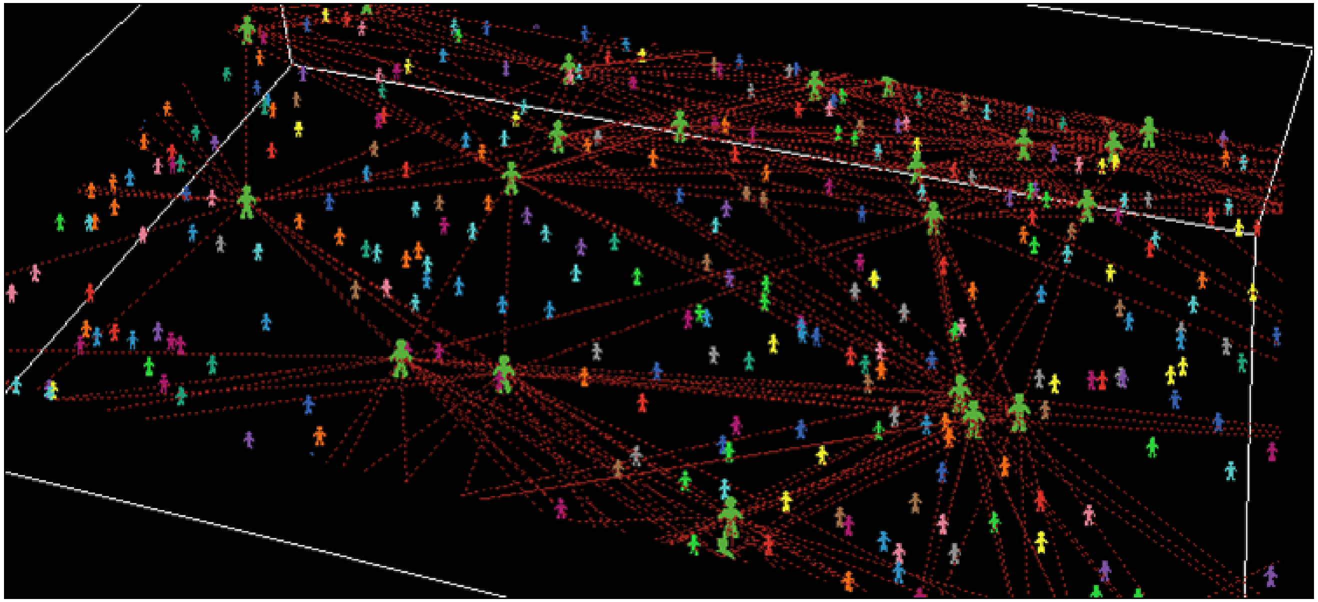
Agent-Based Models



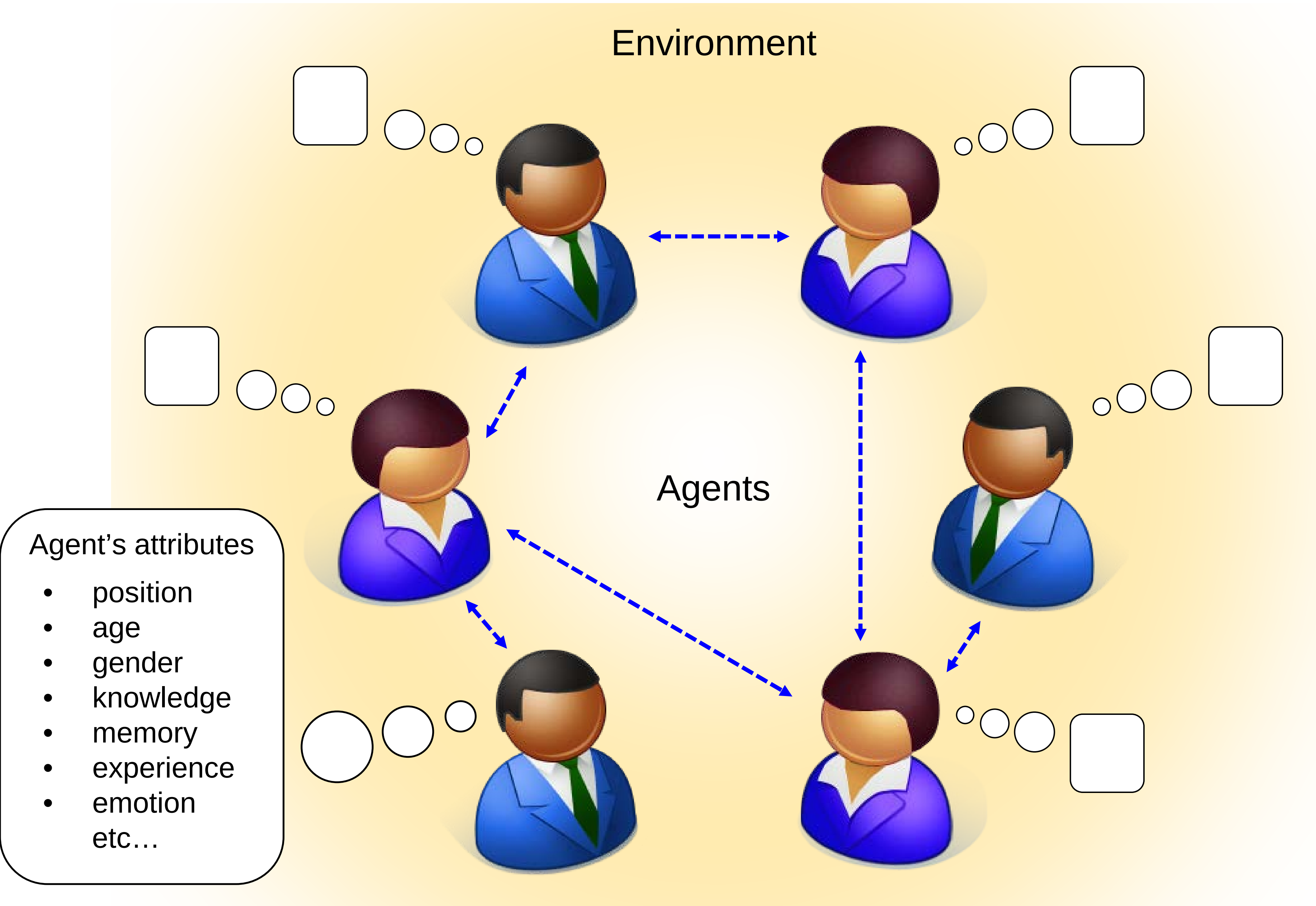
Dr. Dylan McNamara
people.uncw.edu/mcnamarad

Agent-based modeling

- One of the most generalized frameworks for modeling/simulation of complex systems
- You construct many virtual individuals, or "agents", and simulate their behaviors explicitly in a computer

Agents

- Discrete entities
- Have internal properties
- Spatially localized
- Perceive and interact with the environment
- Locally interact with other agents and behave based on predefined rules
- No central supervisor
- May learn autonomously
- May produce non-trivial "collective behavior" as a whole


Environment
Agents
Agent's attributes
• position
• age
• gender
• knowledge
• memory
• experience
• emotion
etc…

Various uses of ABMs in science

- To predict macro-unknowns by simulation using micro-knowns

- To explain macro-knowns by simulation using hypothetical micro-unknowns

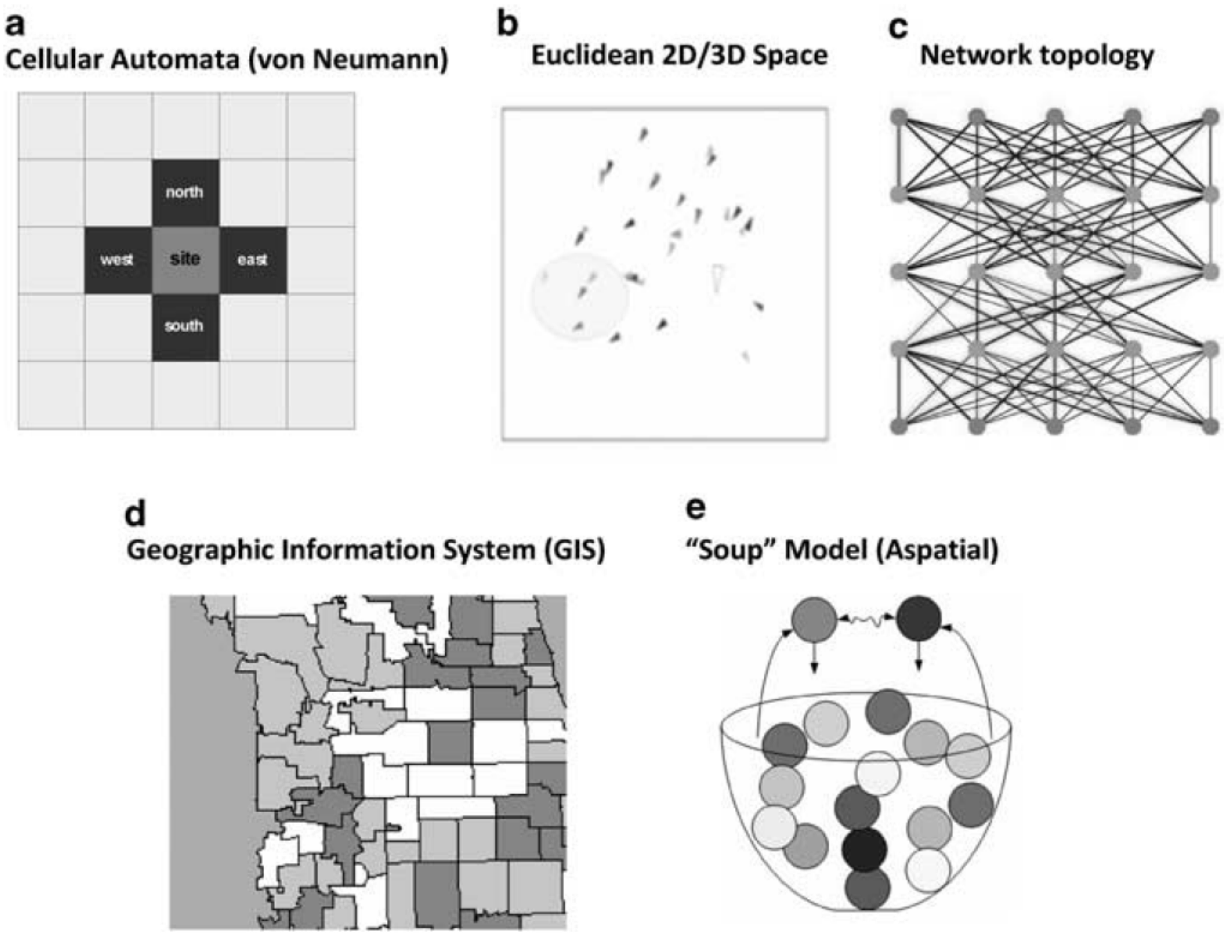
  – Or, to freely explore various collective dynamics models just for fun or learning

Aspects to be considered

1. Specific problem to be solved by the ABM
2. Design of agents and their attributes
3. Design of an environment and the way agents interact with it
4. Design of agents' behaviors
5. Design of agents' mutual interactions
6. Availability of data
7. Method of model validation

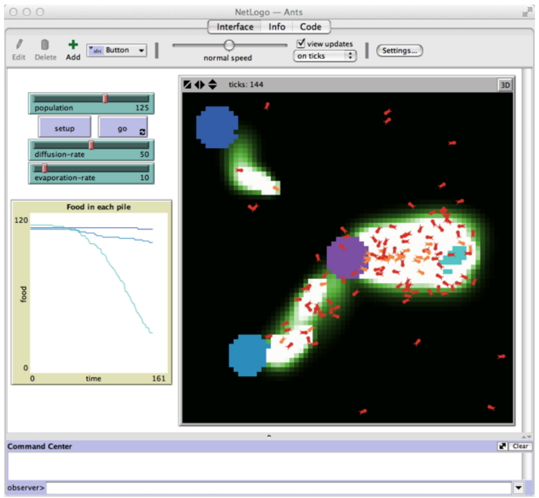
(from Macal & North 2010)

Topologies of agent relationships

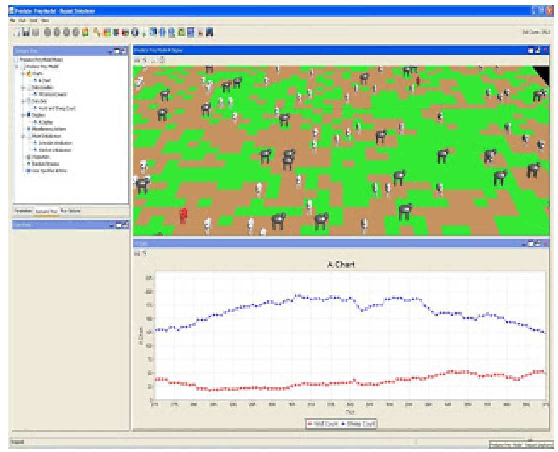


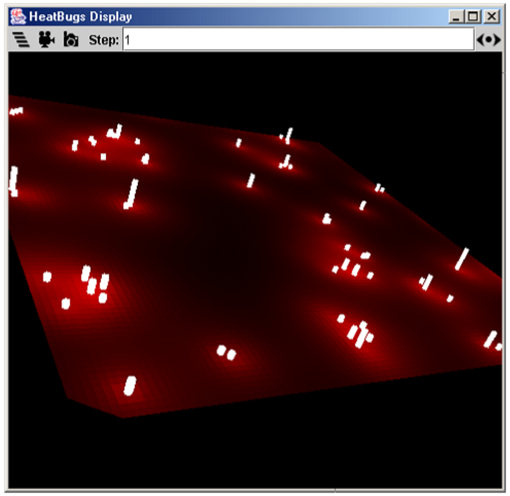
(from Macal & North 2010)

Tools for agent-based modeling

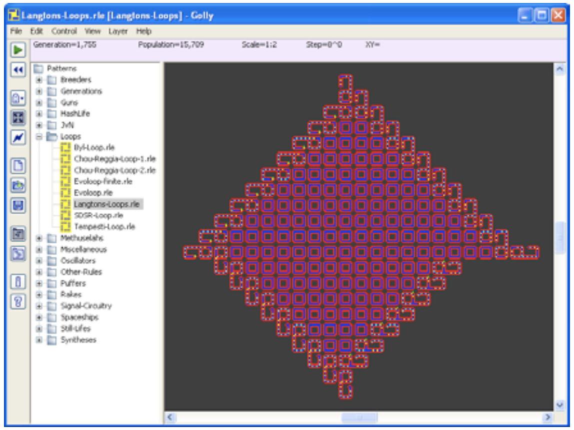


NetLogo

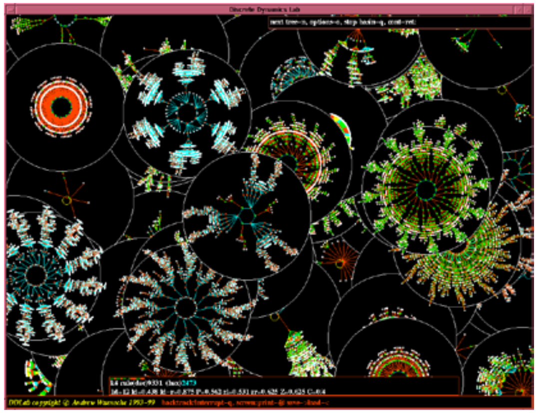

RePast



MASON



Golly


DDLab

Example System - Stock Market

Market Crashes

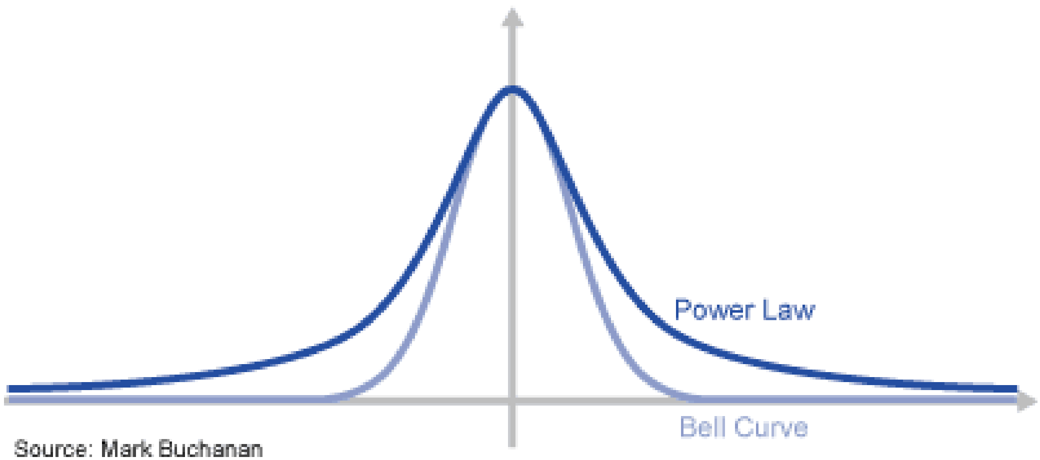
1. Tulip Mania - 1637
2. South Sea Bubble - 1720
3. Great Depression - 1929
4. Black Monday - 1987

Market Crashes

- Normal (Gaussian) Distributions
- Power Laws

Exhibit 1:

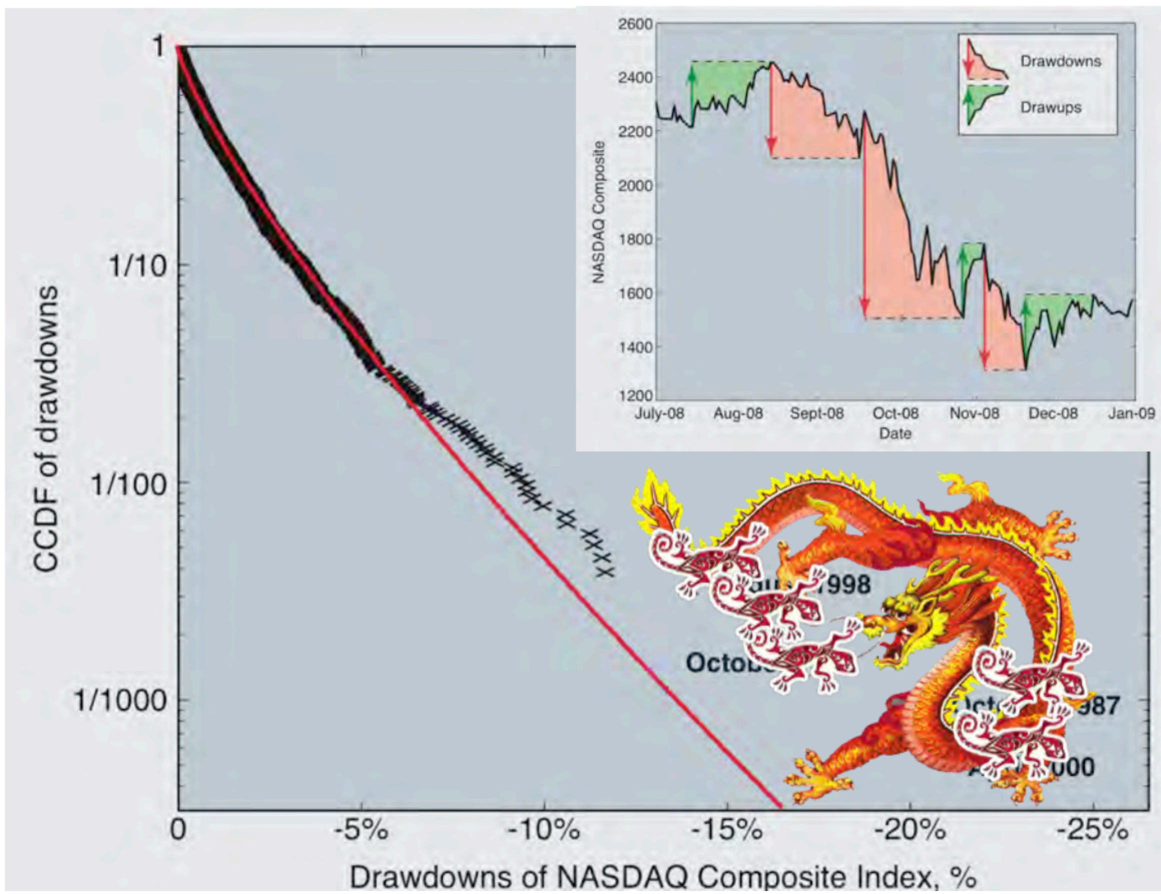
The Bell Curve vs. the Power Law: The Importance of "Fat Tails"



Source: Mark Buchanan

Market Crashes

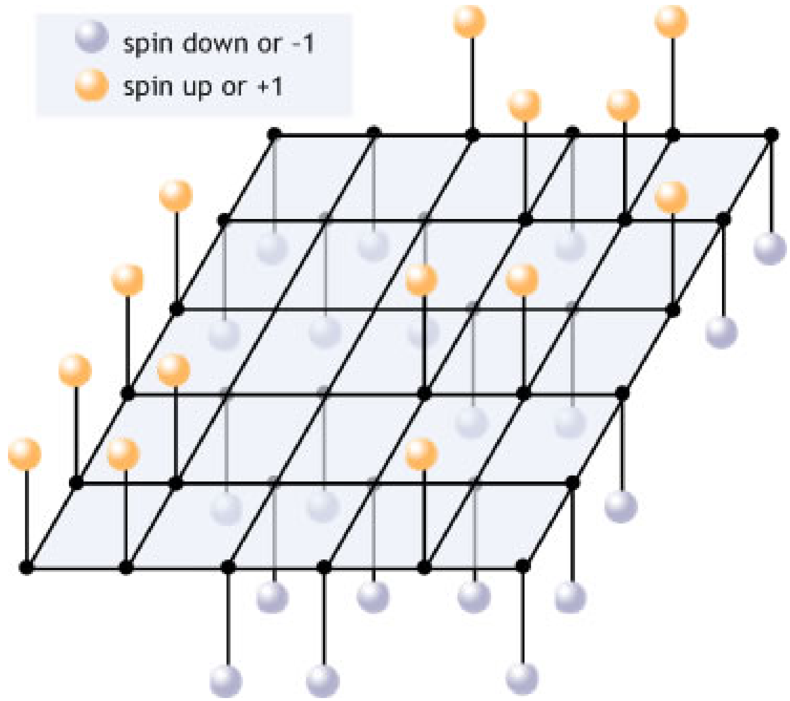
- Scale free - implies big and small same



Black Monday chances -> 1 in 10^{-23} or every 3,000,000,000,000,000,000,000 years

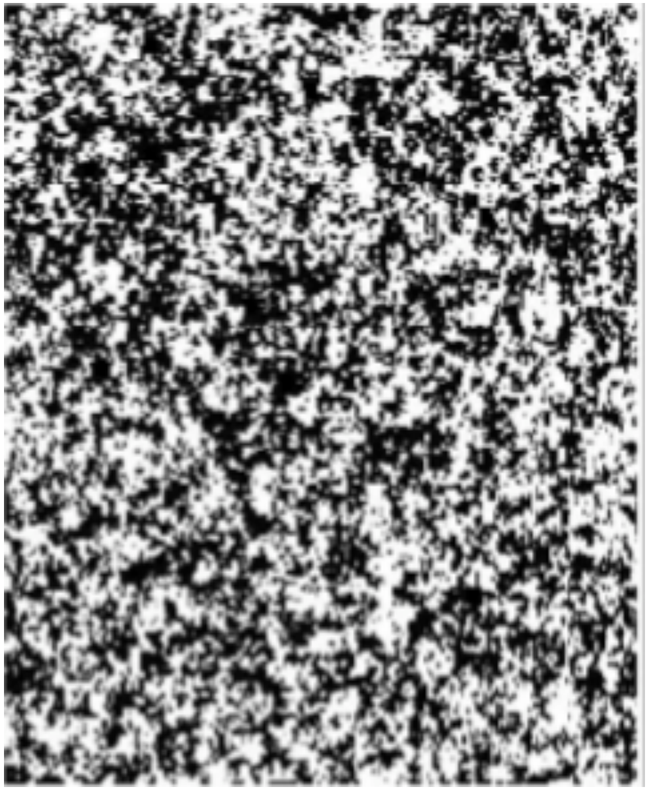
Market Crashes

- Didier Sornette - Dragon Kings
  - crashes have own dynamics
  - "herding" key piece
  - made simple spin model with herding



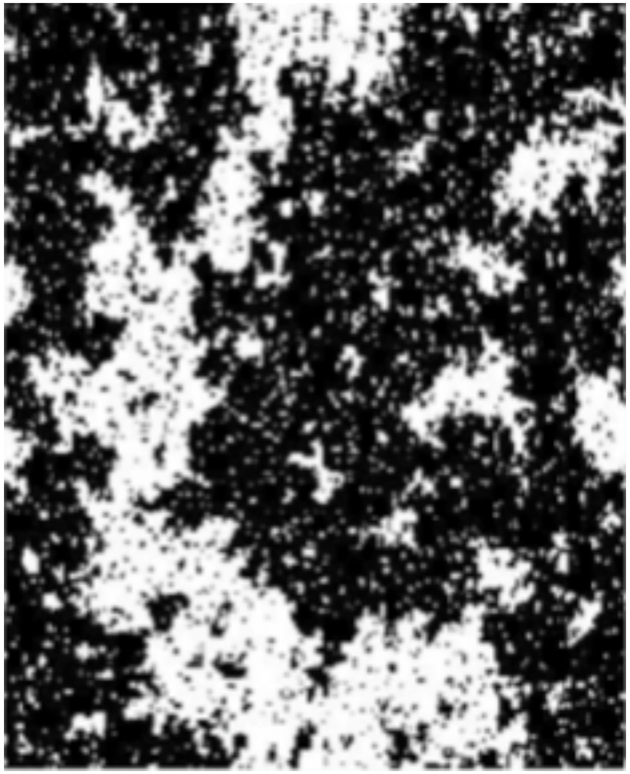
Market Crashes

- Didier Sornette Model - small K



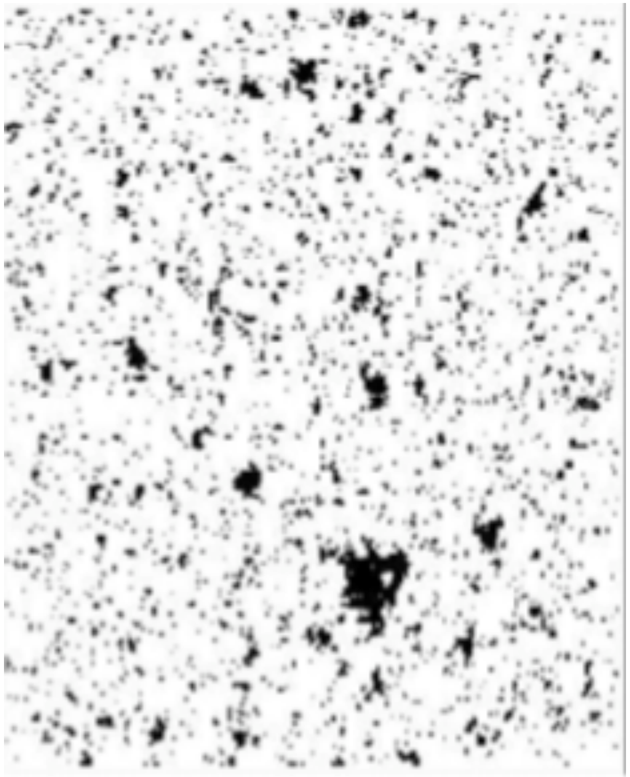
Market Crashes

- Didier Sornette Model - approach critical Kc



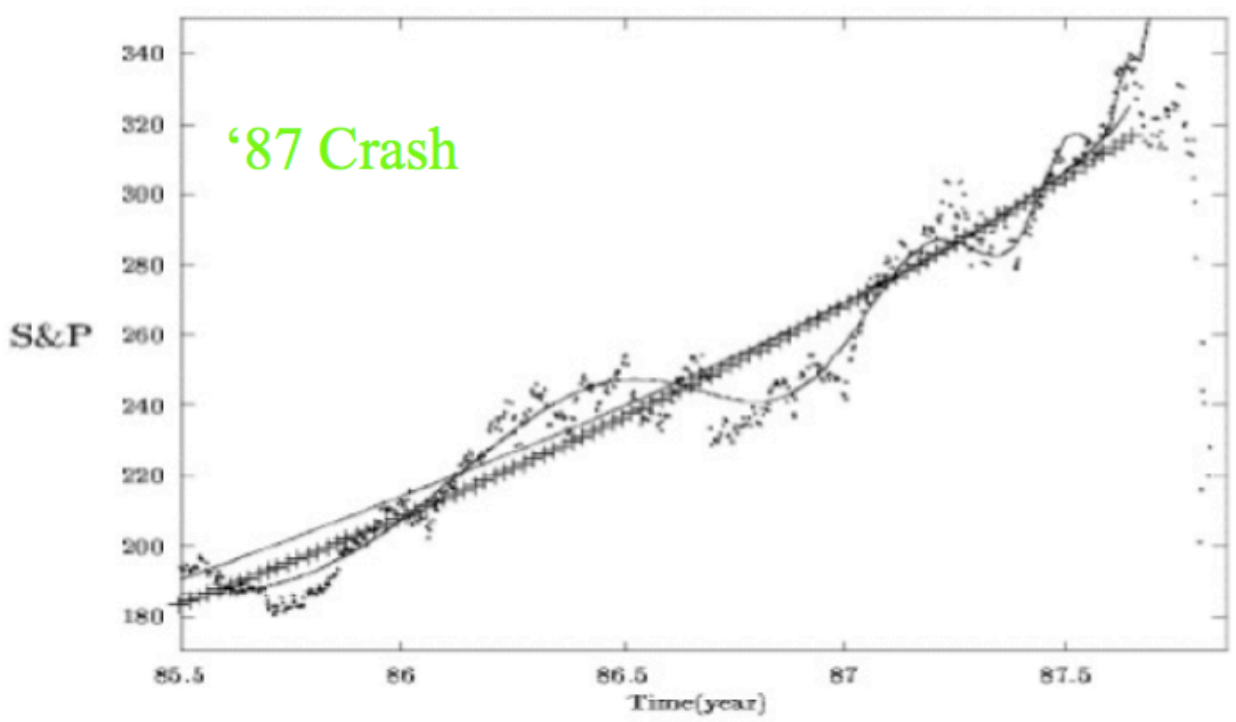
Market Crashes

- Didier Sornette Model - big K



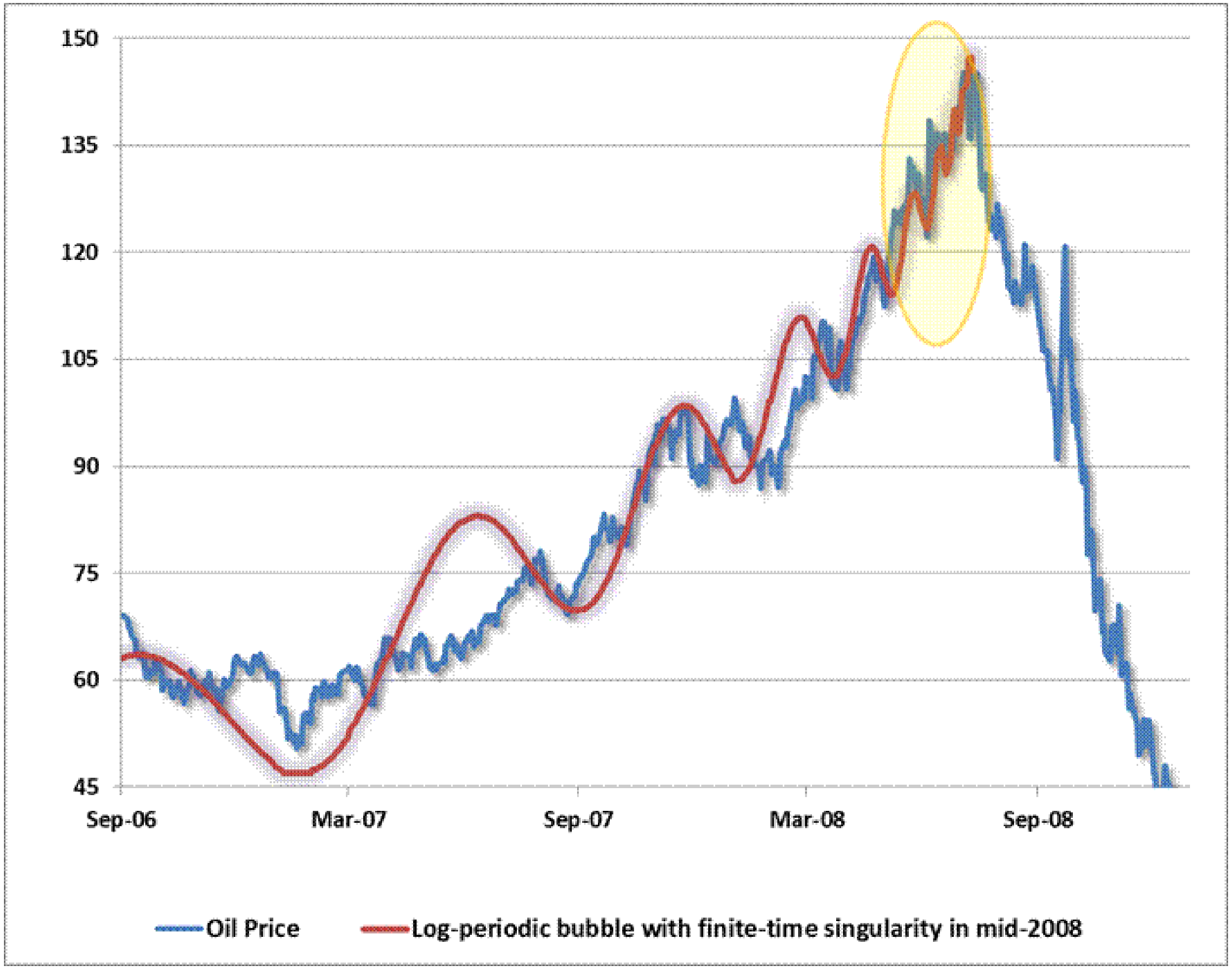
Market Crashes

- Didier Sornette Model - prediction



Market Crashes

- Didier Sornette Model - prediction



Market Crashes

- Didier Sornette TED talk

SANTA FE
INSTITUTE

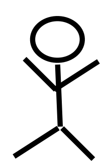
Modleing Induction

- How do people form expectations?
- Brian Arthur Santa Fe Bar Model

Modleing Induction

- **Brian Arthur Santa Fe Bar Model**

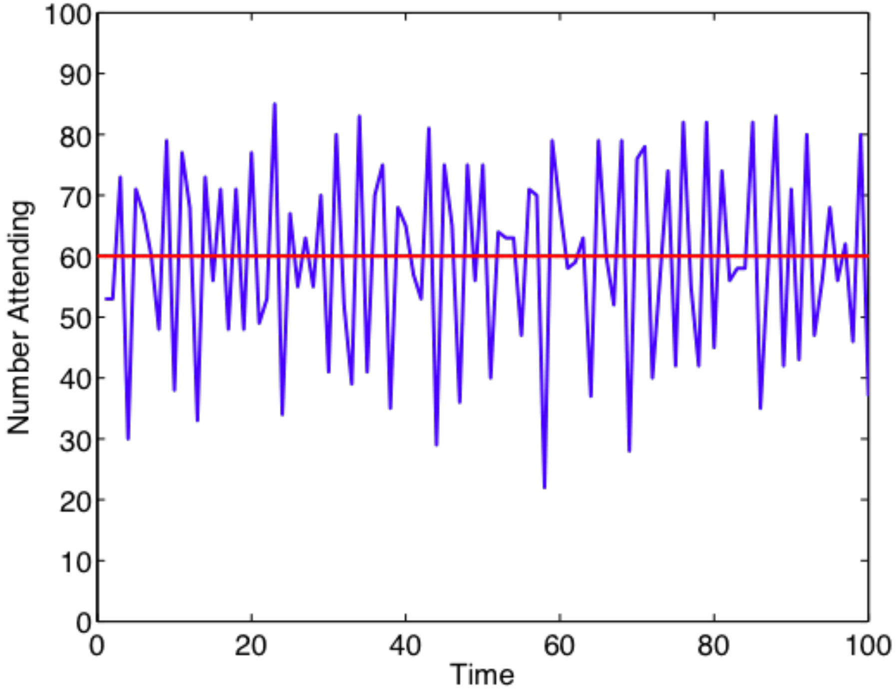
n(t) = a(i,j)*n(t-1)
n(t) = n(t-1)
n(t) = 100-n(t-1)
n(t) = mean([n(t-1) n(t-2) n(t-3) n(t-4)])
n(t) = max(0,min(100,n(t-2)+2*(n(t-1)-n(t-2))))
n(t) = n(t-2)
n(t) = n(t-5)



Use best model based on performance over some period of time.

Modleing Induction

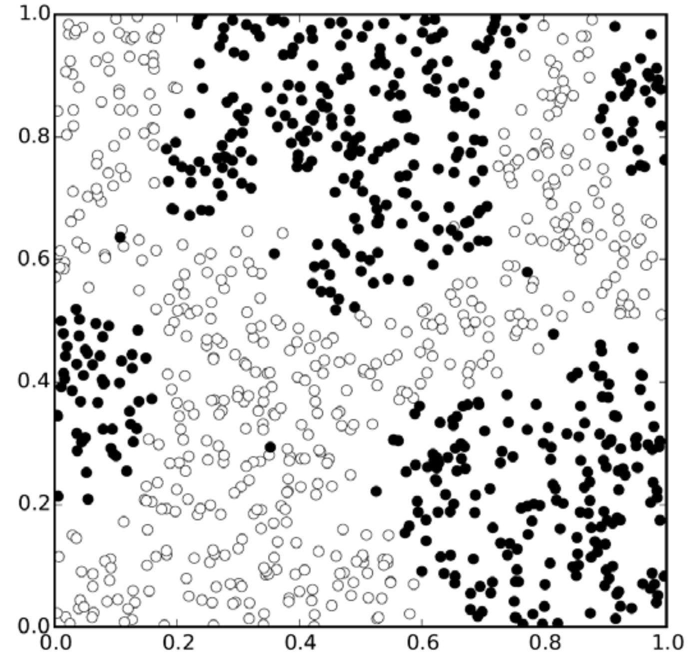
- Brian Arthur Santa Fe Bar Model



Classic Models with Fixed Number of Agents

Schelling's segregation model

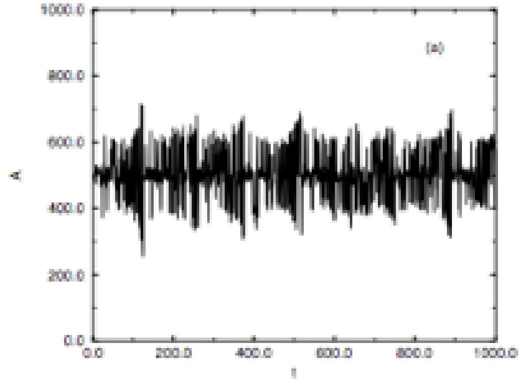
- "The first ABM" proposed by Thomas Schelling in the 70's



- Two types of agents
- Agents jump to another random location if it is surrounded by many other agents of the different type

Minority Model

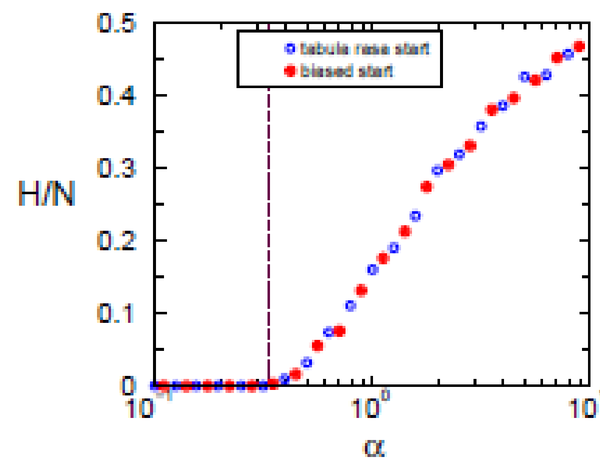
- Traffic, finance, resources
  Odd number agents, choose 0,1, winners in minority room
- Agents have memory



signal	prediction
000	1
001	0
010	0
011	1
100	1
101	0
110	1
111	0

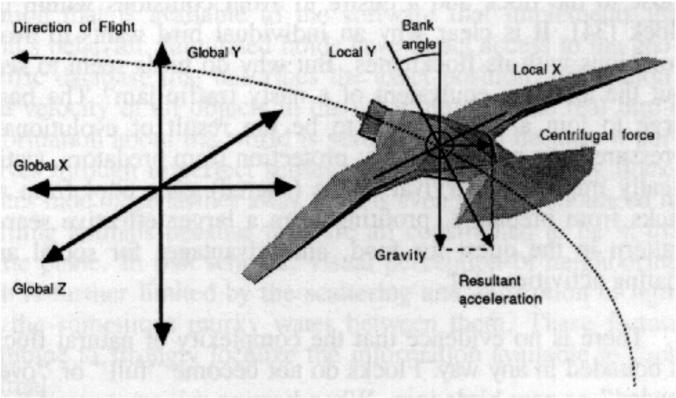
Minority Model

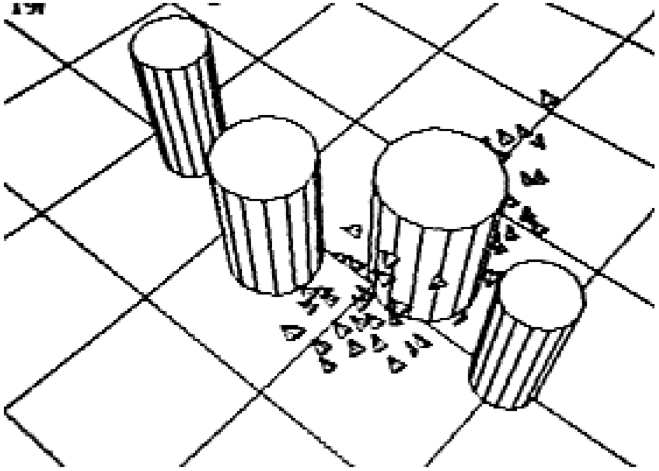
- Markets - buy/sell - price depends on difference between # buy and sell
- Stylized market facts if abstain/ wealth determines trade volume
- alpha = memory/agents
- H/N = predictibility



The Boids model (Reynolds 1987)

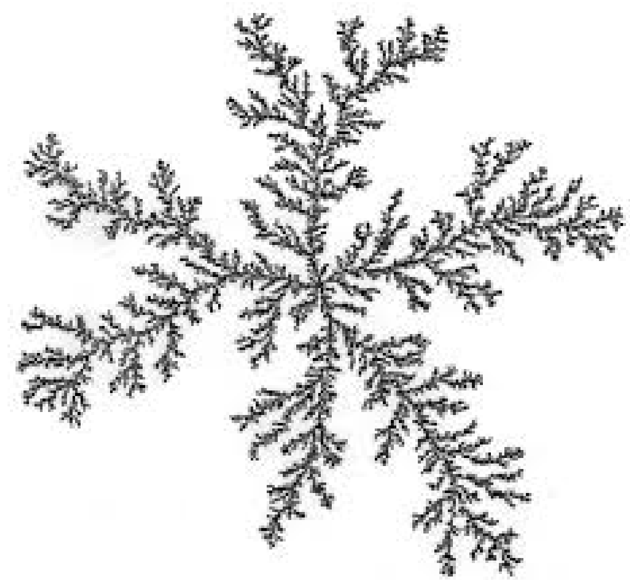
- Virtual birds which show natural flocking behaviors
- Each boid steers to
  - direct toward local center of mass
  - align with local average velocity
  - avoid collisions





Diffusion limited aggregation (DLA)

- Two types of particles, "free" and "fixed"; only free ones can move
- When colliding into a fixed one, a free particle becomes fixed and loses mobility

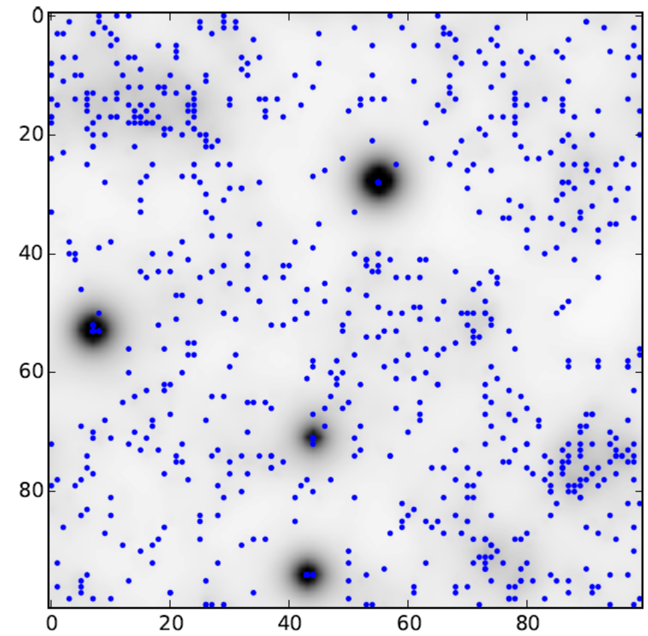


- Starting with only one fixed particle, a complex self-similar pattern emerges (called "spatial fractal")

Models with Agent-Environment Interaction

Keller-Segel ABM

- Agents are attracted to areas with high concentration of signal chemical (cAMP)
- Agents secrete cAMP
- cAMP diffuses and evaporates naturally



Results of ABM simulations

- Are often more “natural-looking” than those of analytical, low-dimensional dynamical models thanks to:
  - Discreteness of agents
  - Stochasticity in their behaviors
  - Algorithmic, detailed representation of behavioral rules

Models with Agent Replacement

Models with birth/death of agents

- The updating procedure should:
  - Determine whether or not each of the current agents can survive to the next step
    - If yes, the state of the agent will be updated as needed
    - If no, the agent will be removed from the list of current agents
  - Simulate the birth of new agents
    - They will be added to the list at the end

Predator-prey model

- Rabbits and foxes wander and reproduce in a space
  - Foxes move faster than rabbits
  - A rabbit will survive if it is not caught by foxes
  - A fox will survive if it ate rabbits not long ago
  - Foxes' reproduction depends on whether they successfully eat rabbits