Complexity and Fly Swarms

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What is Complexity?

Starling Flock

- Whole system made up from individual, interrelated parts
- Individual parts have simple interactions with one another
- System exhibits emergent properties (often unexpected)

There is no absolute definition of complex systems

Why is it Important?

Many complex systems:

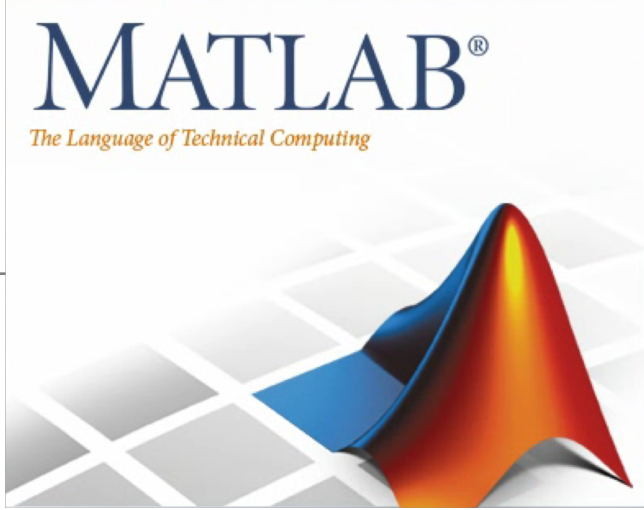
Forest fires, earthquakes, stock market, quantum to cosmological systems, and biological systems (fish schools, bird flocks, plant root-growth, fly swarms).

Understanding the nature of complexity

Help us to understand all complex systems

https://www.moneyjournals.com/earnings-season-boost-stock-market/ https://bluethumb.com.au/david-clare/Artwork/fish-school-7

Computational Models

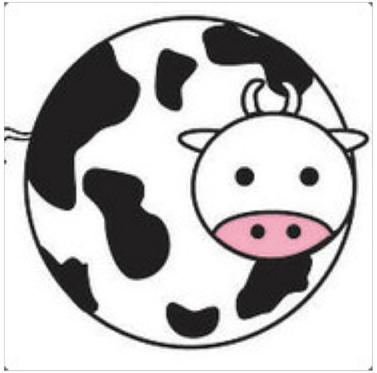


Drawback

- Could miss out on key component of system

Power of a computational model

- Control variables
- Set parameters
- Make adjustments
- Gather data/plot



Example of Part of our Code

```
for i = 1:size(moves,1) % Determine each potential move
    potential_moves(i,:,fly,sec,iteration) = current_position + moves(i,:);

    %Boundary Conditions
    if abs(potential_moves(i,1,fly,sec,iteration)) > Wall
        potential_moves(i,:,fly,sec,iteration) = NaN;
    else
        potential_moves(i,:,fly,sec,iteration) = potential_moves(i,:,fly,sec,iteration);
    end
    if abs(potential_moves(i,2,fly,sec,iteration)) > Wall
        potential_moves(i,:,fly,sec,iteration) = NaN;
    else
        potential_moves(i,:,fly,sec,iteration) = potential_moves(i,:,fly,sec,iteration);
    end
    if abs(potential_moves(i,3,fly,sec,iteration)) > Wall
        potential_moves(i,:,fly,sec,iteration) = NaN;
    else
        potential_moves(i,:,fly,sec,iteration) = potential_moves(i,:,fly,sec,iteration);
    end
```

Fly Swarms and Our Goals

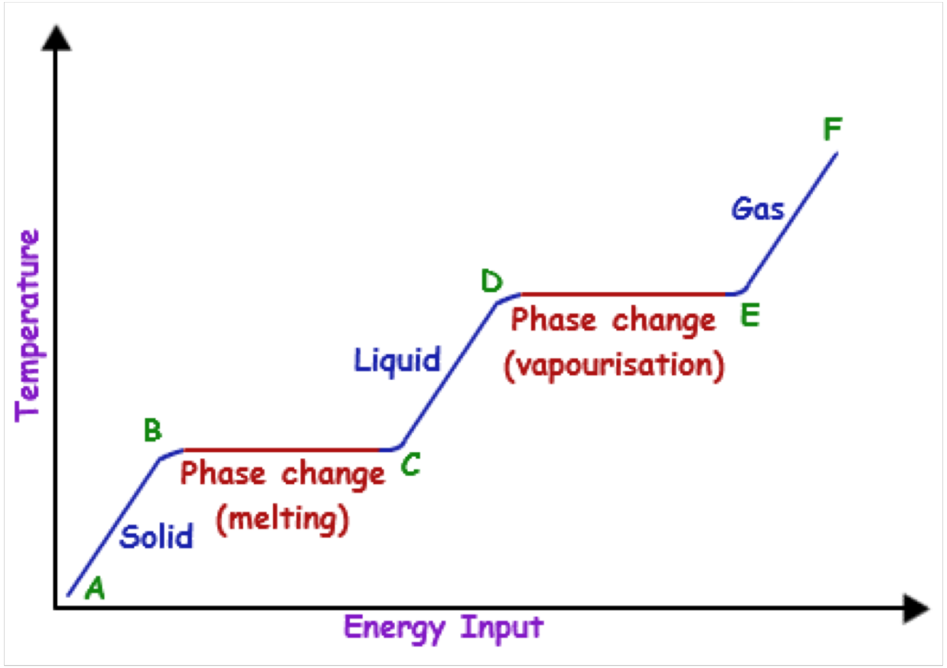
Fly (midge) swarms exhibit complex behavior

More simple system

Want to distinguish when flies are and aren't **swarming**

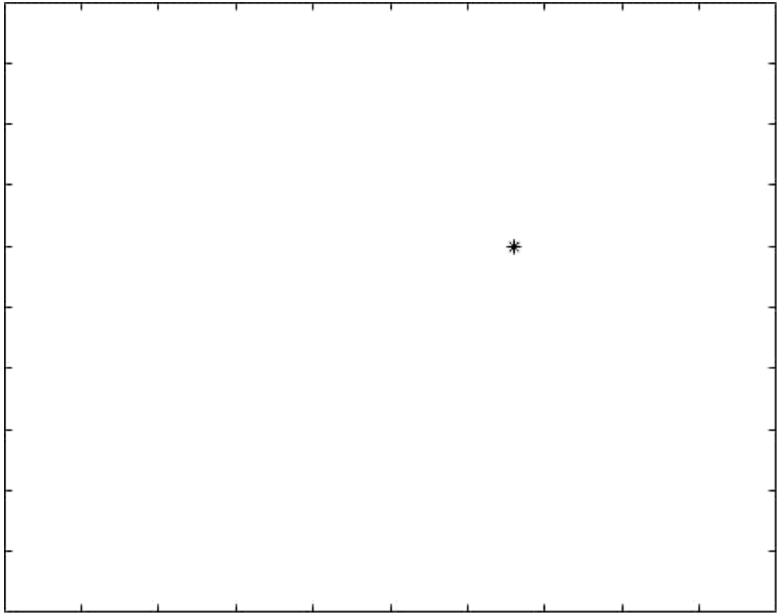
Looking for critical state to emergent property

Phase transition?

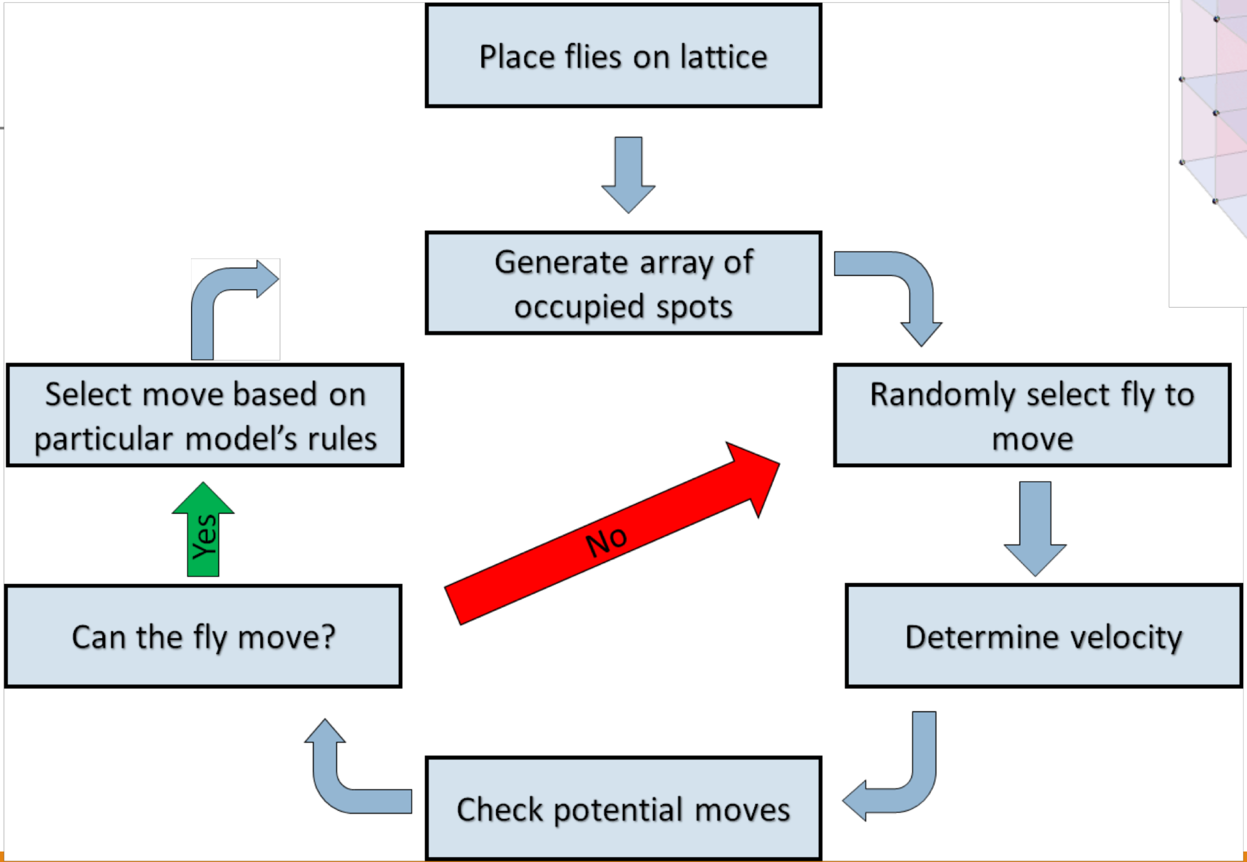


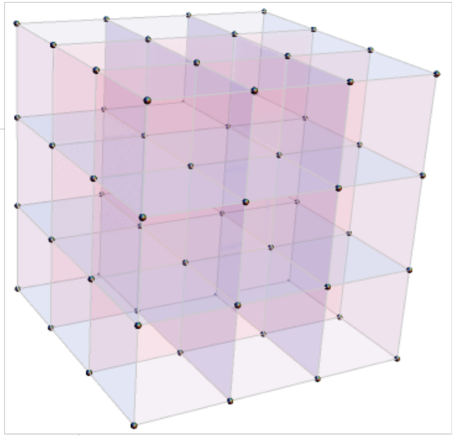
Our Various Models

- Base (random walkers[Shown on right])
- Local Center of Mass
- Center of Mass Velocity
- Local Velocity Averaging
- Any Combination
- Also can include Gravity



Model Flowchart

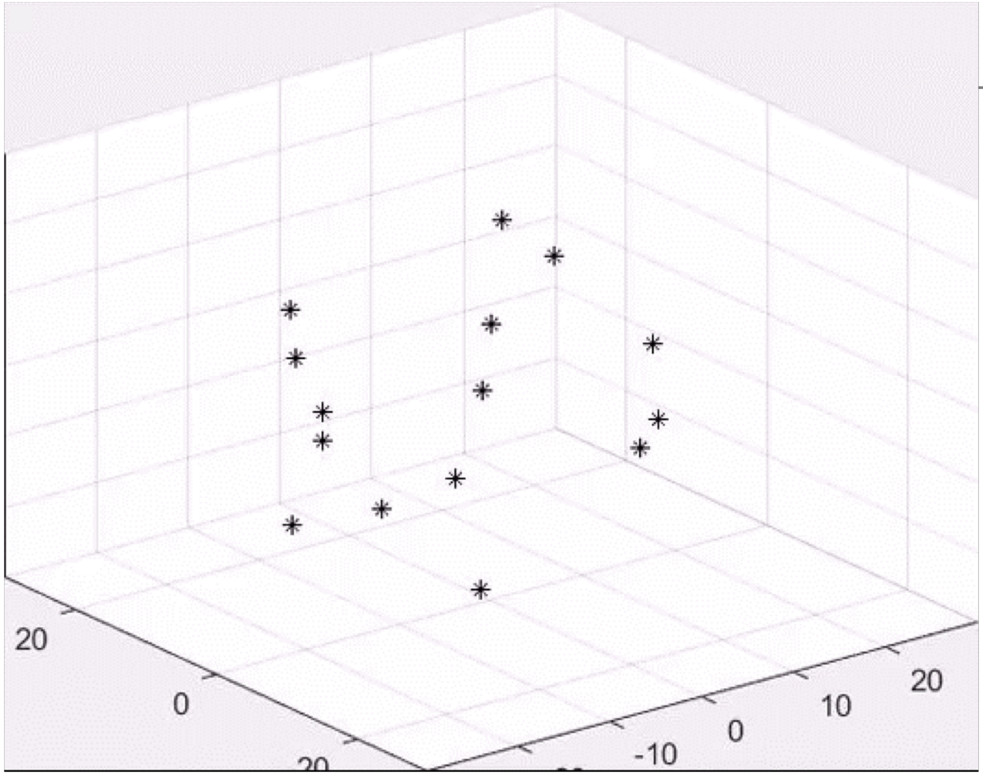




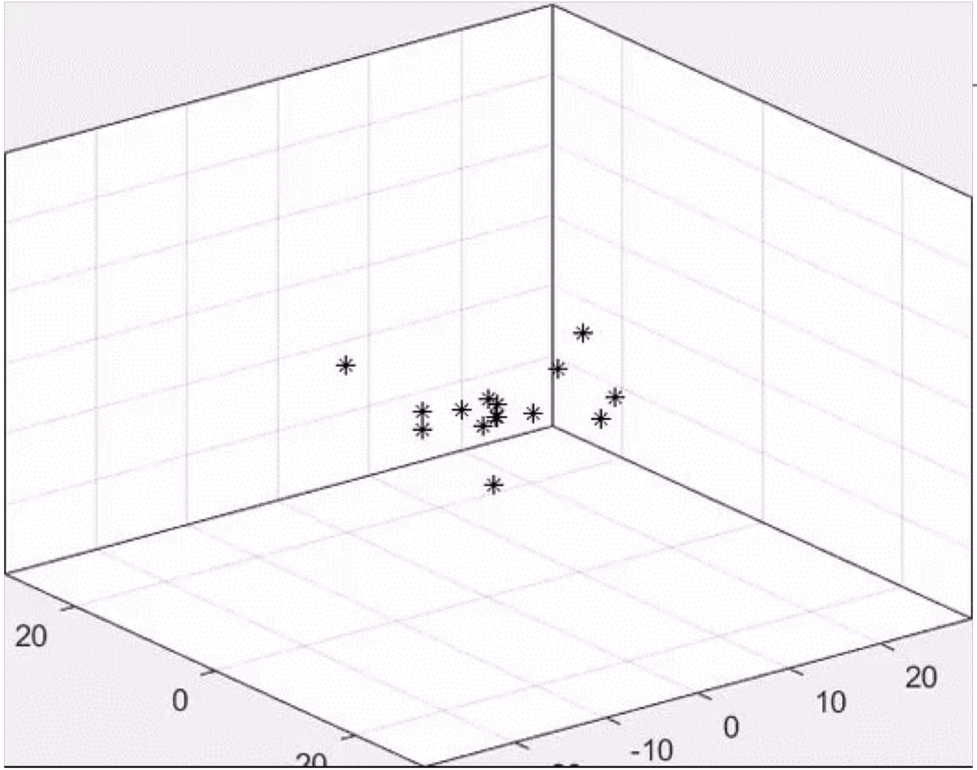
3D Lattice Example

https://mathematica.stackexchange.com/questions/19165/how-to-generate-a-3-d-simple-cubic-lattice-of-length-4-in-each-dimension

3D Visual (Base vs Local CM/Velocity)



3D Visual (Base vs Local CM/Velocity)

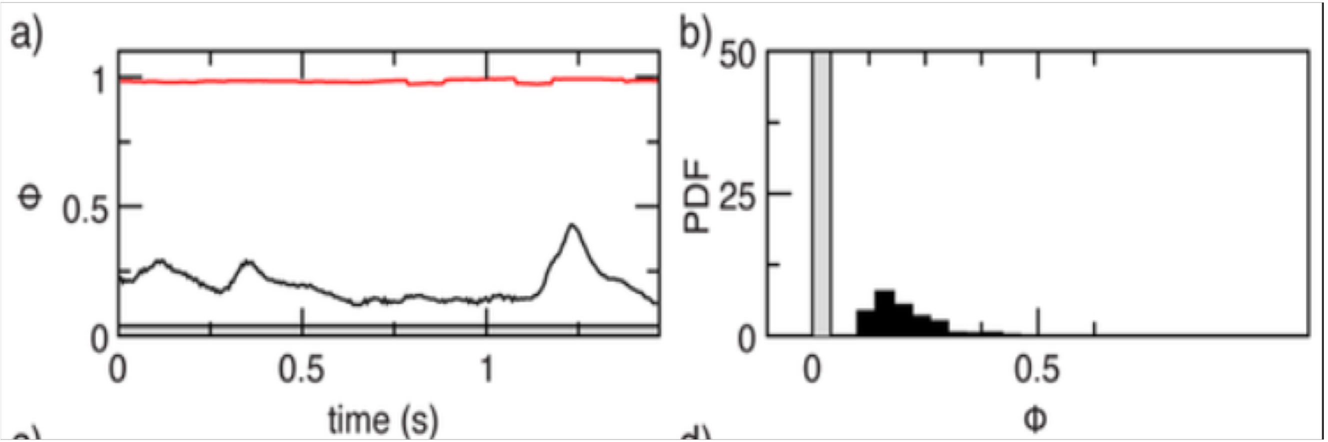


Experimental Results to Compare

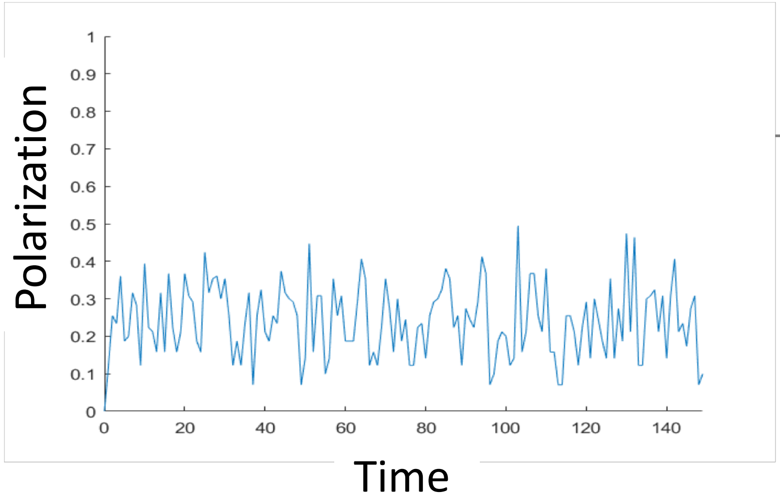
- Douglas H. Kelley and Nicholas T. Ouellette studied actual fly systems and found **polarization** of ~0.25, where polarization is defined:

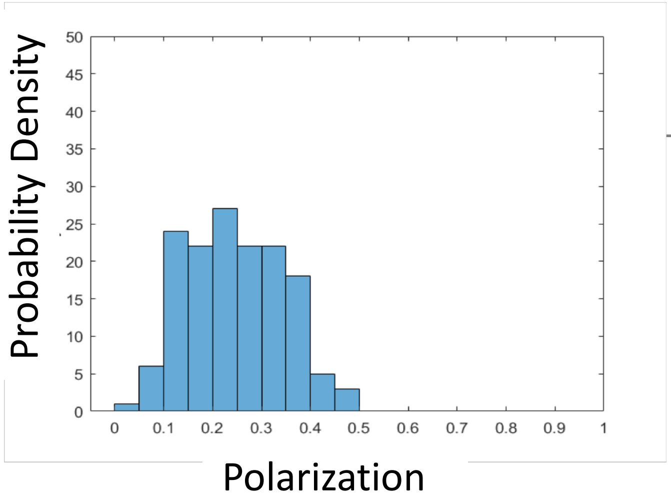
$$\Phi = \left| \frac{1}{N} \sum_i \frac{\vec{v_i}}{v_i} \right|$$

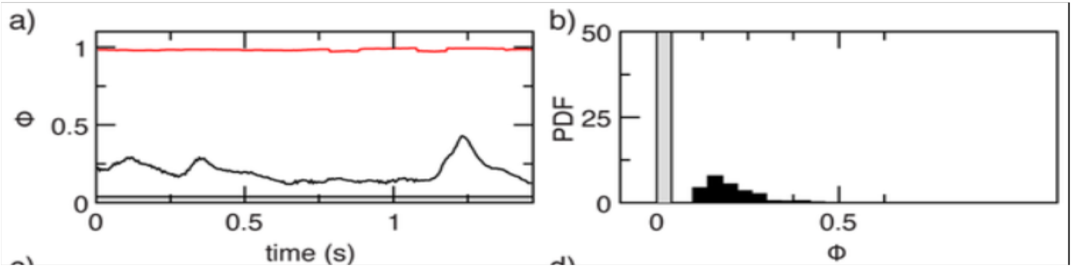
- Their results were as follows:



Our Polarization Measurements







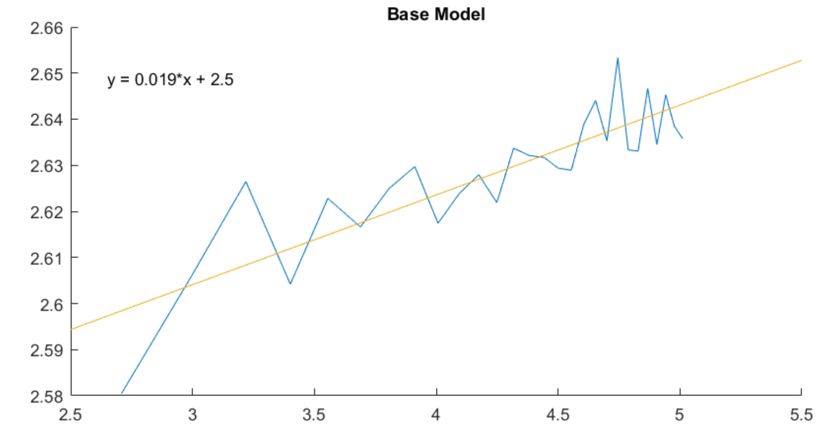
Emergent dynamics of laboratory insect swarms -- Douglas H. Kelley & Nicholas T. Ouellette

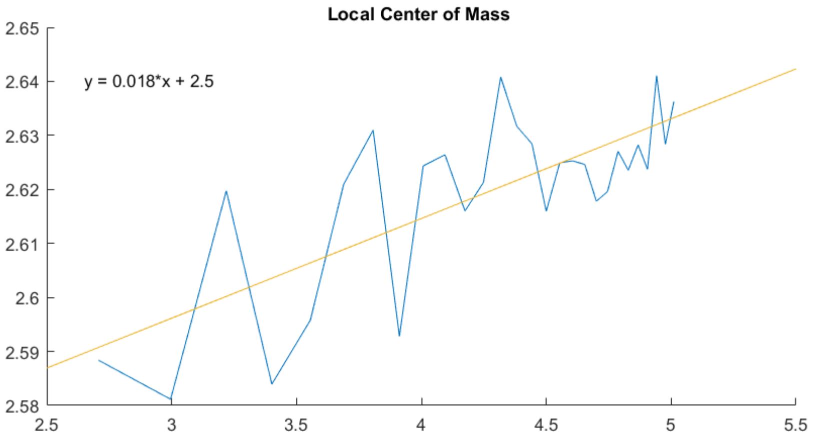
Swarm Radius

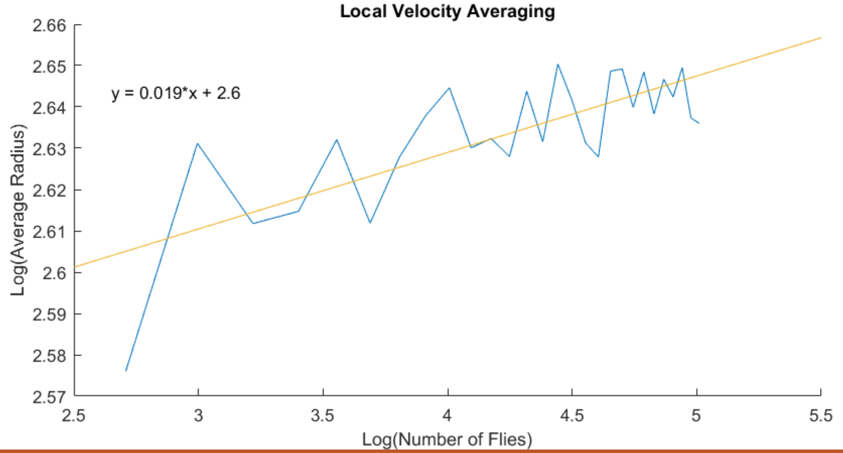
Douglas H. Kelley and Nicholas T. Ouellette also found the following relationship:

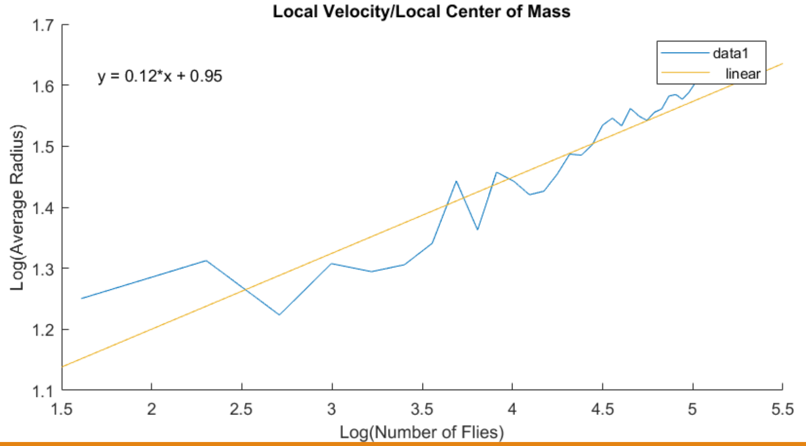
$$< r > \propto N^{1/3}$$

Results on Power Law









Future Goals and Directions

Compare with other experimental and computational groups' data

Continue to modify and improve our computational model

Define "swarming" more definitively

http://www.wesa.fm/post/swarms-gnats-seen-around-philly-are-actually-flying-ants#stream/0

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Questions?