

# *Part III – Towards in silico Cells: Simulating processes in entire cells*

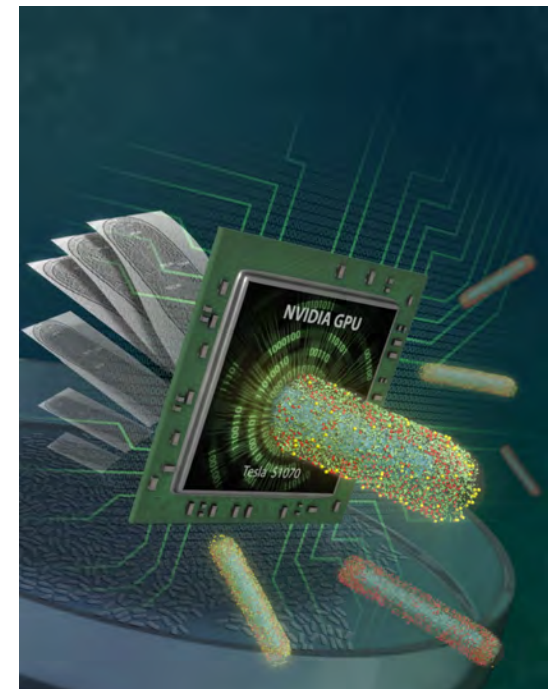
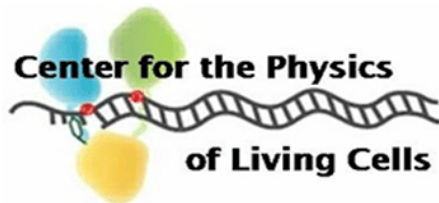
Zaida (Zan) Luthey-Schulten

Dept. Chemistry, Physics, Beckman Institute, Center for Biophysics, and

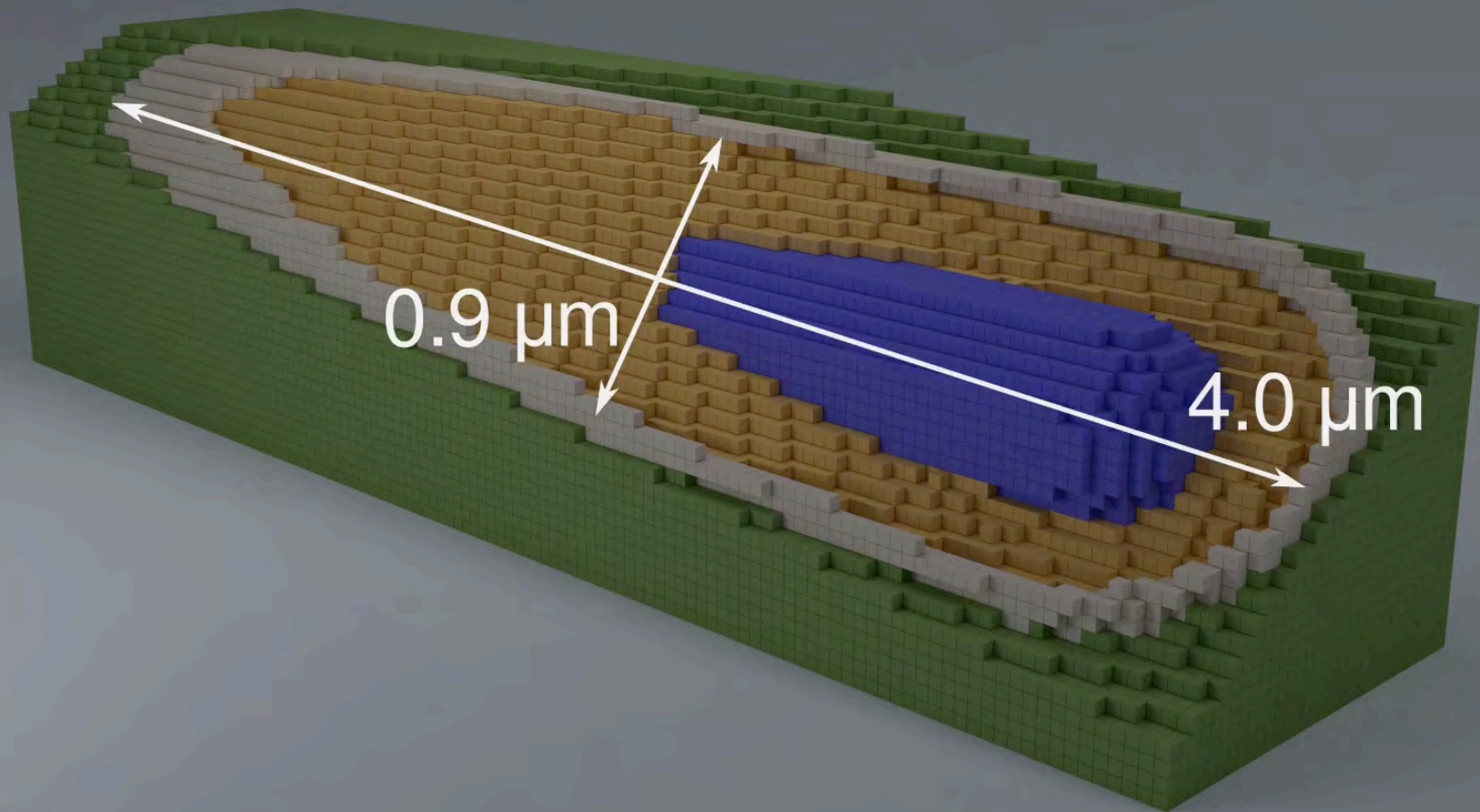
Carl Woese Institute of Genomic Biology, UIUC

NIH Computational Biophysics Workshop, Pittsburgh, June 6-8, 2016

with **Mike Hallock and Joe Peterson**



# Cell dimensions

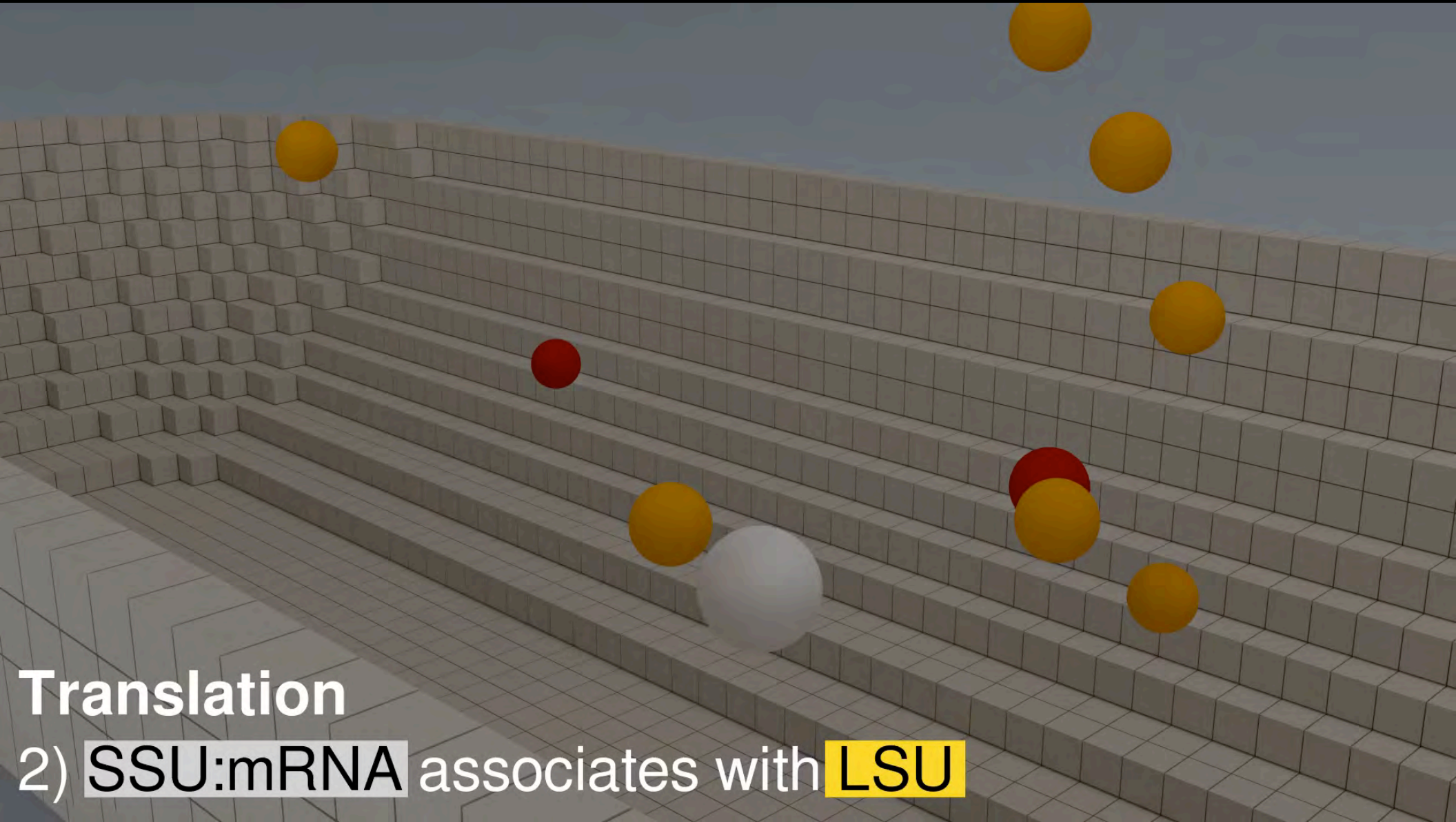




# Translation

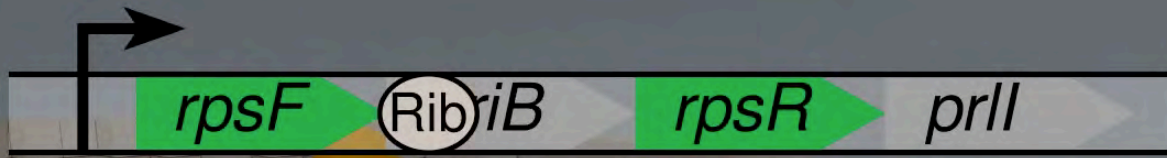
1) mRNA associates with SSU





## Translation

2) **SSU:mRNA** associates with **LSU**

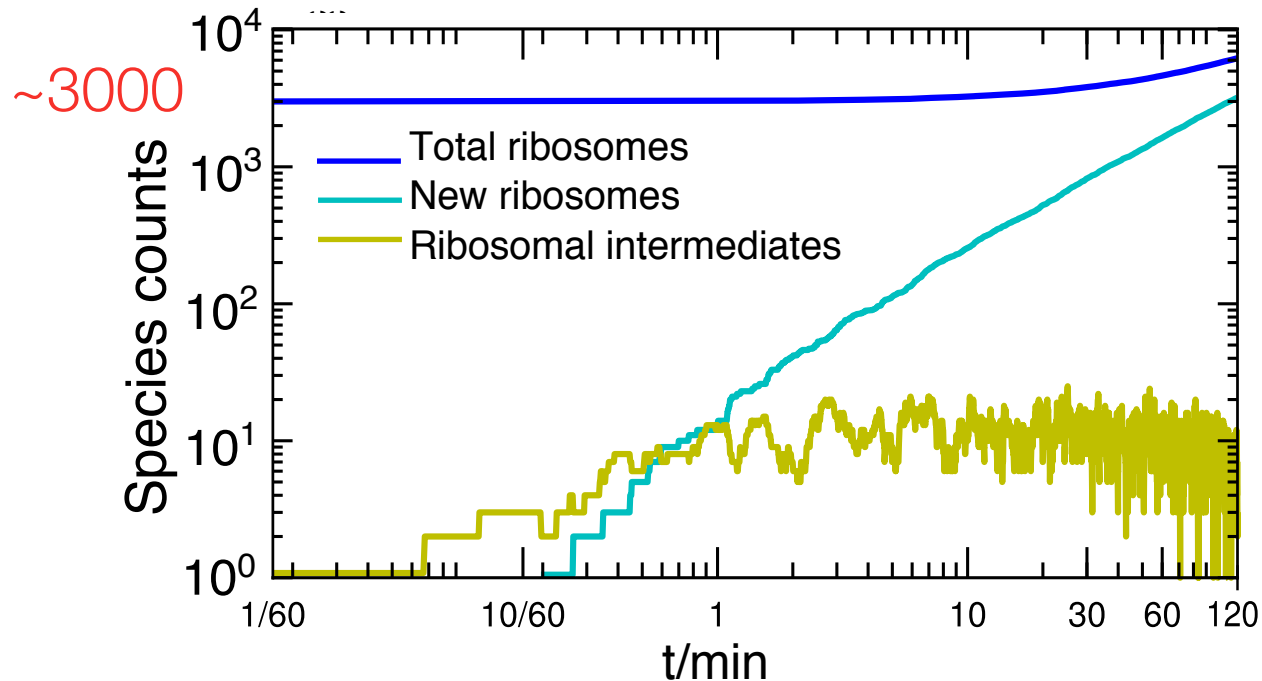
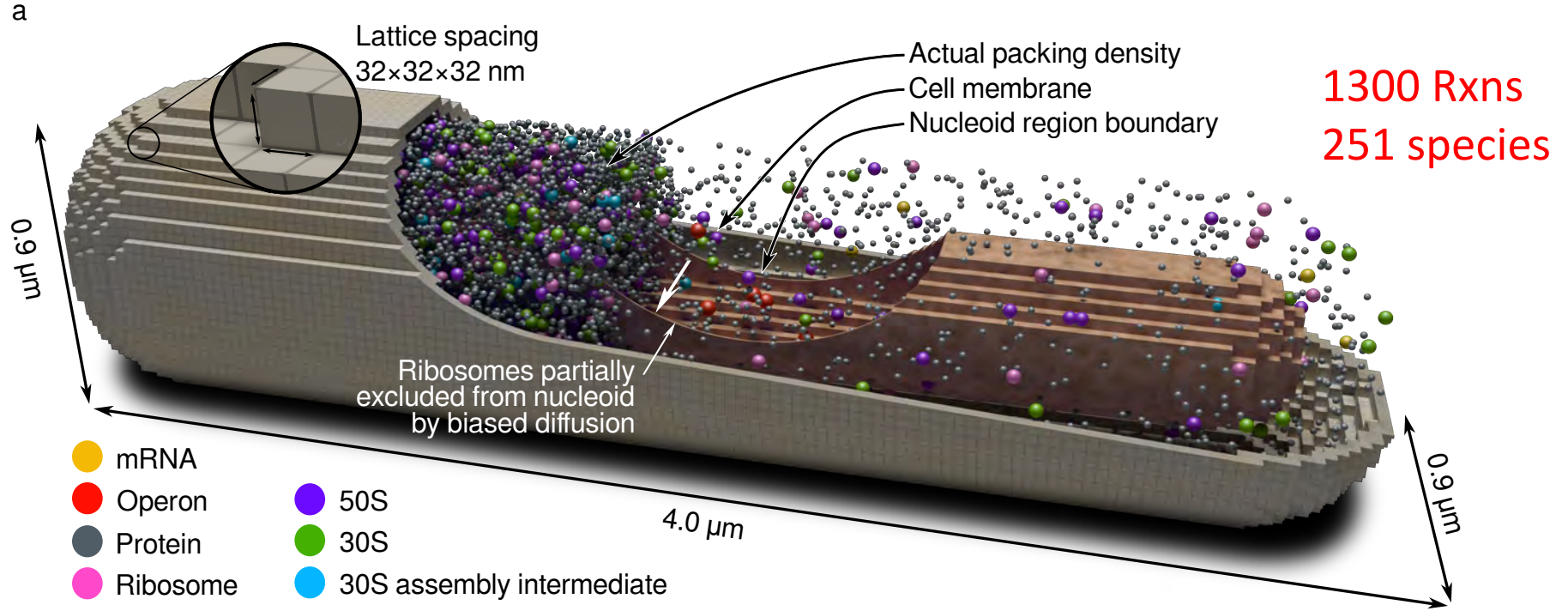


## Translation

3) Ribosome produces protein with rates derived from operon structure

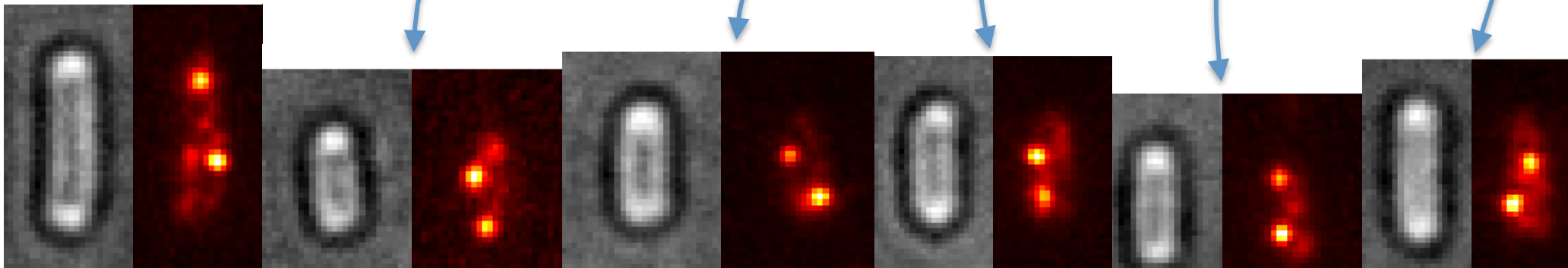
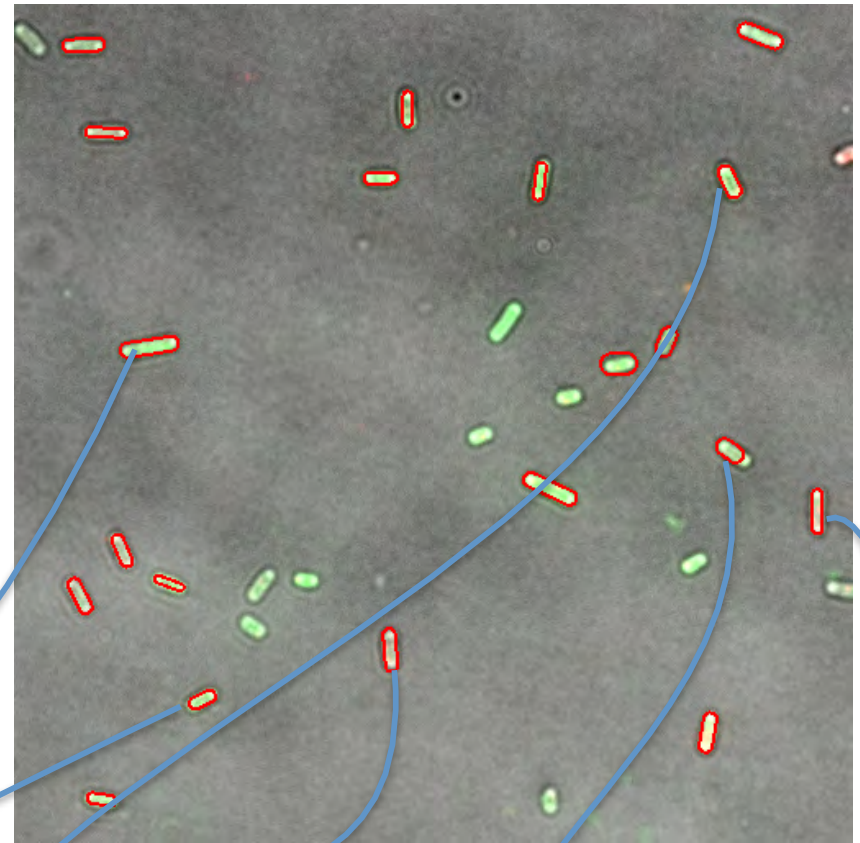
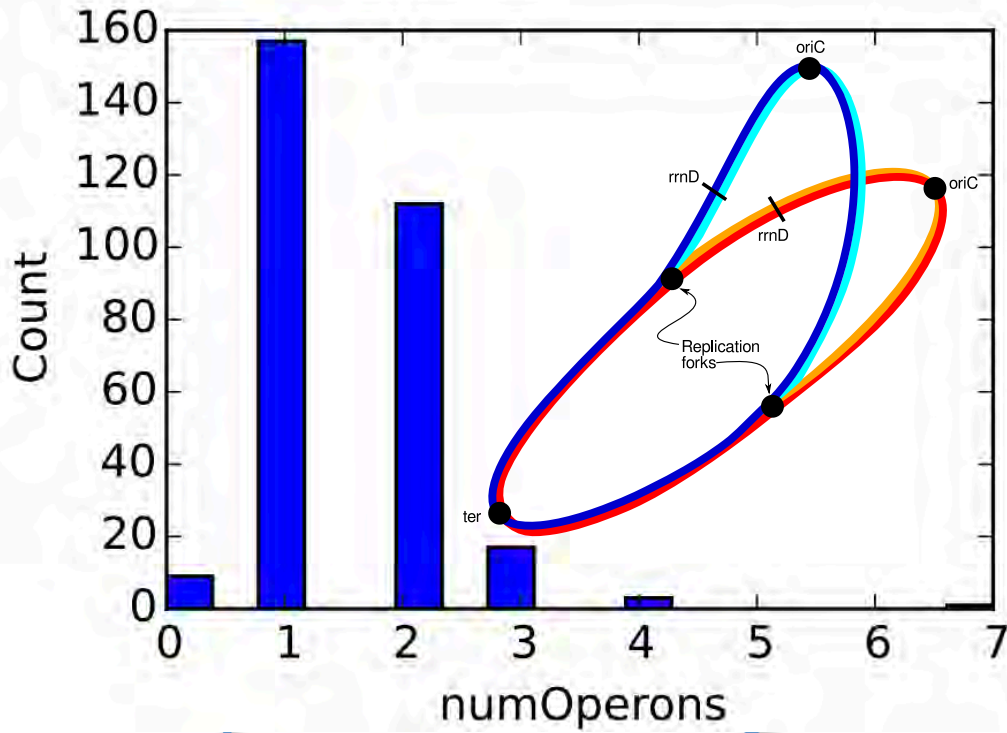


# In silico Ribosome Biogenesis

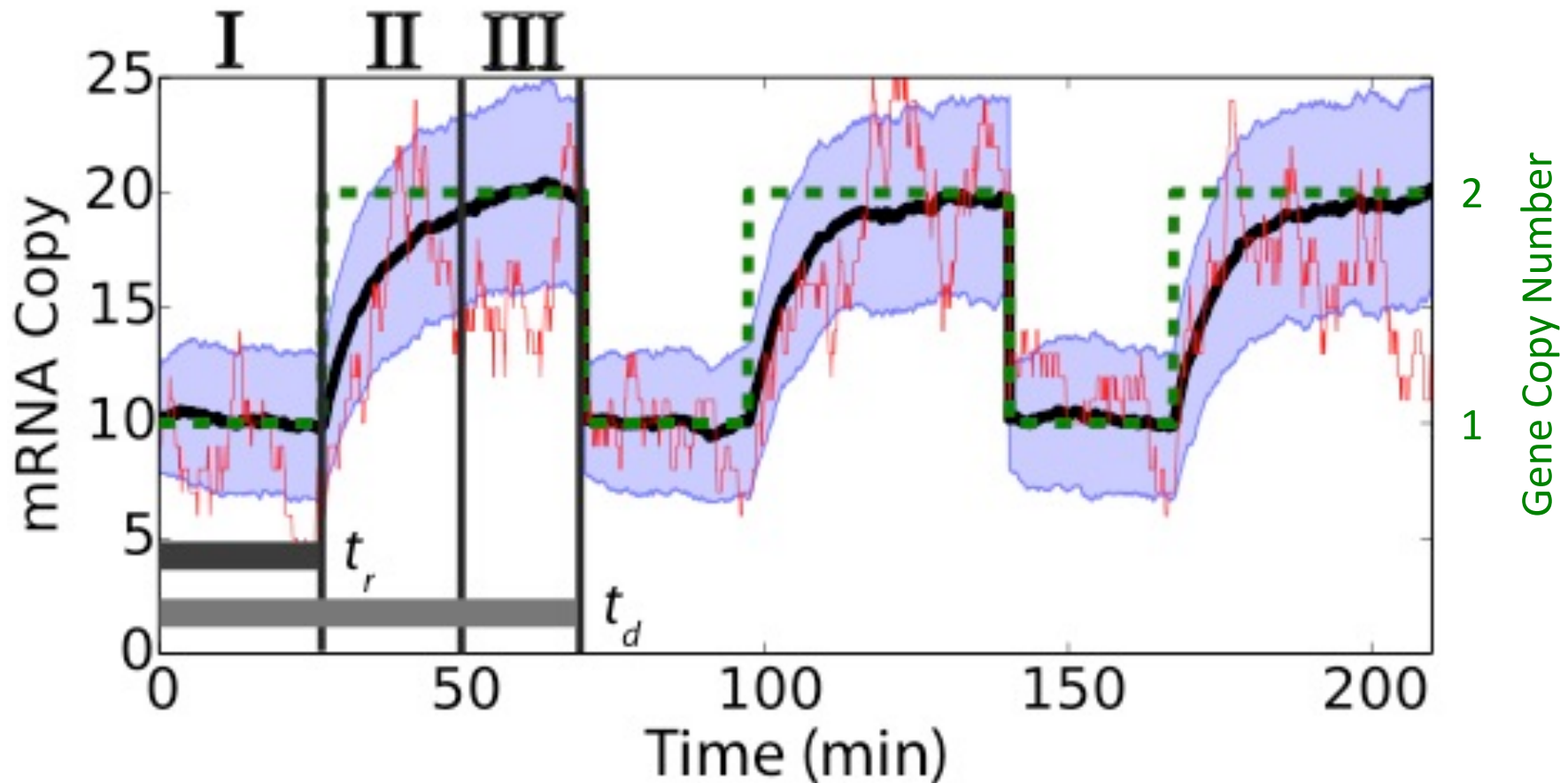
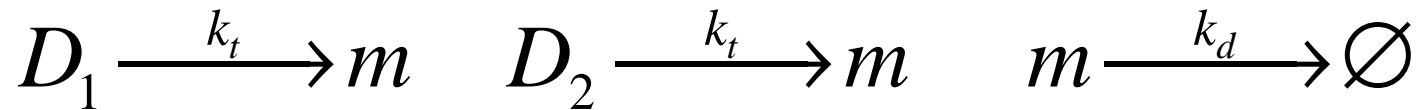


# Correcting for gene copies?

rrnD operon distributions



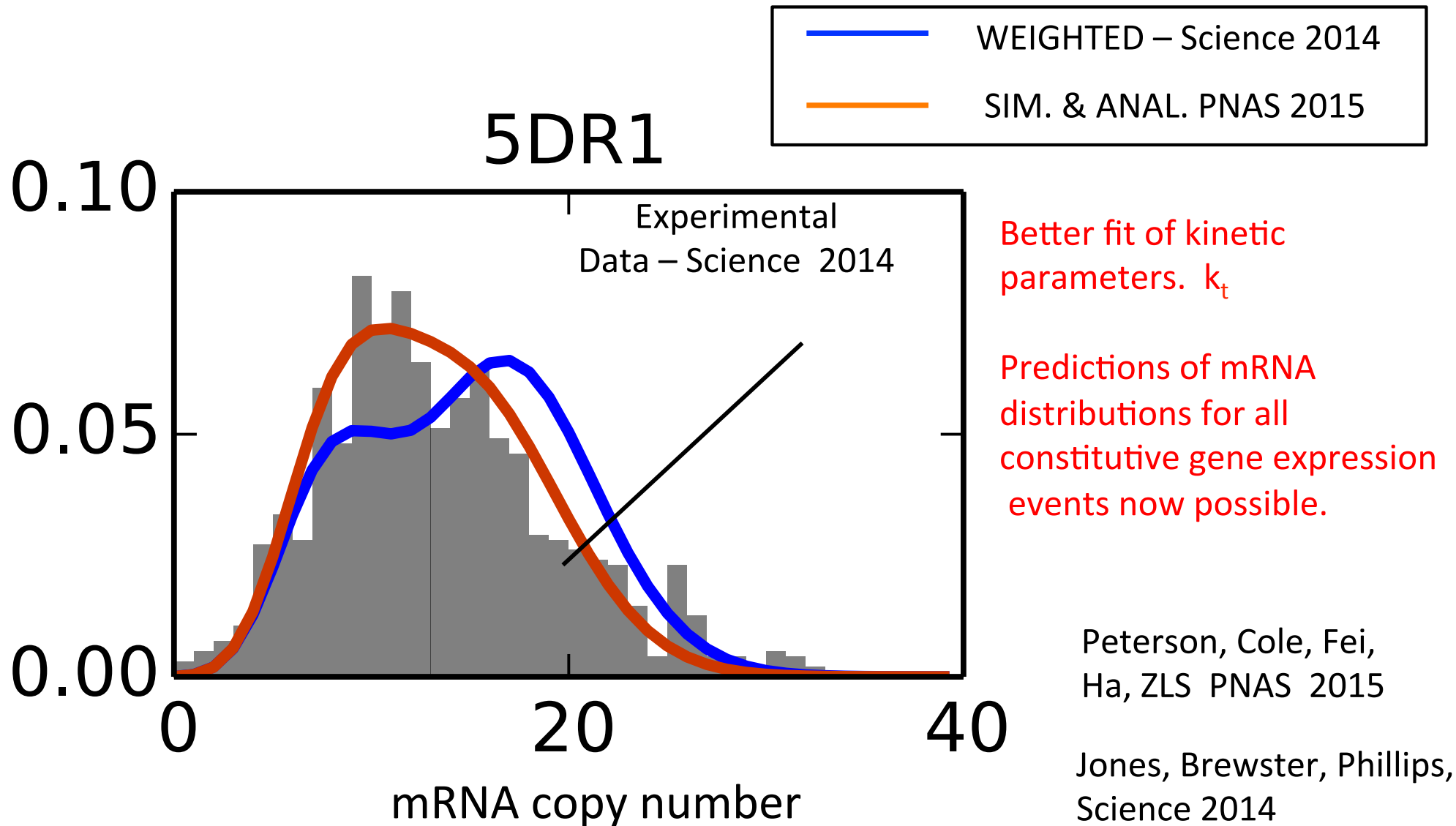
# Stochastic Simulations with 2 Gene Copies



— Single trajectory    — mean    ■ (+/-) 1  $\sigma$     - - - Gene copy number



# Explicit Replication Model Matches Experimental mRNA Distributions

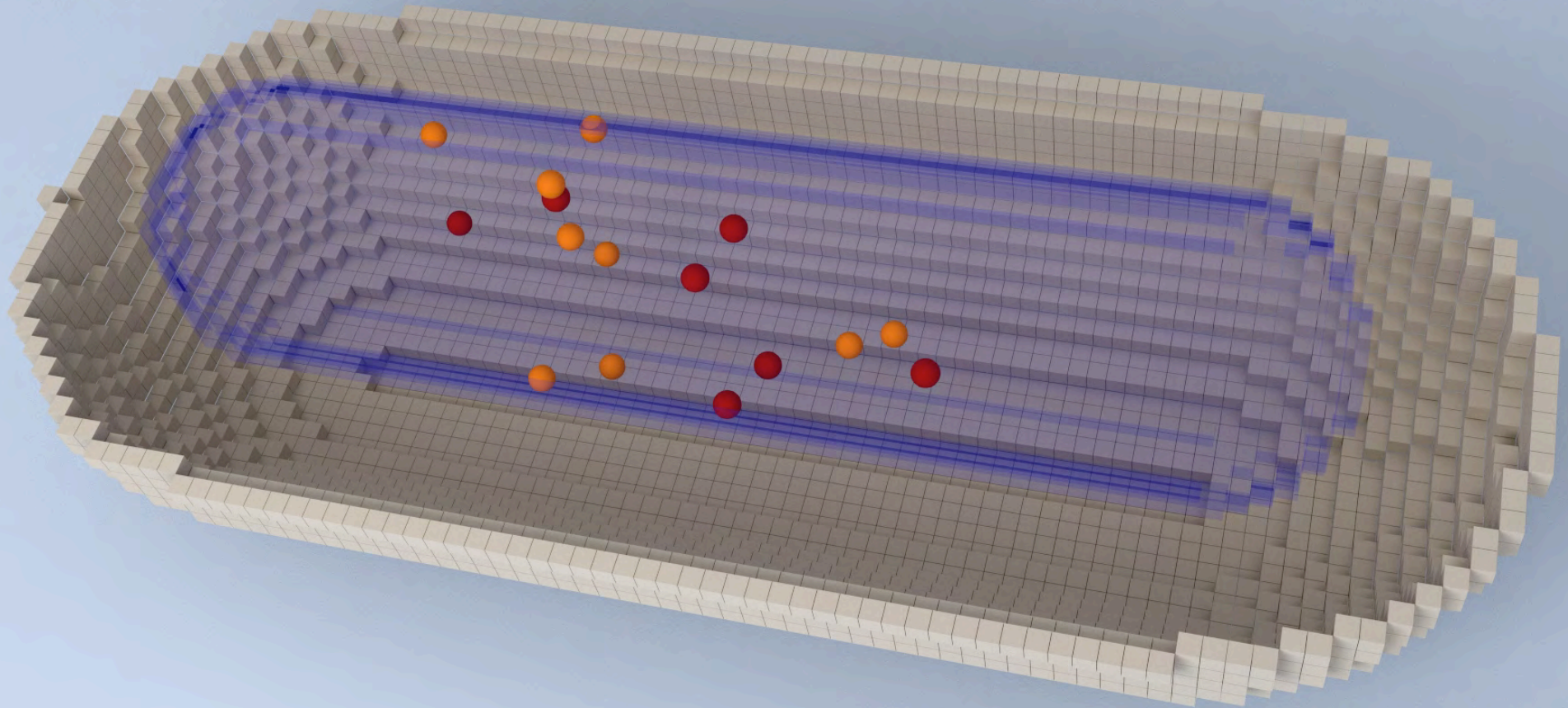




# Dividing Cell in Lattice Microbes - Slow Growing *E. coli*

*Correcting for DNA Replication*

- |                           |                  |                  |                  |
|---------------------------|------------------|------------------|------------------|
| ● New SSU                 | ● rRNA operon    | ● Intermediate 1 | ● Intermediate 4 |
| ● Translation initiation  | ● r-prot. operon | ● Intermediate 2 | ● Intermediate 5 |
| ● Translation termination | ● mRNA           | ● Intermediate 3 | ● Intermediate 6 |



00:00:00

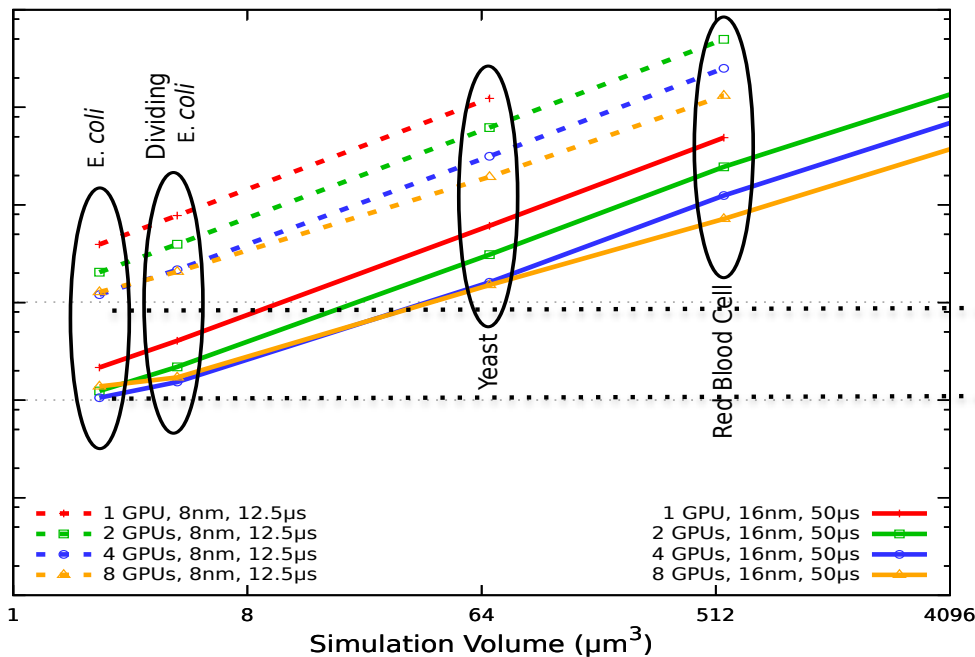


# Improving Multi-GPU Performance

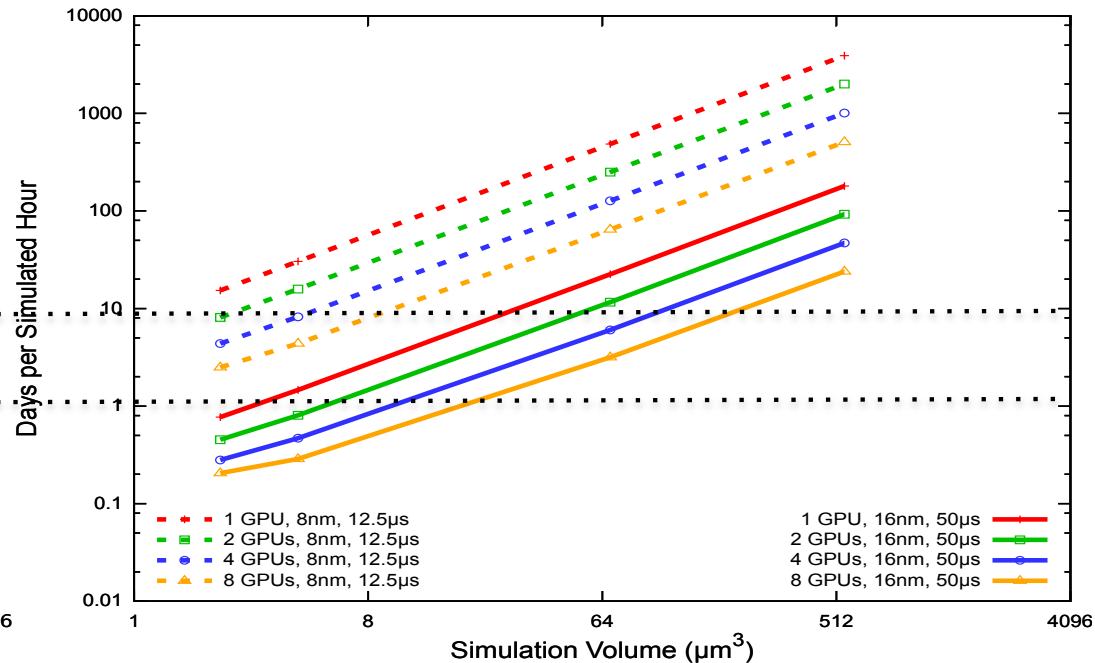
“Old” – January 2014 Hallock, et al. *Parallel Comp.*

New – Nov. 2014 *Supercomputing 2014*

Benchmark System Runtimes - NCSA Forge (Eight M2070s)



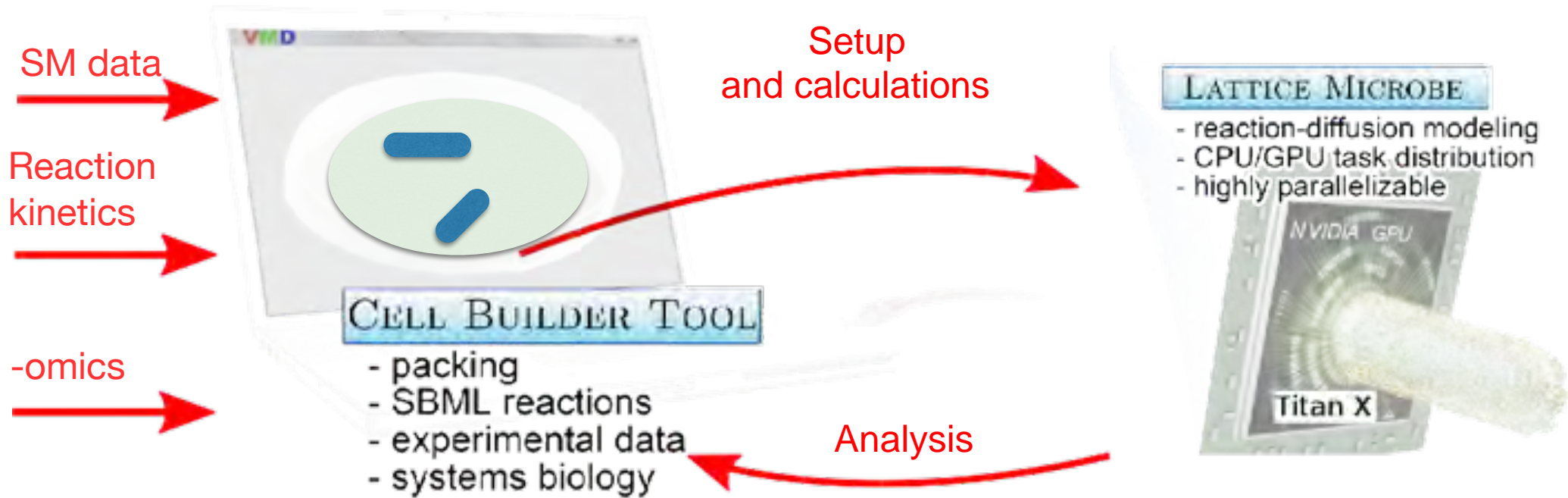
Benchmark System Runtimes - Cirrascale Eval (8x K40)



- Today -2 hr cell cycle of ~1000 rxns, 251 species in ribosome biogenesis in dividing cell requires 1 day using GTX980 / TitanX, Cuda 7.0 and LM 2.3a
- Program Lattice Microbes and PyLM with tutorials available at <http://www.scs.illinois.edu/schulten/lm/>



# Facilities for GPU Parallel Computing



Tutorial - Amazon Cloud

single nodes



NSF/CPLC



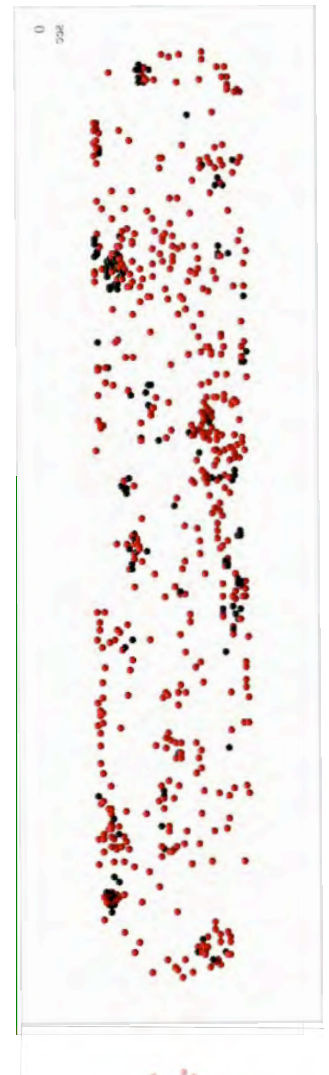
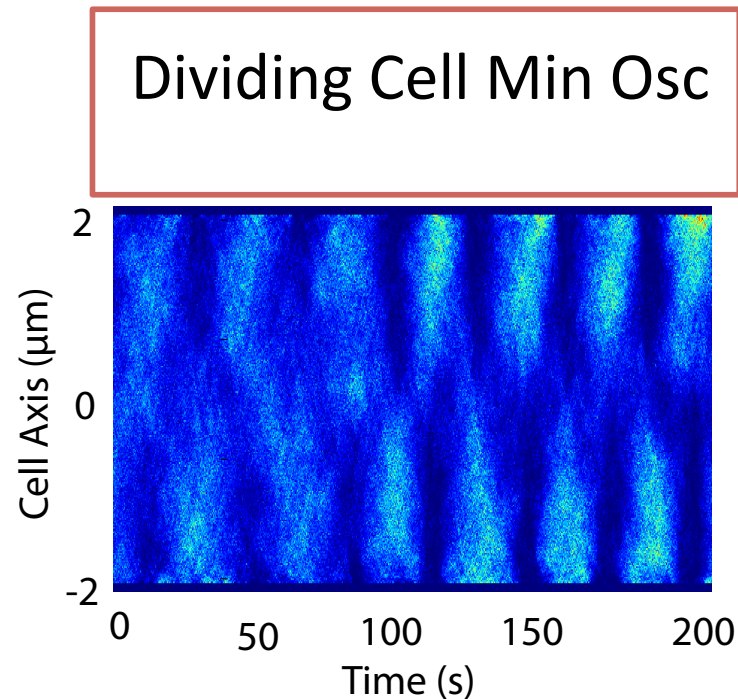
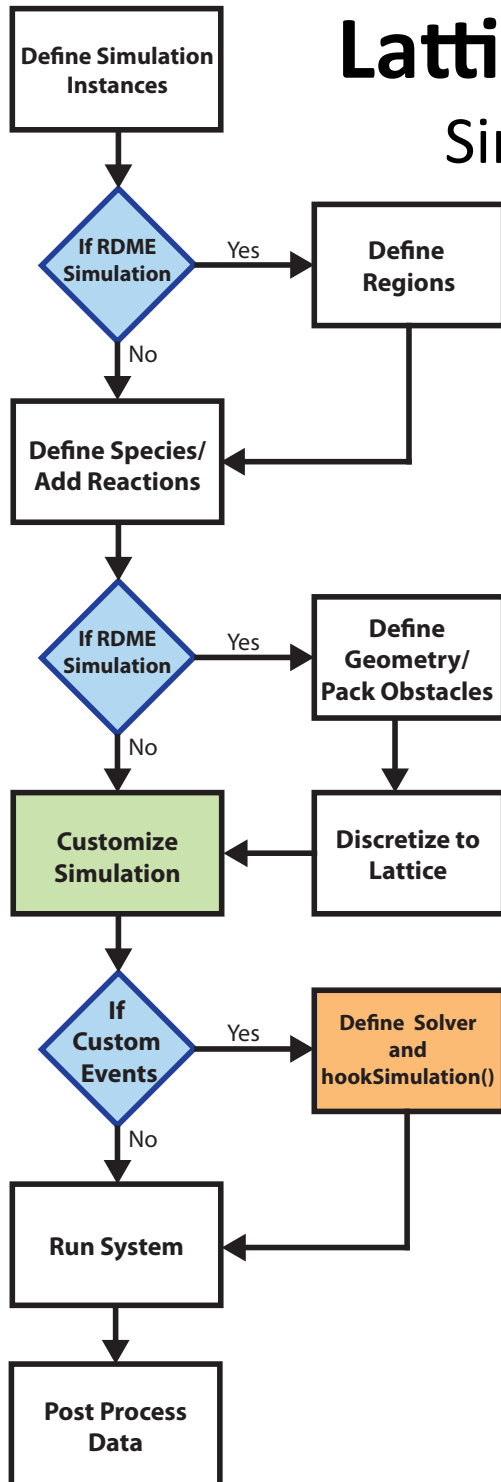
NSF/UIUC



# Lattice Microbe Tutorials on the Cloud

Simple Rxns, Lac Genetic Switch, Min Osc

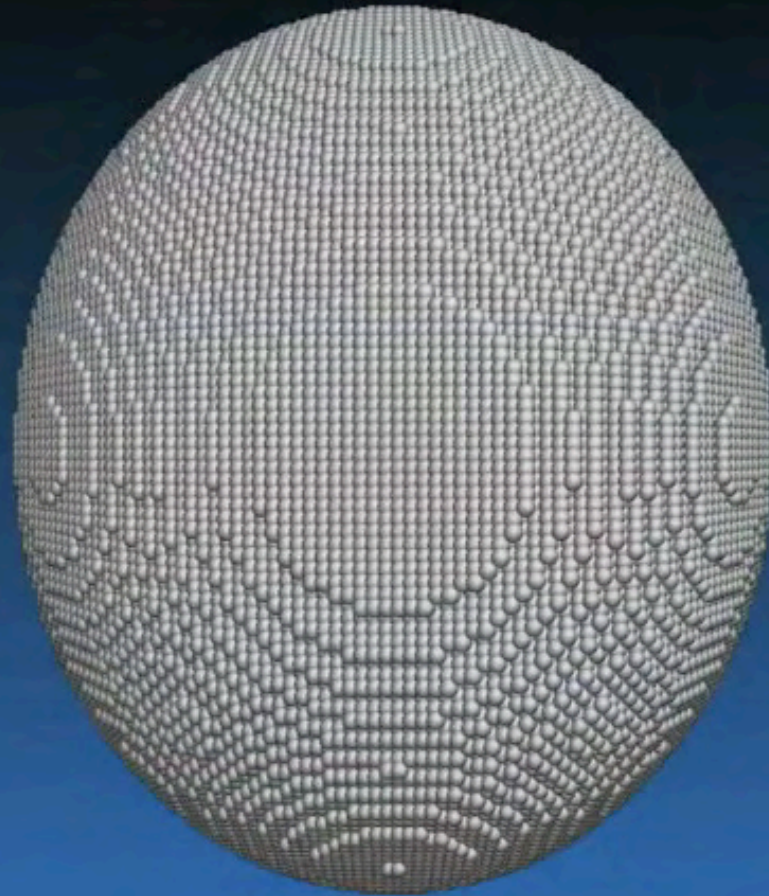
Mike Hallock and Joe Peterson





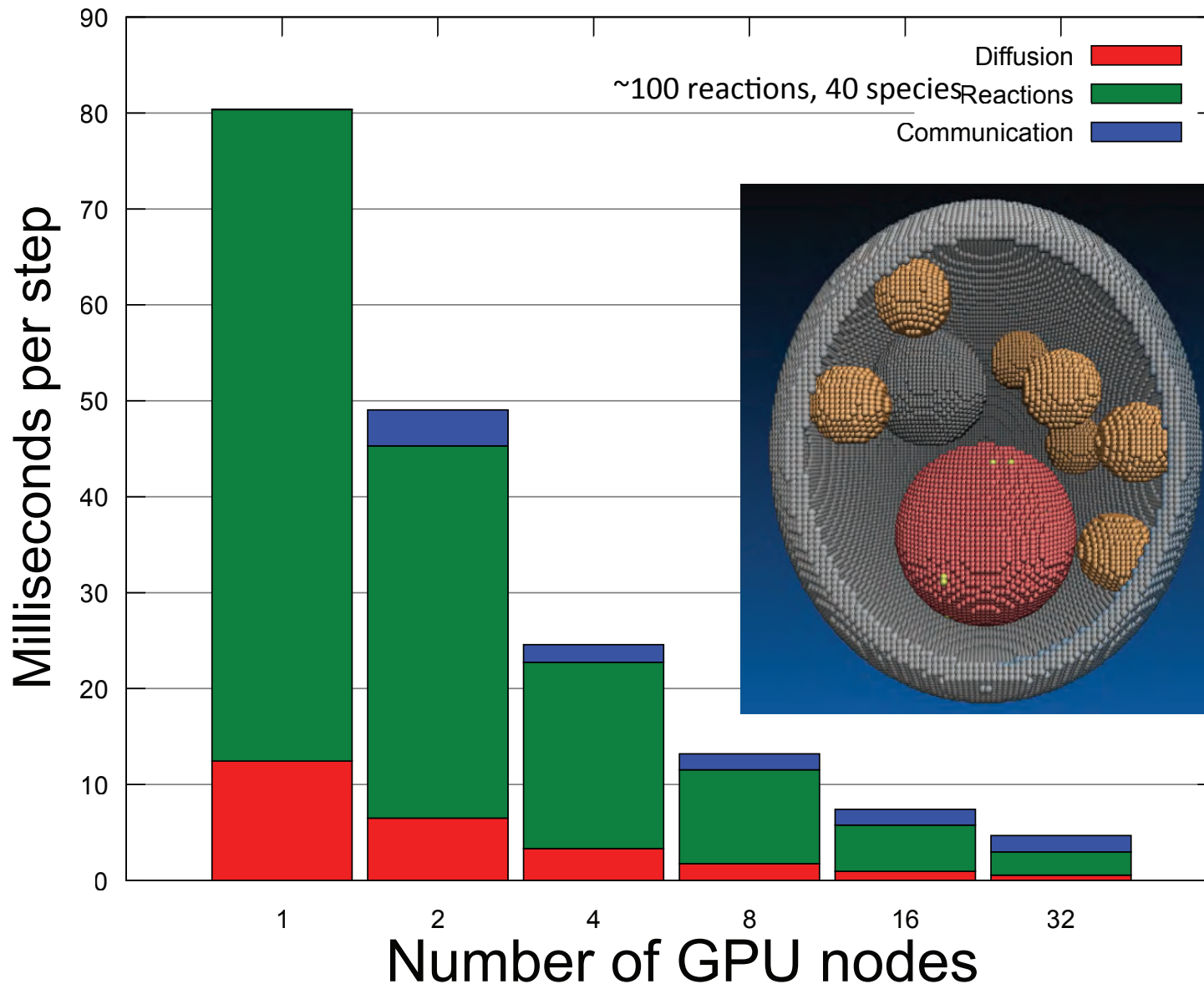
# Modeling Yeast in Lattice Microbes

*PyLM Shapes Demonstration by Joe Peterson*



# Challenges in Modeling Eukaryotic Cells

## Full MPI version – Lattice Microbes



Preliminary  
Results on  
Galactose Switch