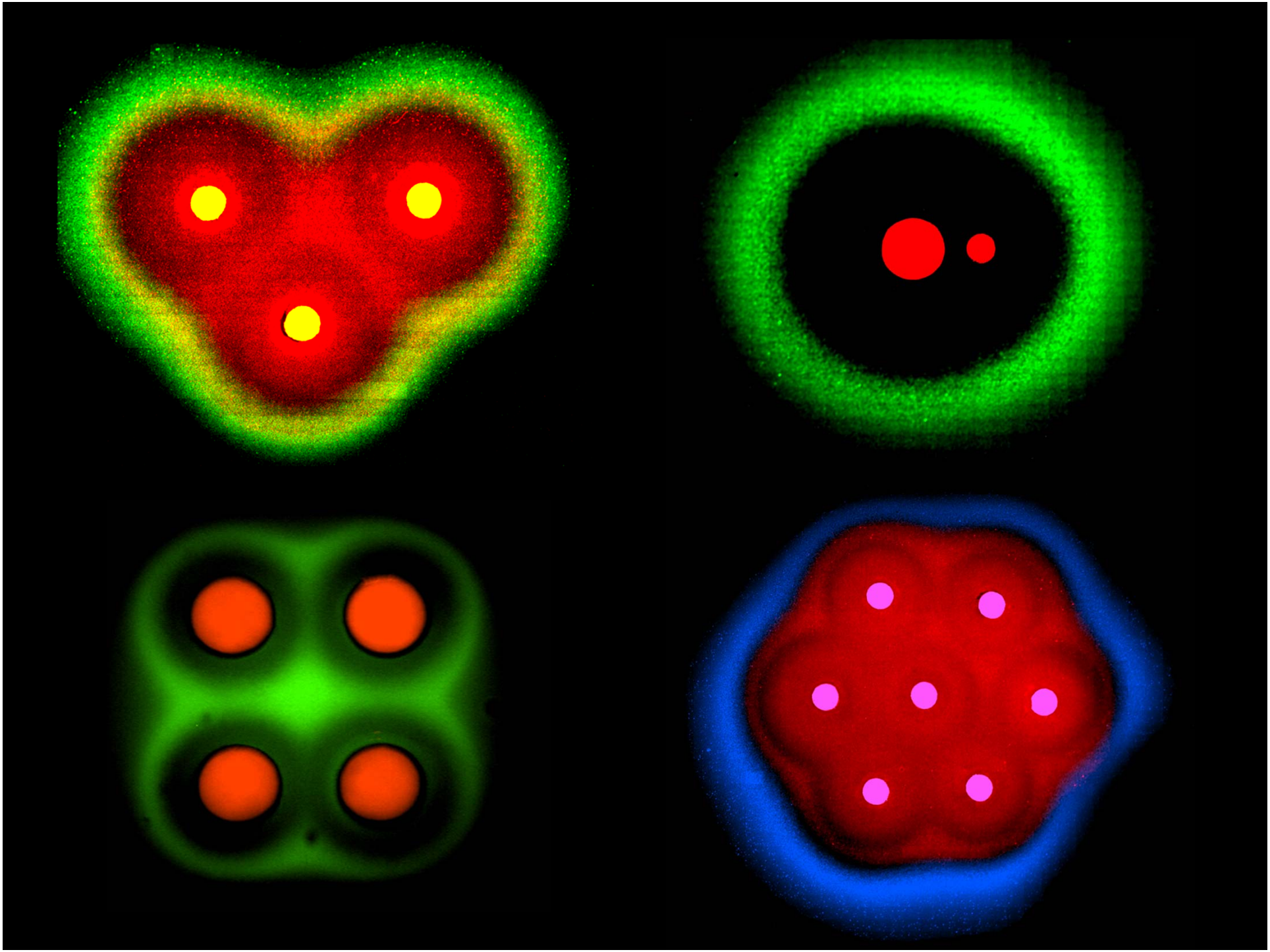



Green

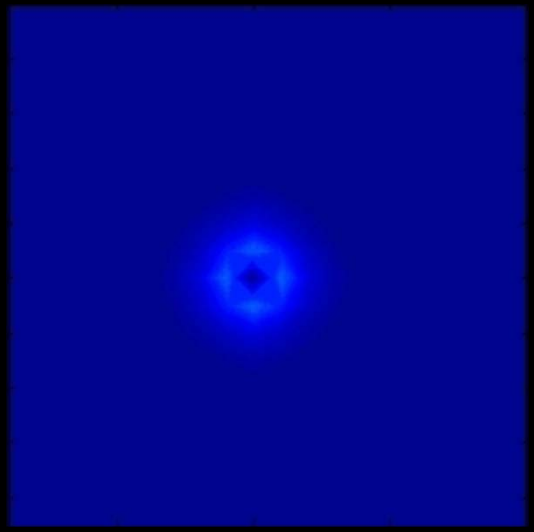



Red

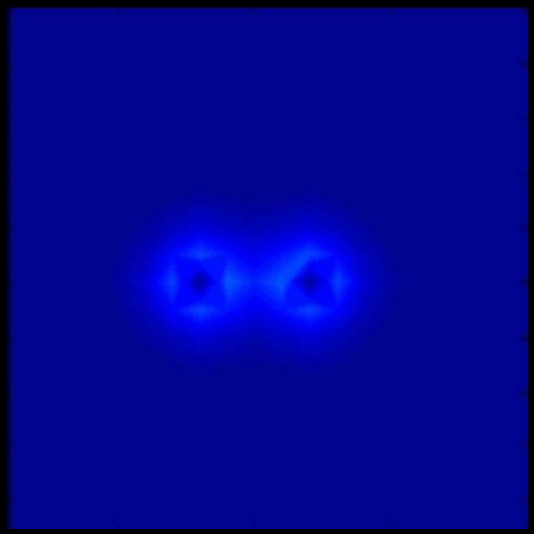


# Spatiotemporal Simulation

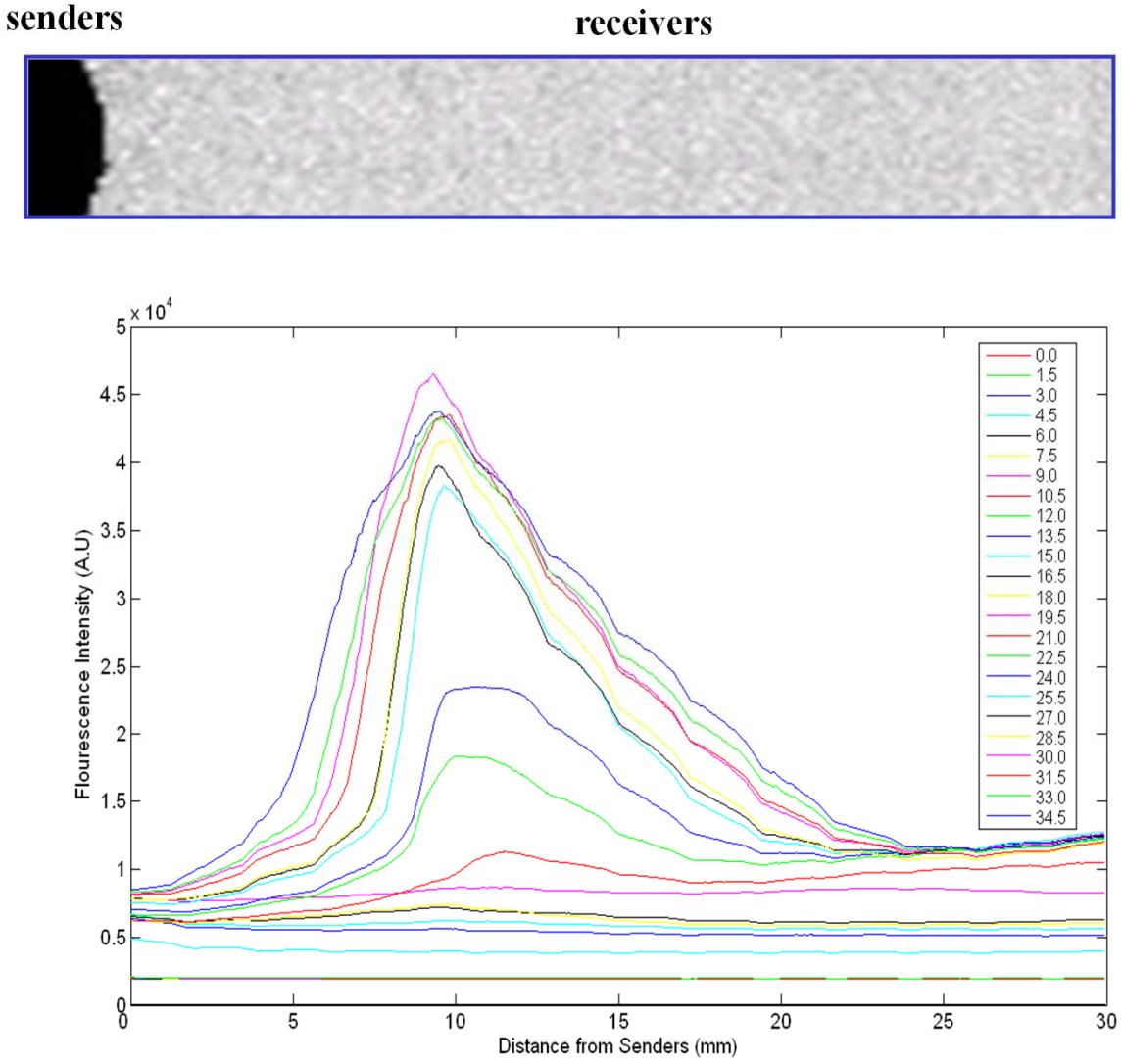
***One sender***



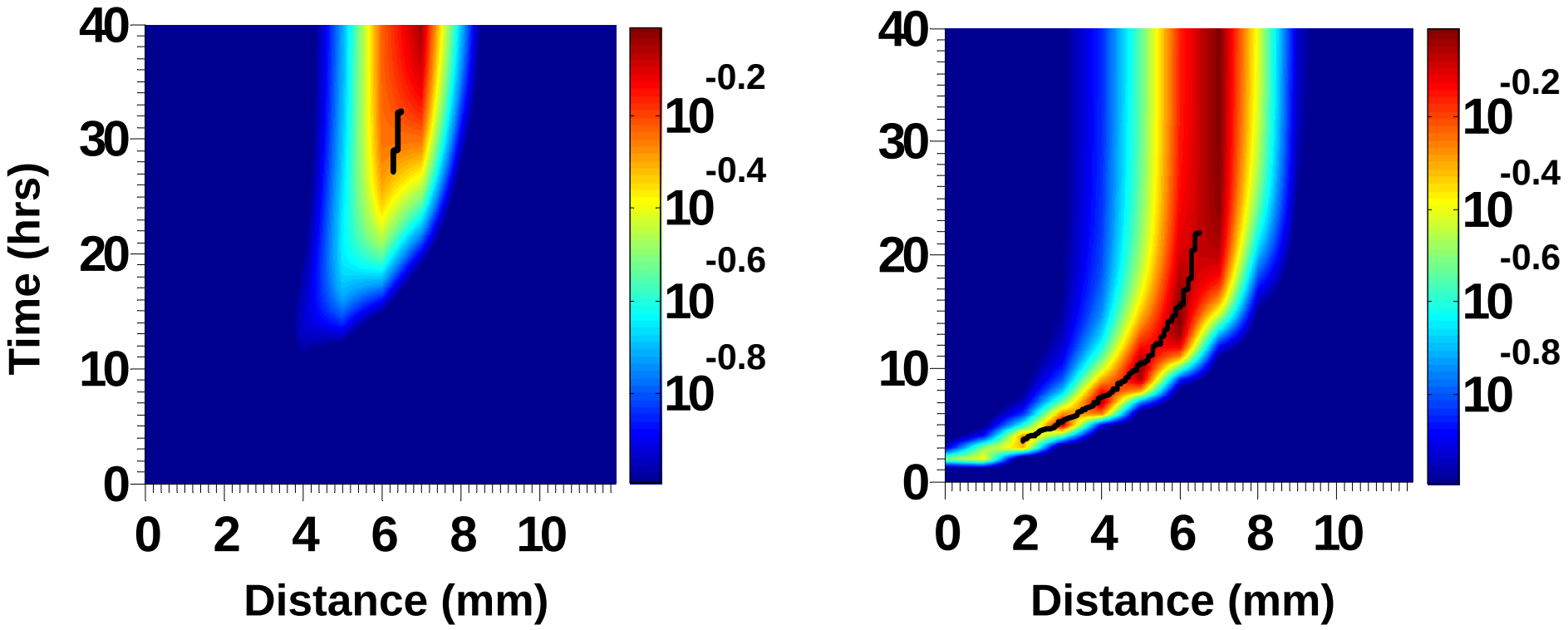
***Two senders***



# Experimental Spatiotemporal Behavior



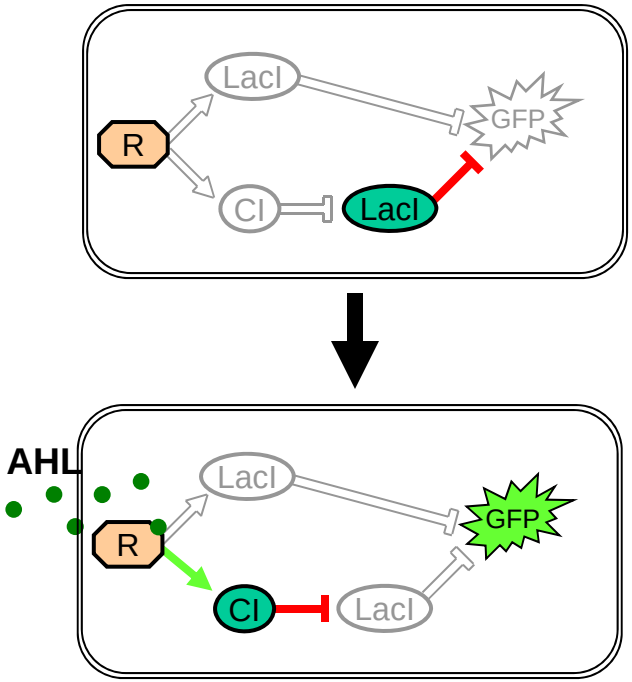
# Spatiotemporal Simulations – Shift

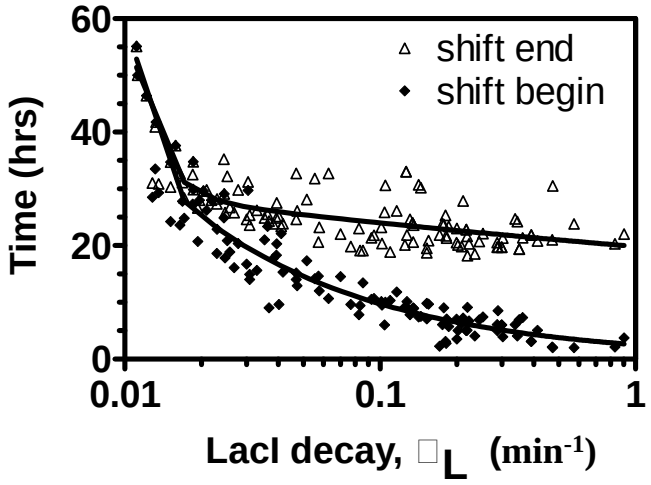


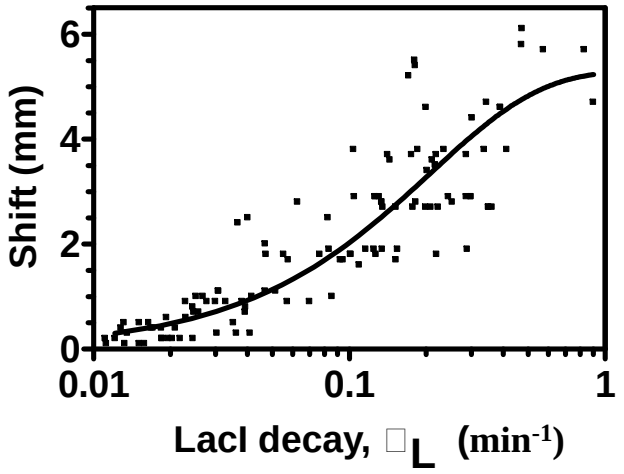

- Analysis of the effect of kinetic parameters on positional shift through simulations

# Regression Analysis

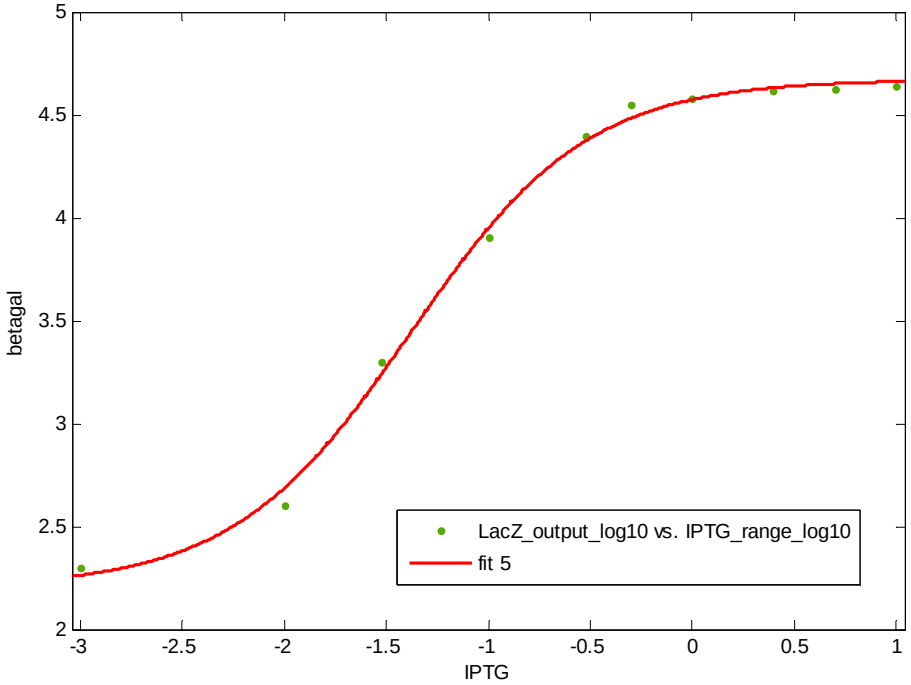
- Generated sets with random kinetic rates
- Selected for band-detect behavior (~30%)
- Regression analysis to find correlations

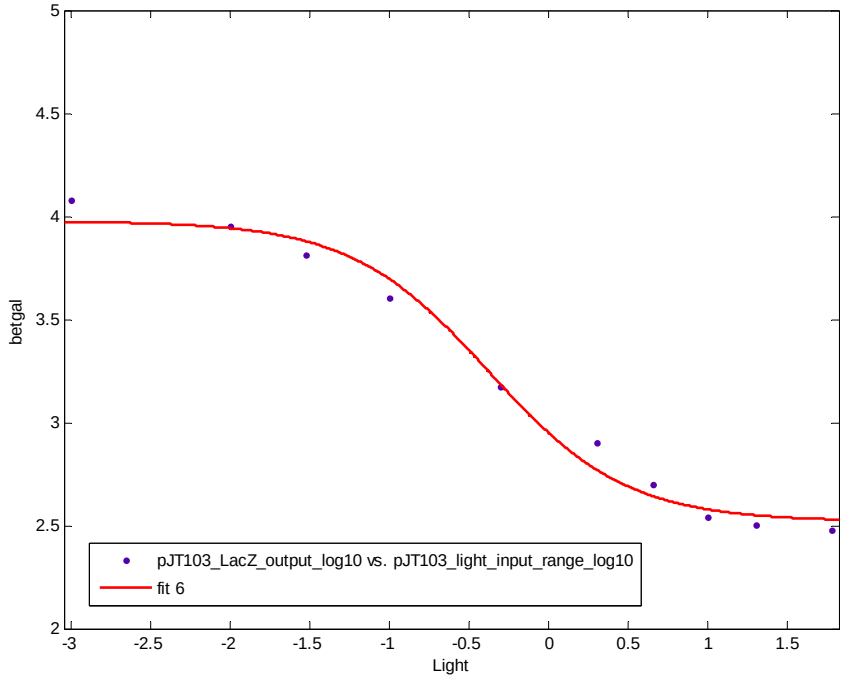


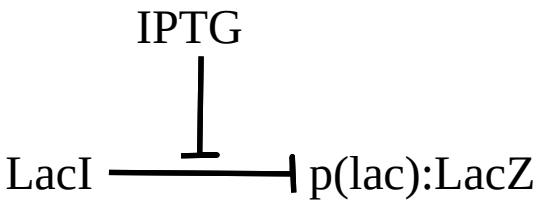



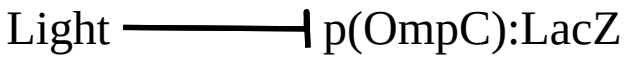



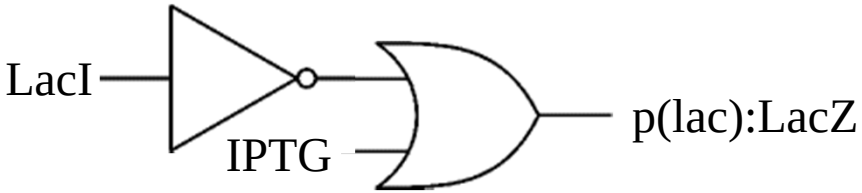
# Edge detector:
## Lab data & computational models

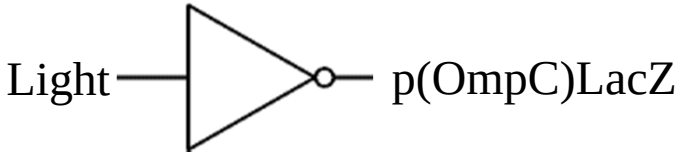


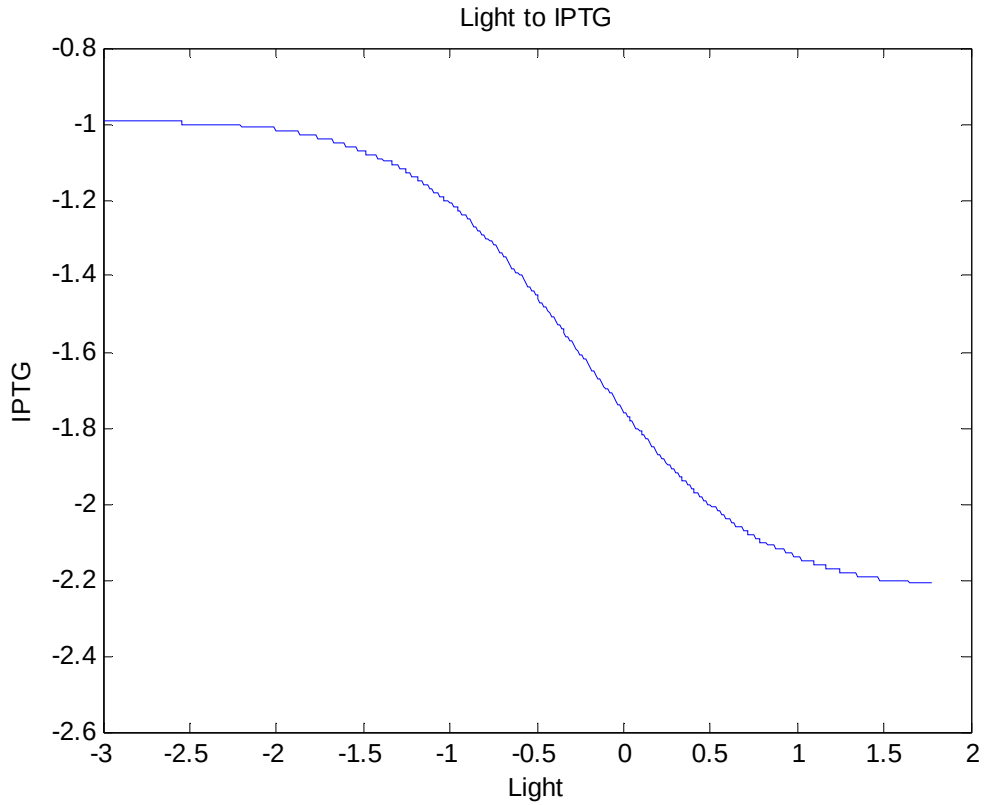



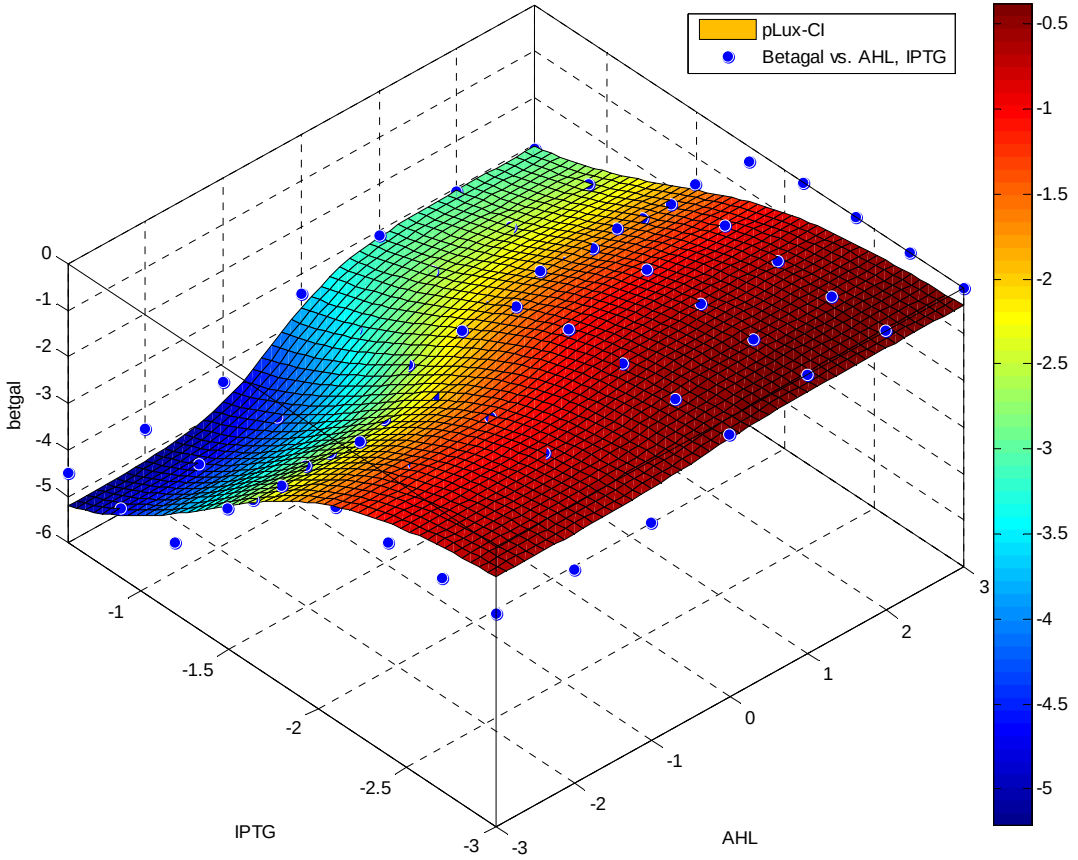



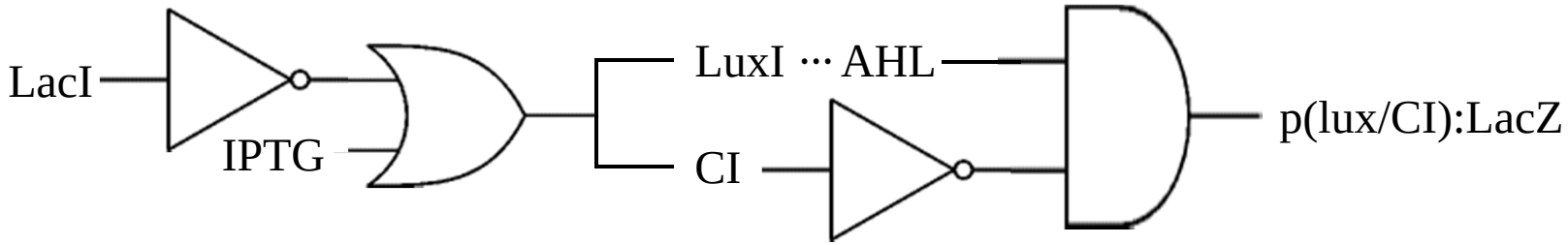
# Correlating IPTG & Light induction



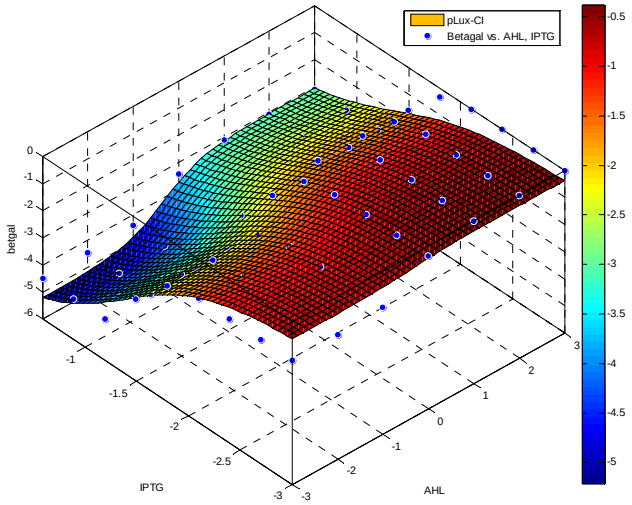

IPTG/p(lac) ←→ Light/p(Ompc)

# Evaluating pLux/CI with IPTG

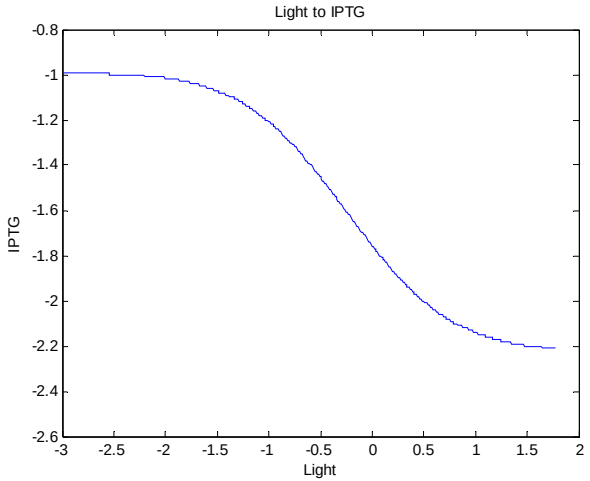


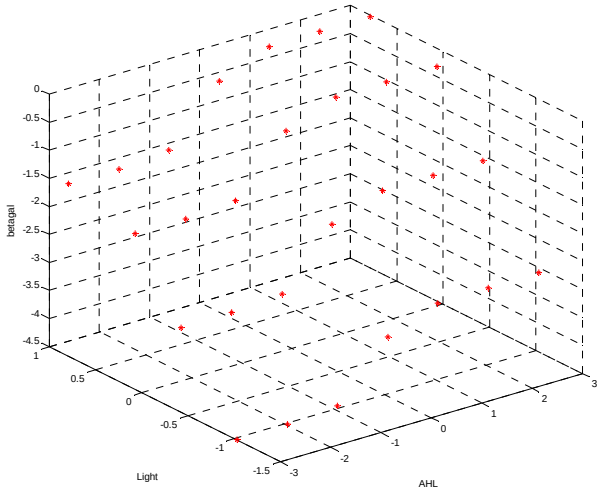
# Predicting pLux/CI with light induction



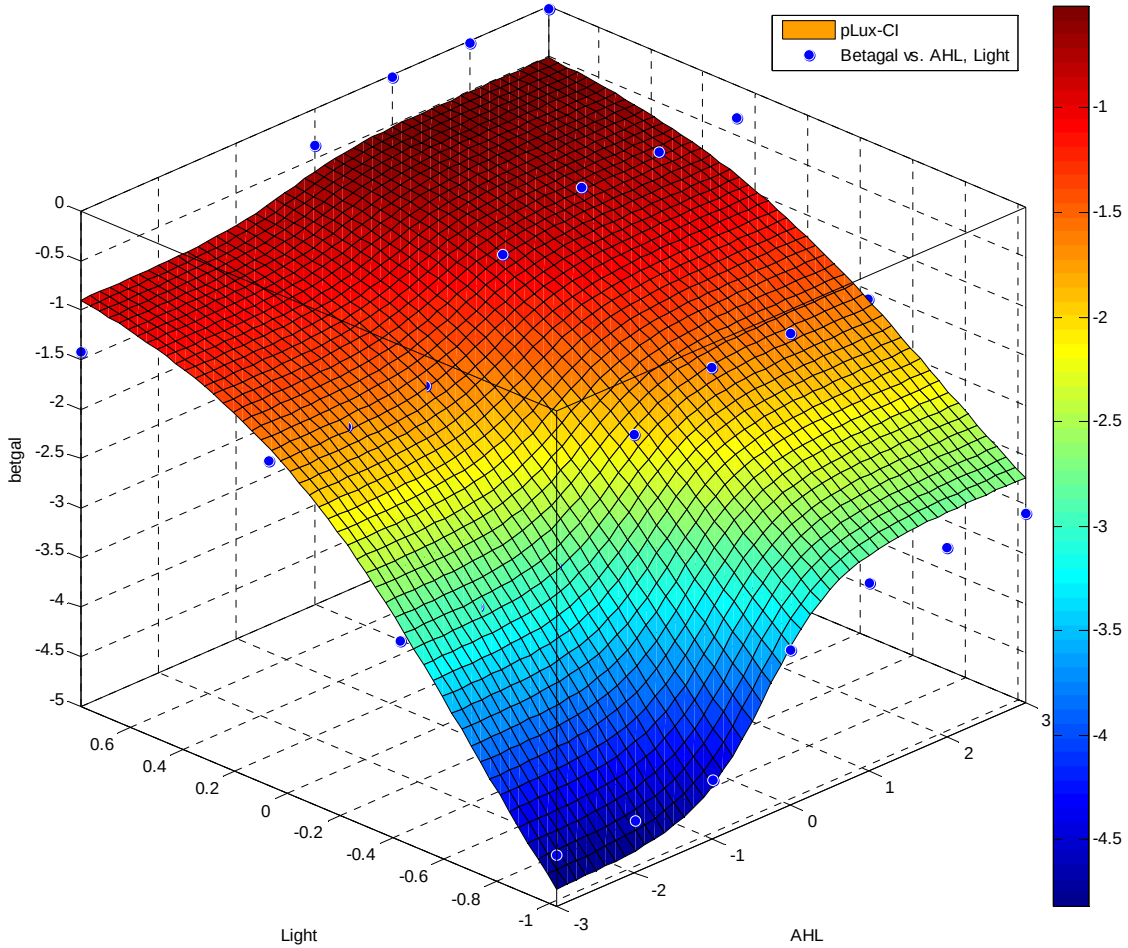

+




→



# Curve fit for pLux/CI with light induction



# pLux/CI transfer function for simulation

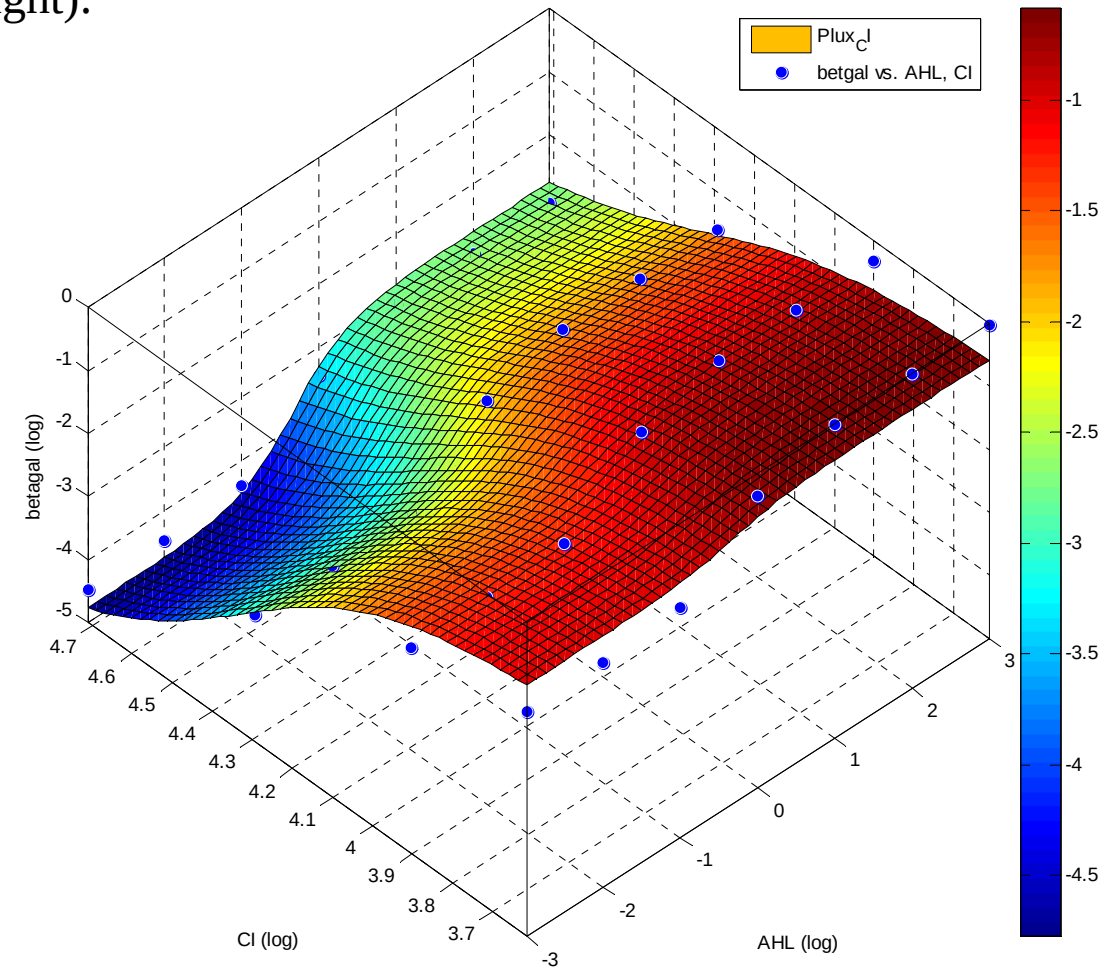
For simulation, need CI as input (not light):

NlacZ = Ncells*(MU*mL*min*0.5)

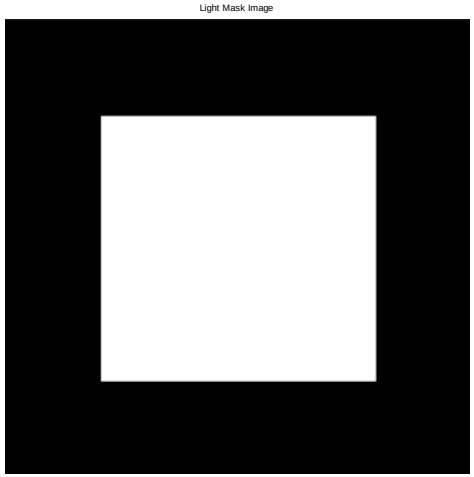
where:

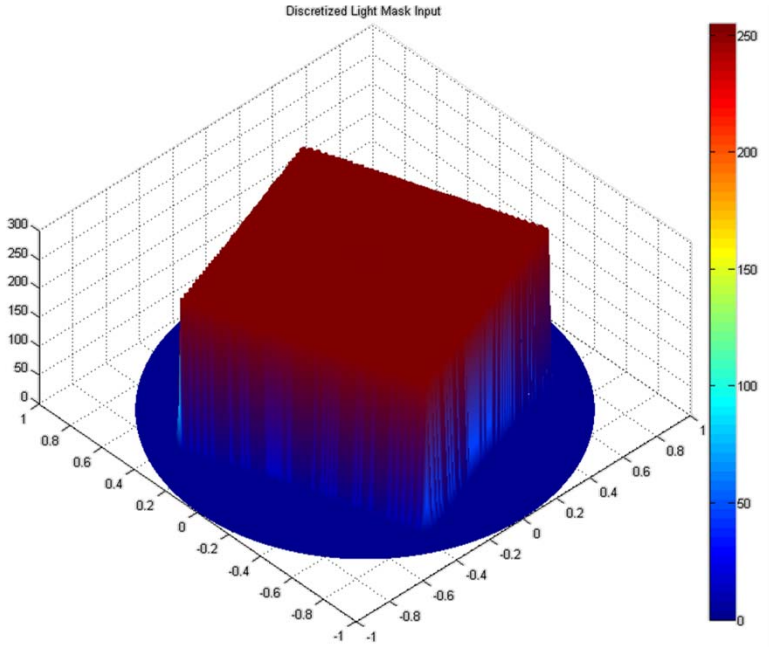
- MU is the miller units
- mL is the volume of the reaction
- min is the time of the reaction

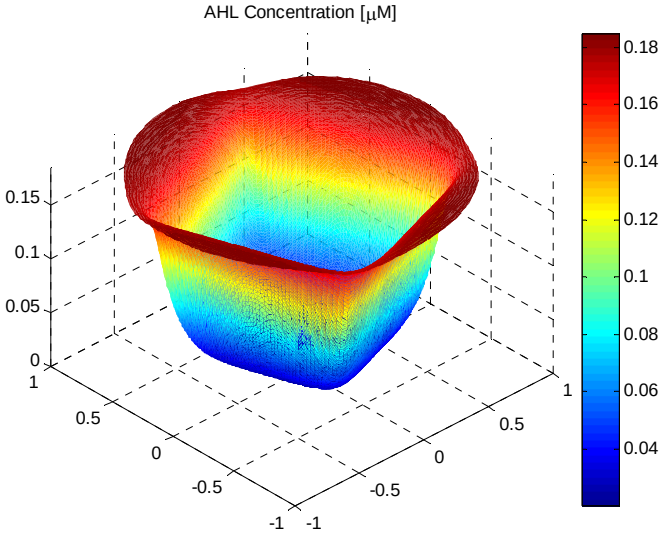
and assuming [CI] = [LacZ]

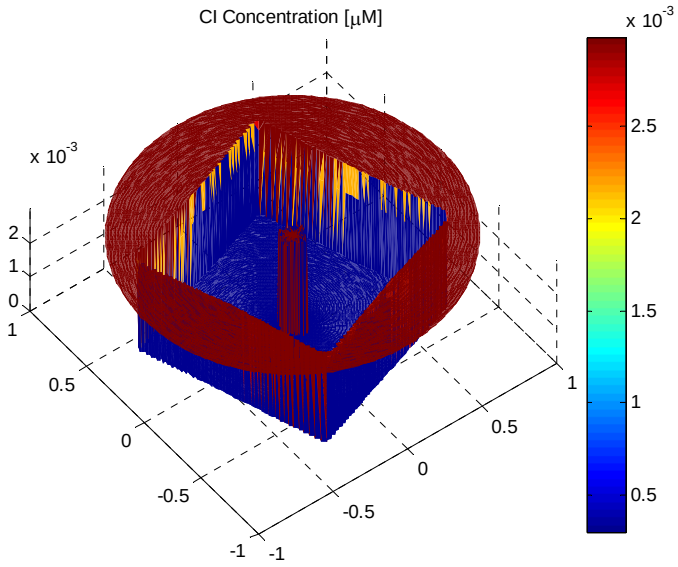


# Spatiotemporal simulation: square light mask

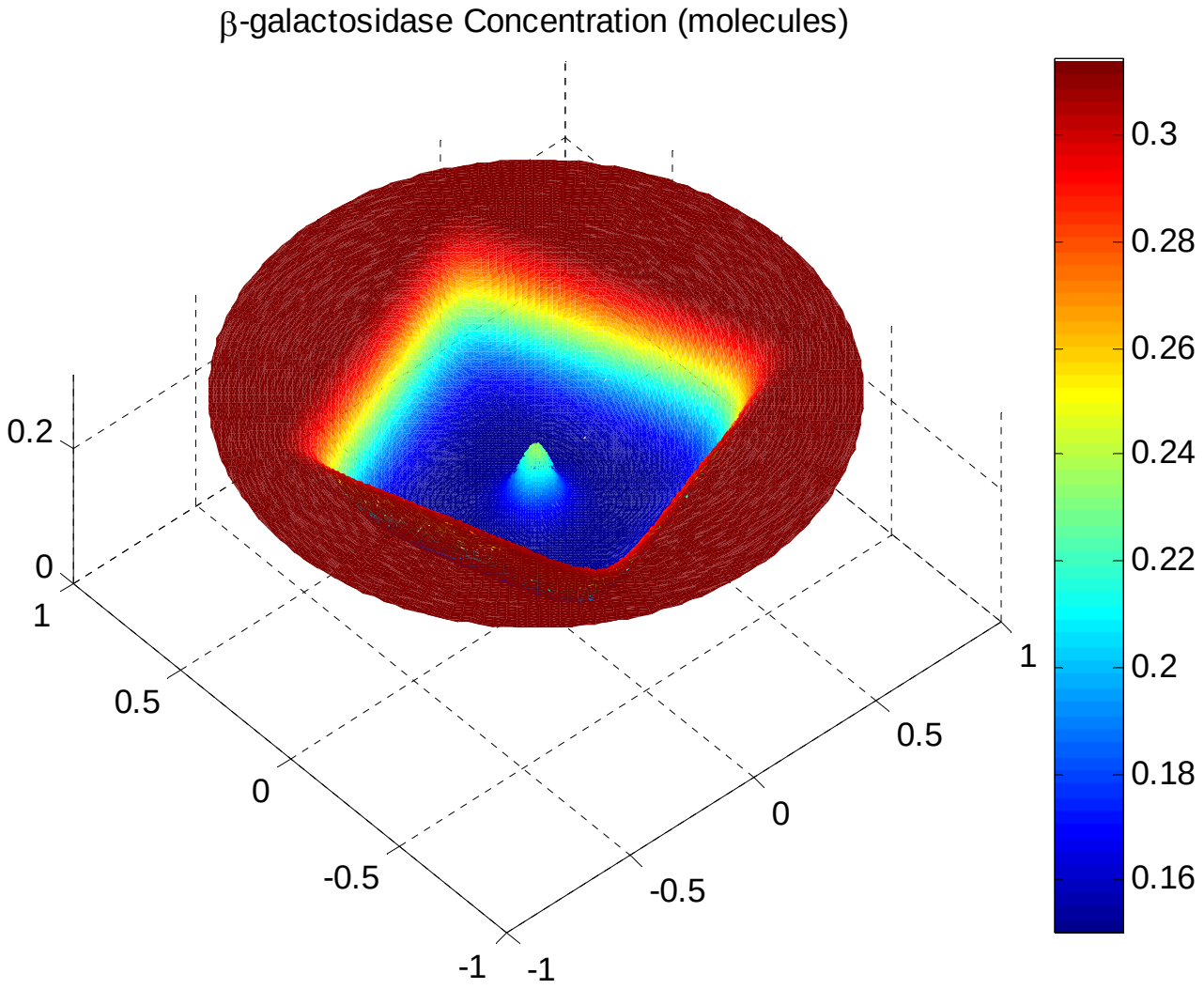


# Simulated edge detection




Key question: with a fixed pLux/CI, will the simulations produce good edges?