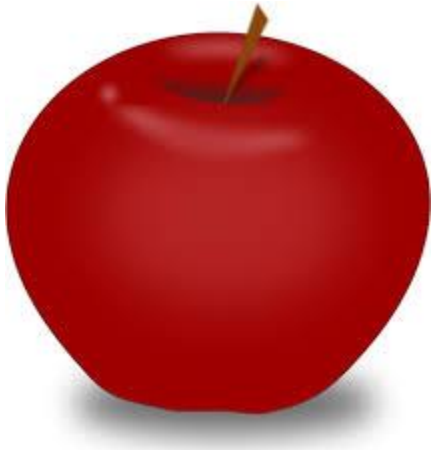


The Gravitational Theory of the Midges

Dan Gorbonos

MAX PLANCK INSTITUTE
OF ANIMAL BEHAVIOR

Universität Konstanz

National Institute for Modeling Biological Systems (NIMBioS)

University of Tennessee, Knoxville

February 20, 2025

Collective Animal Motion

Short range interactions

Flocks

Schools

Herds

Herd behavior

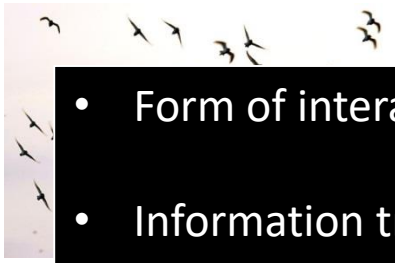
Long range interactions

Flying insect swarms

Collective Animal Motion

Short range interactions

Long range interactions



- Form of interaction between individuals ?
- Information transmitted ?
- Modes of collective motions ?
- Collective decision-making ?

Schools

Flying insect swarms

Herds

Herd behavior

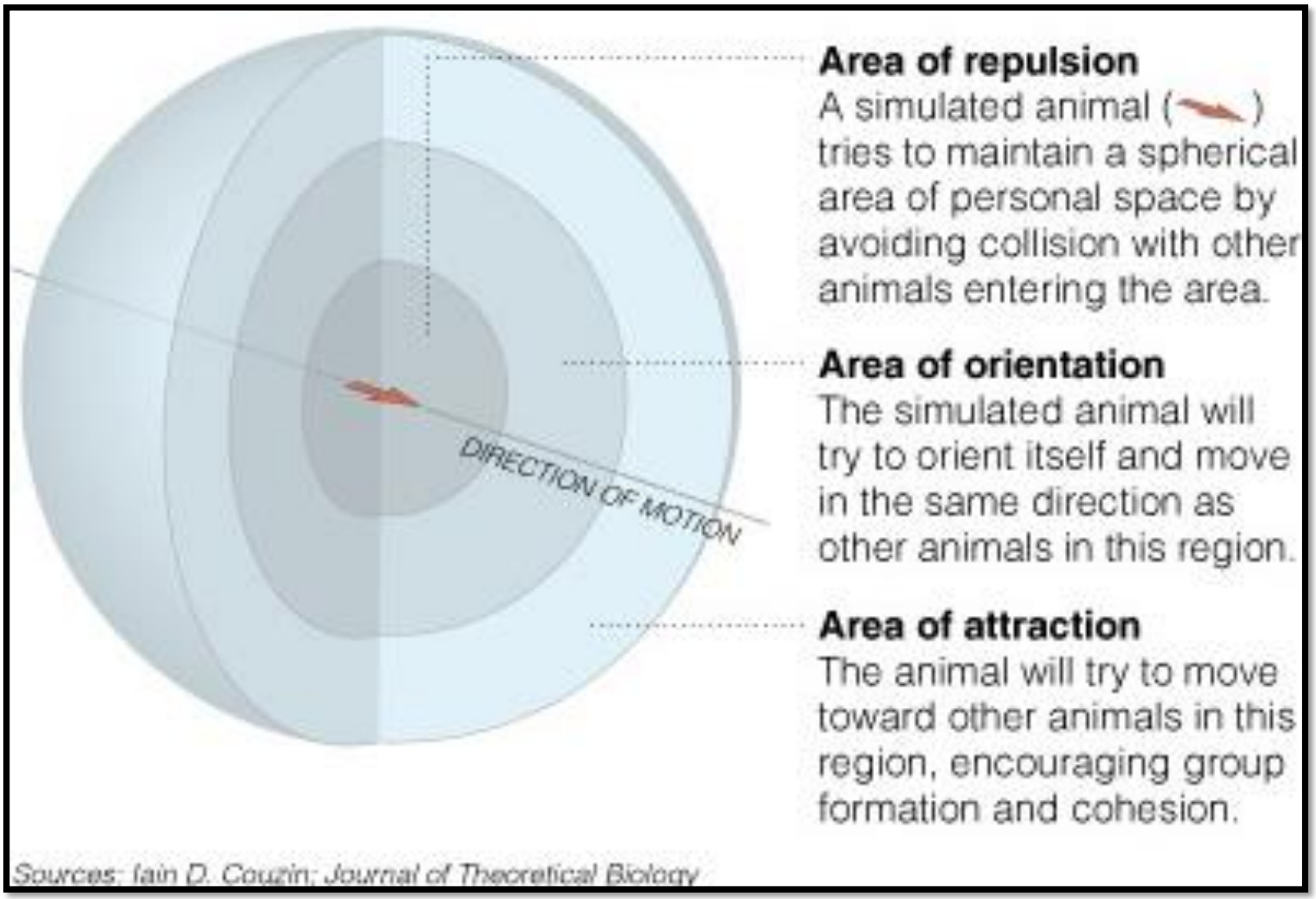
Collective Animal Motion

Flocking - mainly short range interactions

Collective Animal Motion

Swarming - mainly long range interactions

Collective Animal Motion



The Midges

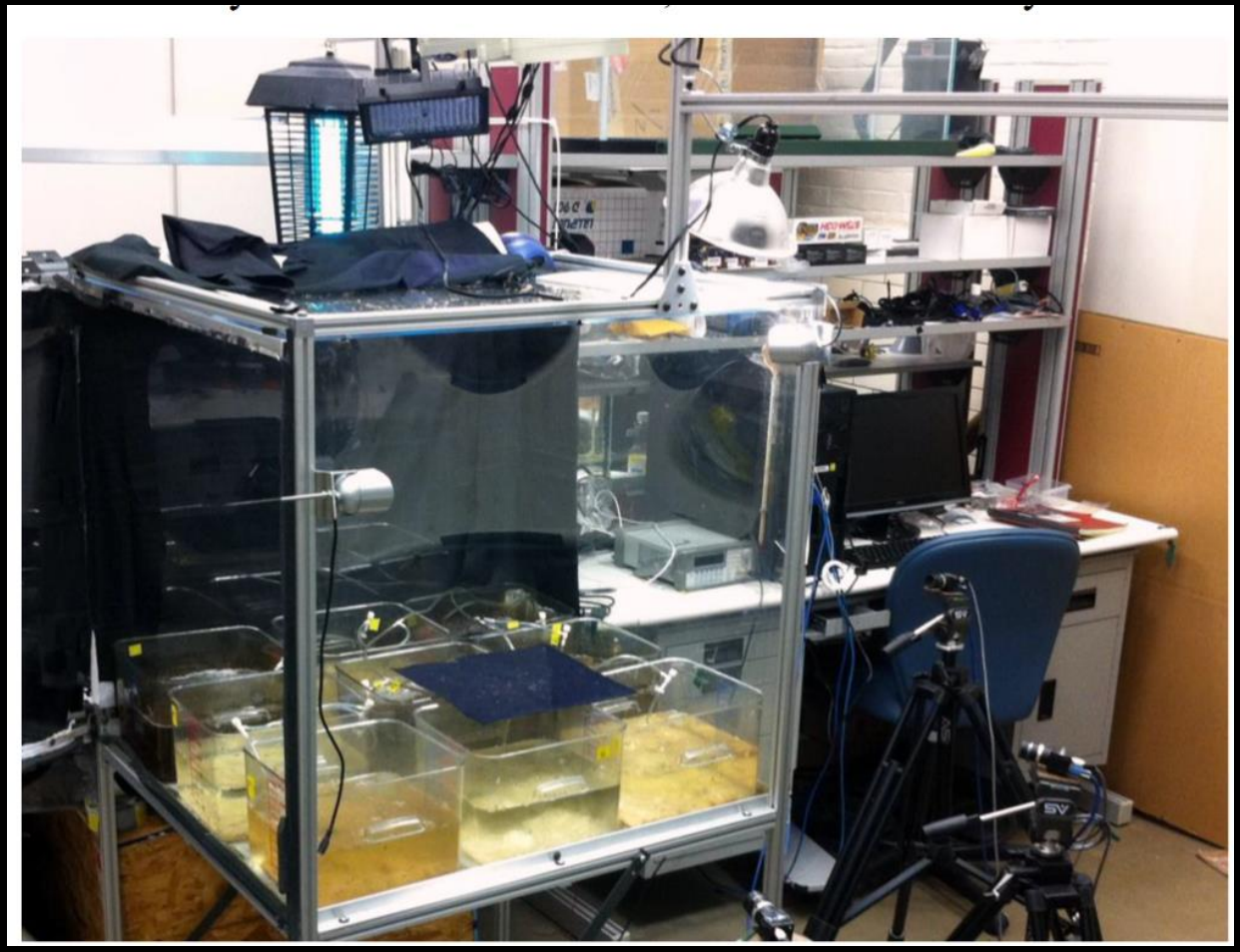

© Joe Boggs
Chironomid Midge Fly Swarm
(Small White Spots in Image)

The midges (Chironomidae)

- Non-biting midges
- Only male swarm (mating ritual)
- Length - 5 mm

- How many ? 10—10,000
- Where ? stream edges
- When ? dawn and dusk

The lab (Stanford U.) :

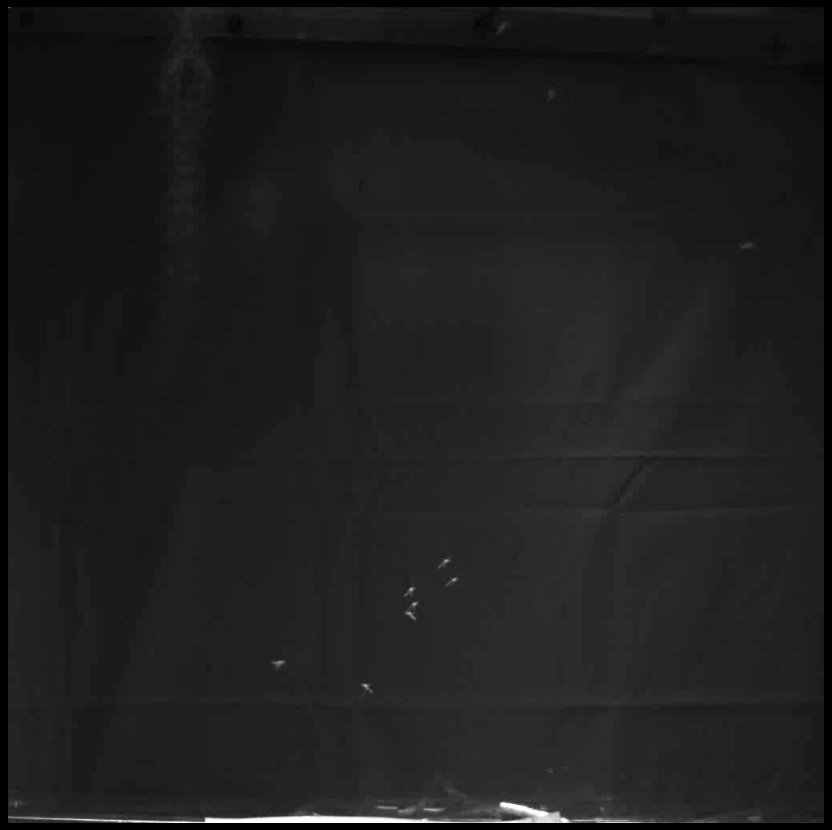


Nick Ouellette - PI

James Puckett

Rui Ni

In the lab (Stanford U.) :



Nick Ouellette - PI

James Puckett

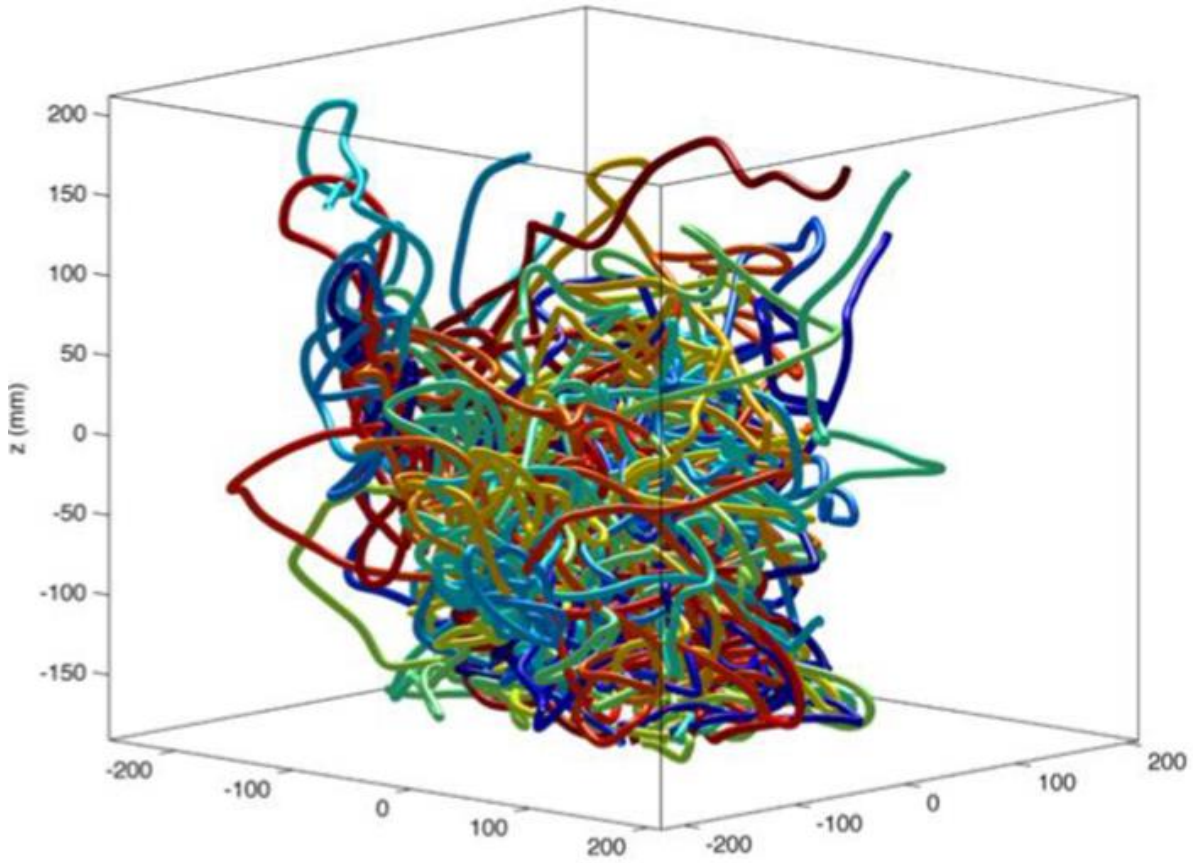
Rui Ni

The midges (Chironomidae)

- Non-biting midges
- Only male swarm (mating ritual)
- Length - 5 mm

	Nature	Lab
• How many ?	10—10,000	1—100
• Where ?	stream edges	Black felt “swarm markers”
• When ?	dawn and dusk	Overhead light source – ON/OFF

In the Lab (Stanford U.) :
Trajectories of midges vs. time



Method:

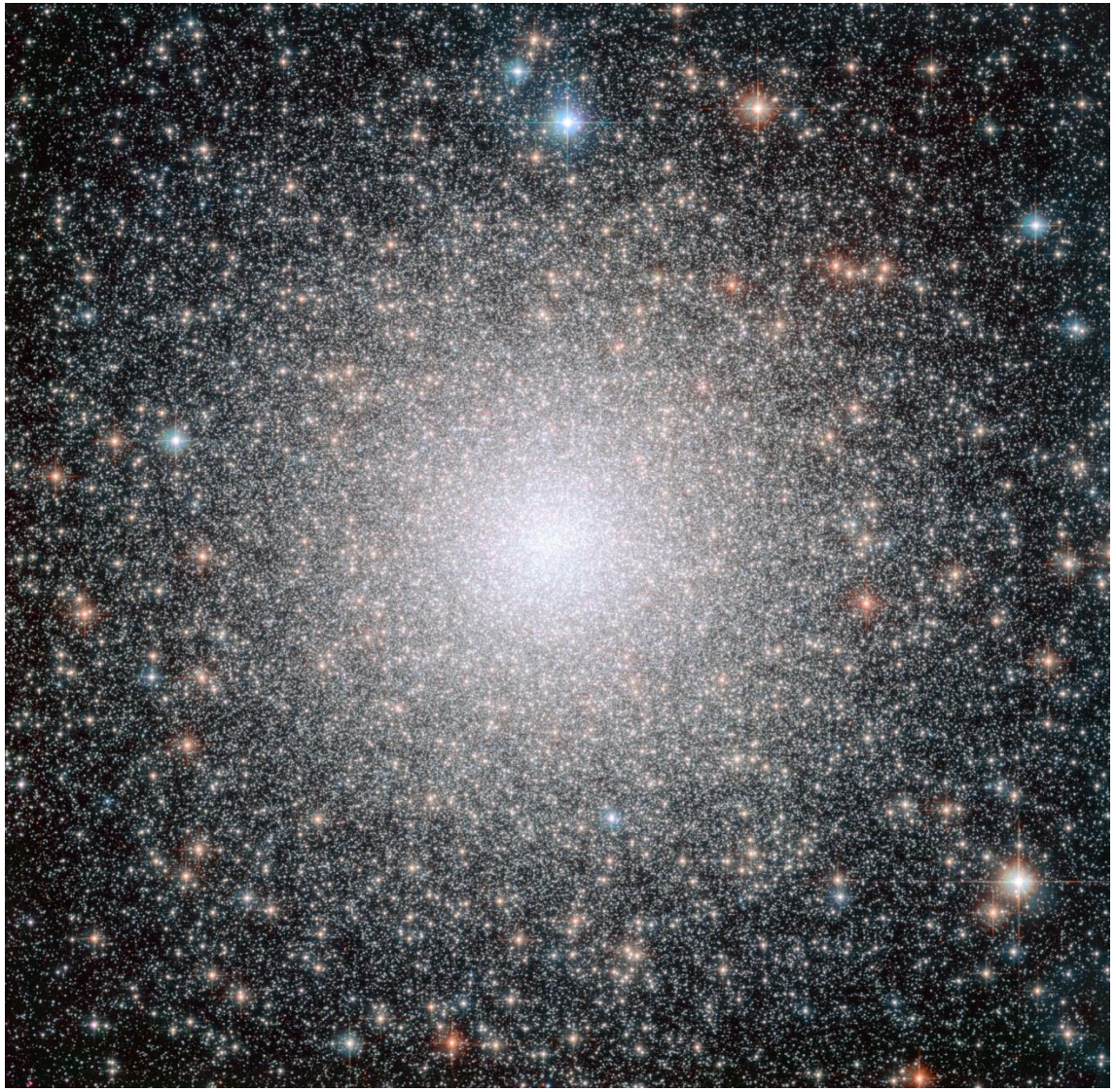
- High-speed stereo-imaging using three synchronized cameras (100 fps)
- Automated motion tracking algorithm

What are the forces that keep the swarm cohesive?

Globular Clusters

10,000-1,000,000 stars

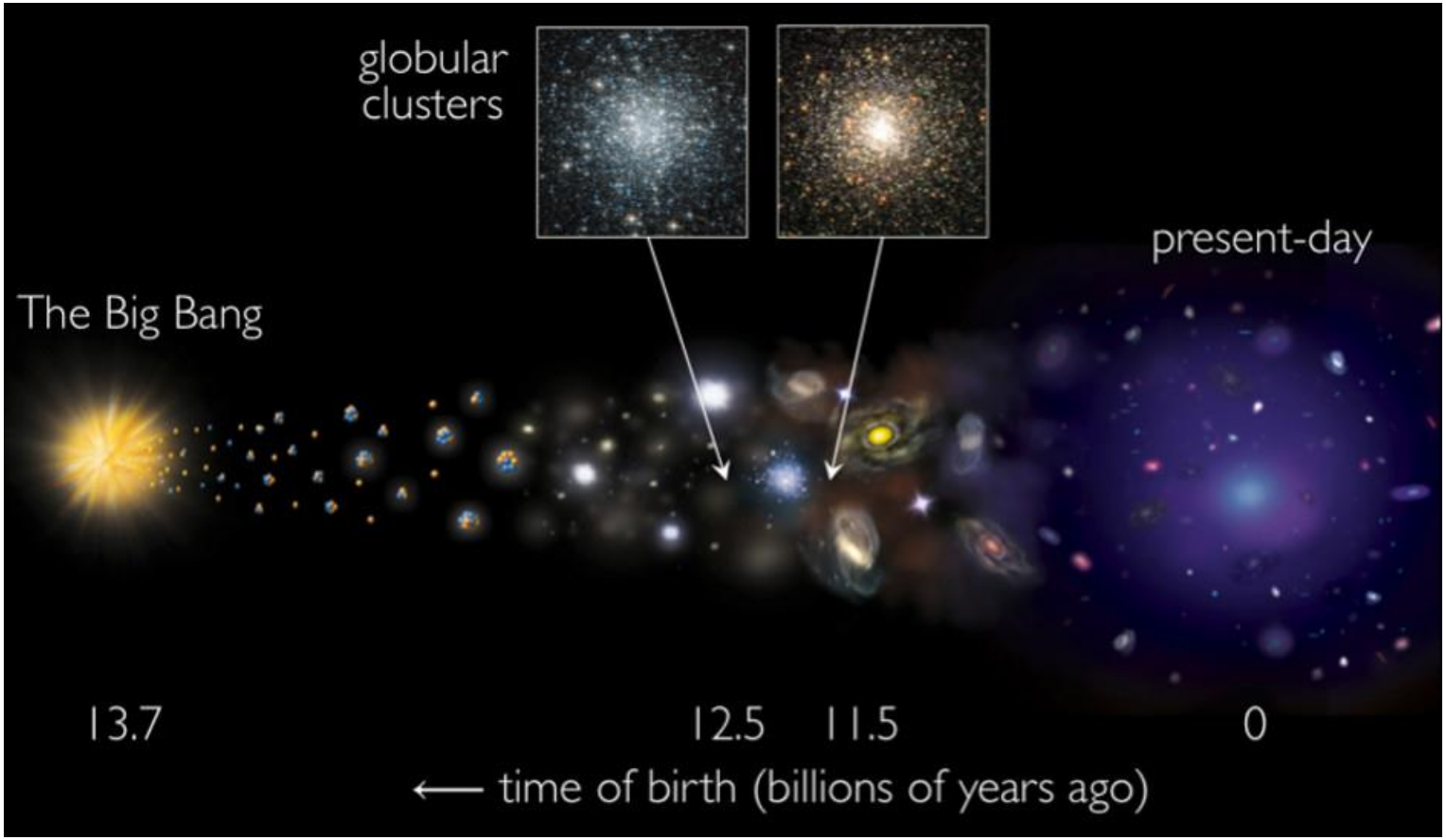
Size: 100-300 light years



Globular Clusters

Globular Clusters

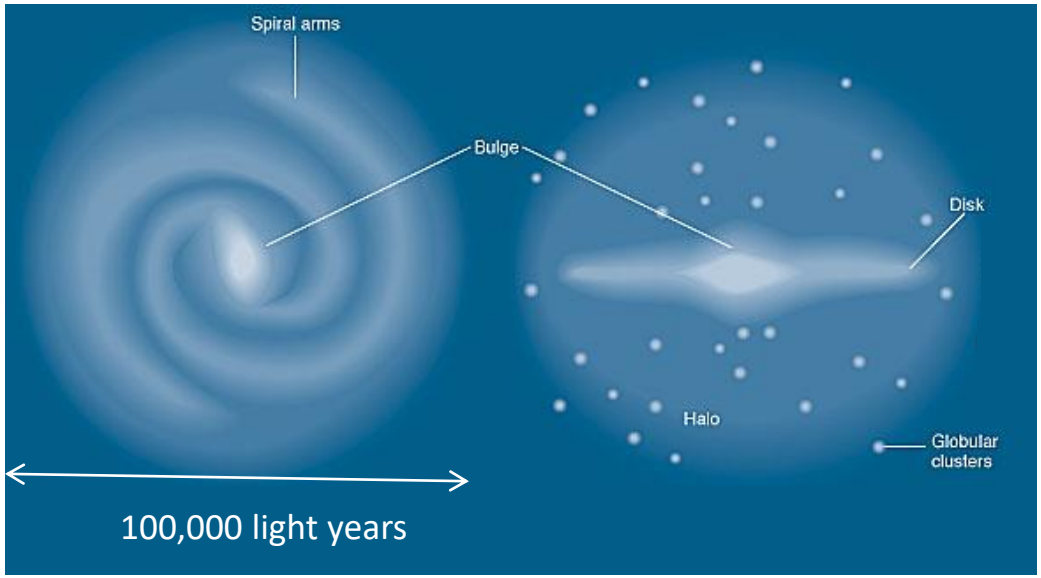
The oldest objects in the universe



Globular Clusters

The building blocks of the galaxies

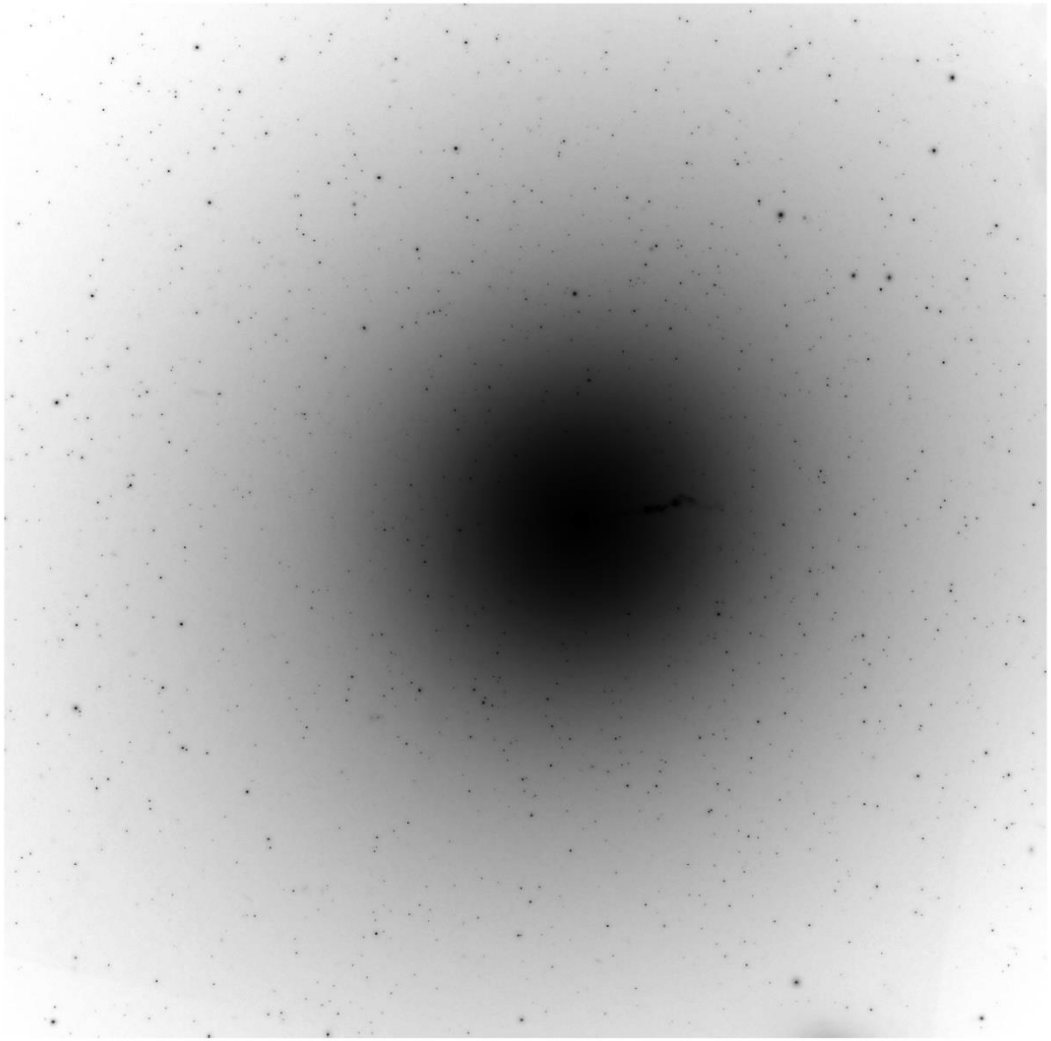
In the galaxy – 200 billion stars



Construction waste:

ca. 150 clusters
around the galaxy

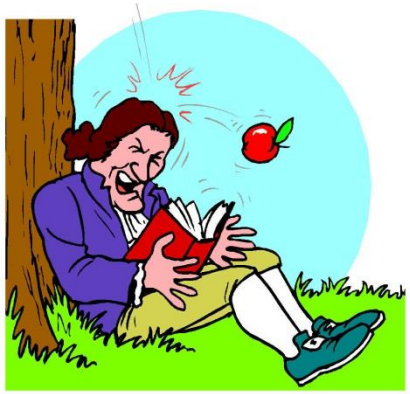
M87 Galaxy

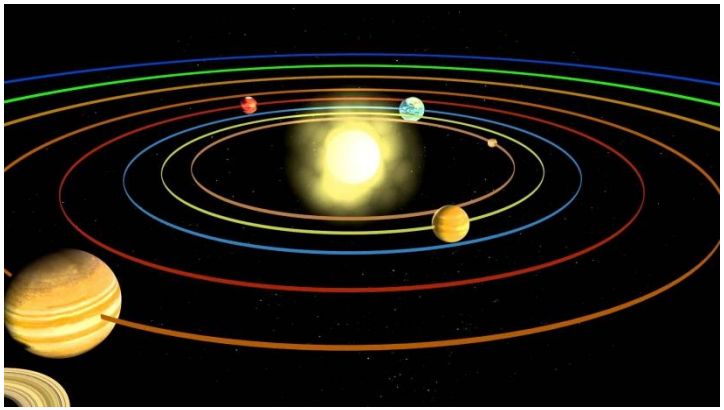


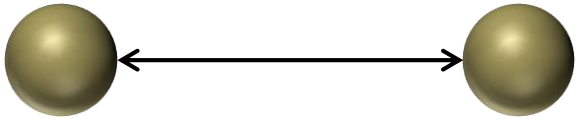
15,000 Globular clusters!

What are the forces that keep the cluster cohesive?

Newton's law of universal gravitation







gravitational pull between masses

$$\frac{Gm_1m_2}{r^2}$$

A simulation of the dynamics of a globular cluster

ca. 6000 stars

https://www.youtube.com/watch?v=_mr9y4F6ME4

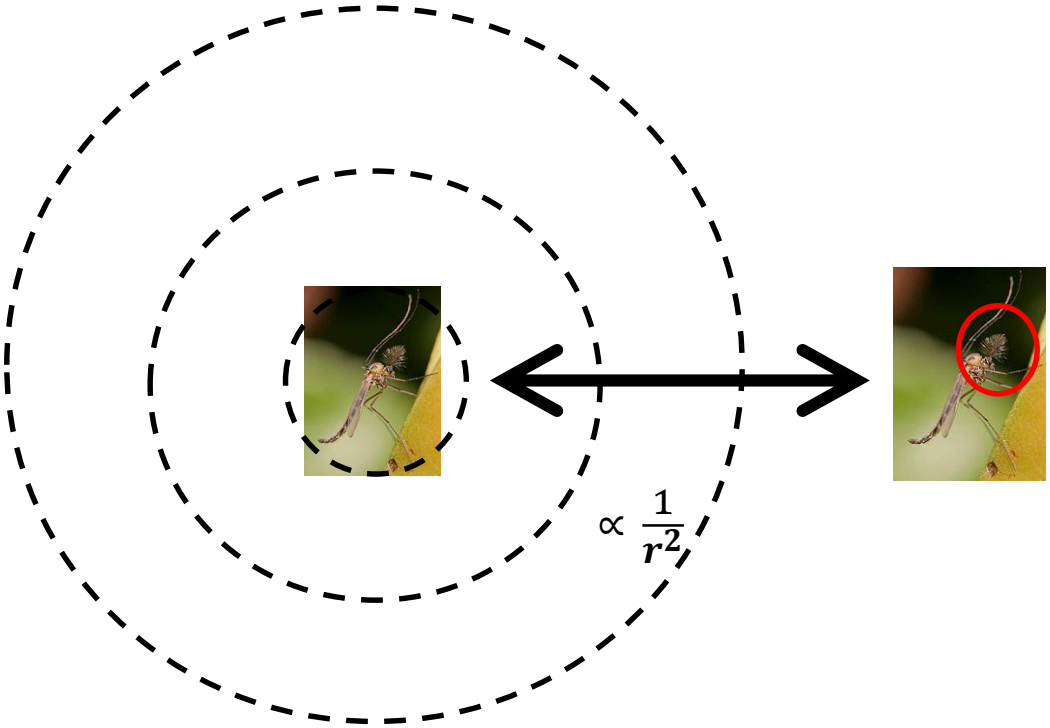
gravitational pull between masses

$$\frac{Gm_1m_2}{r^2}$$

The model of the interaction in the swarm – acoustic “gravity”

gravitational pull between masses

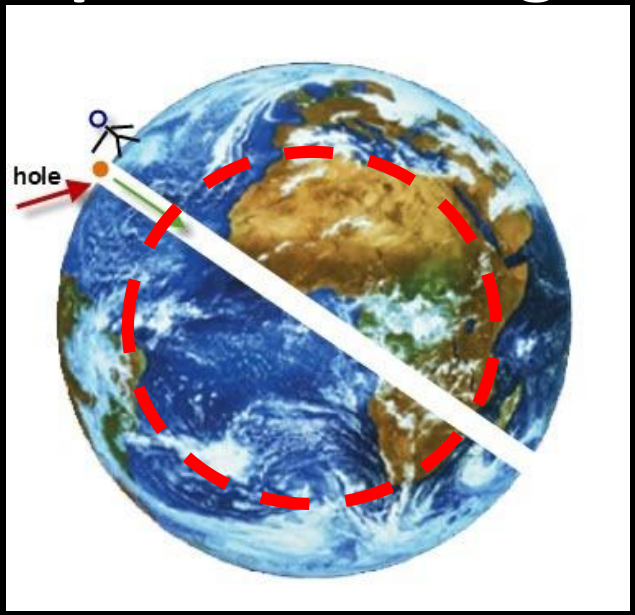
$$\frac{Gm_1m_2}{r^2}$$



How can we test this hypothesis?

A model of the acoustic interactions

- **What will happen when a ball is dropped in a tunnel that passes through the center of the Earth?**



Gauss's law for $1/r^2$ forces :

$$\oiint \vec{F} \cdot \mathrm{d}\vec{A} = -4\pi GM$$

$$F(r) \cdot A = -4\pi G\rho \cdot V$$

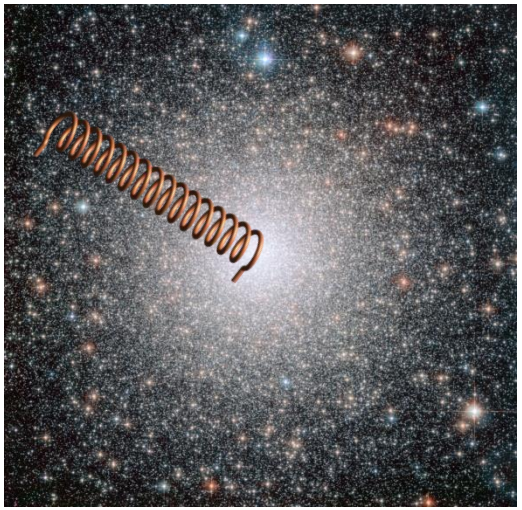
$$F(r) \sim V/A \sim r^3/r^2 \sim r$$

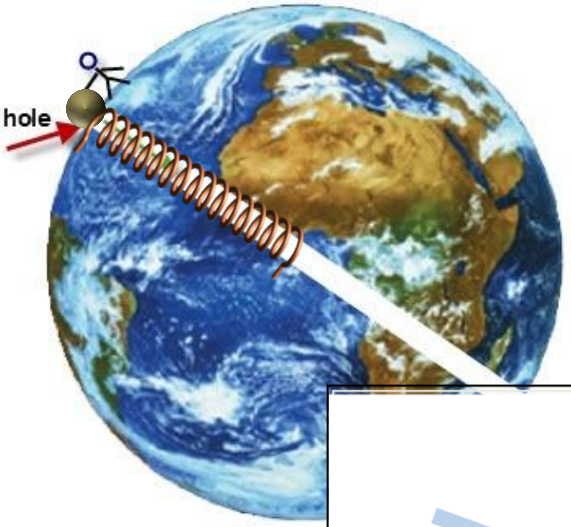
Isotropic Harmonic Oscillator (restoring and linear in $\vec{r}$)

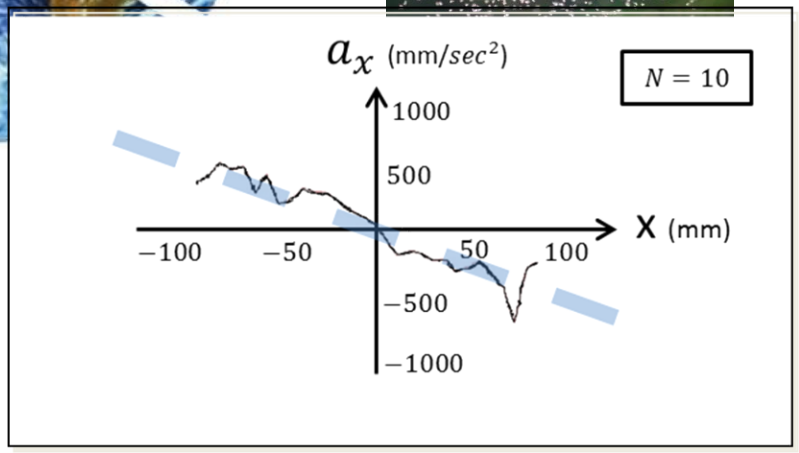
$$\vec{a} \propto \vec{F} = -k\vec{r}$$

What will happen when a ball is dropped in a tunnel that passes through the center of the Earth?

$$\vec{a} \propto \vec{F} = -k\vec{r}$$

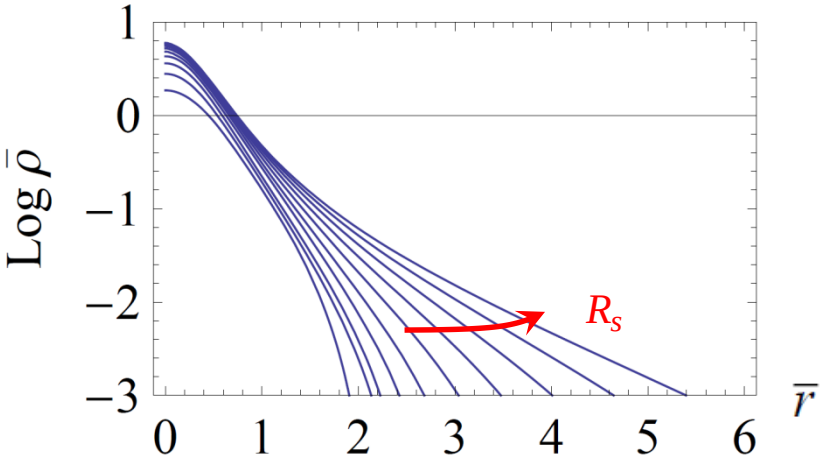




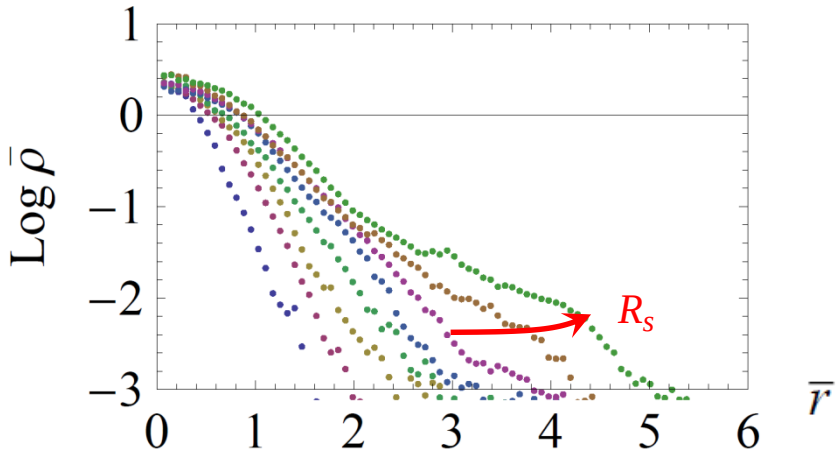


The ball will oscillate back and forth around the center when the acceleration toward the center is directly proportional to the distance from it.

The Density Profile



Theory of star clusters

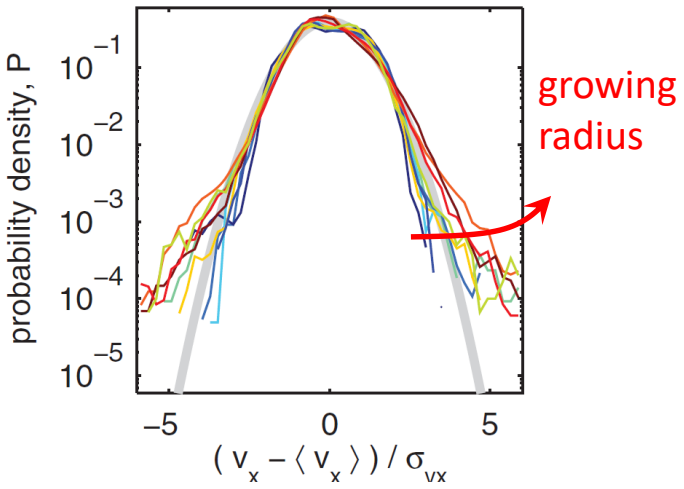


Midge swarms

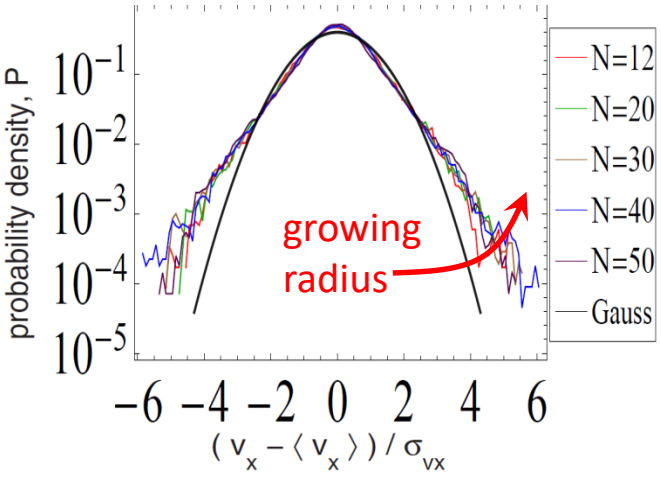
R_s - The radius of the star cluster/swarm

Distributions of velocities and accelerations

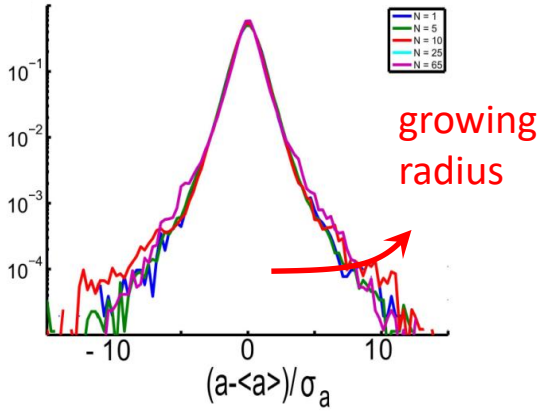
Swarms

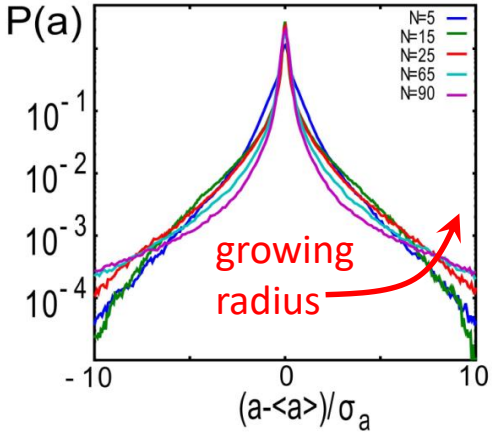


Theory



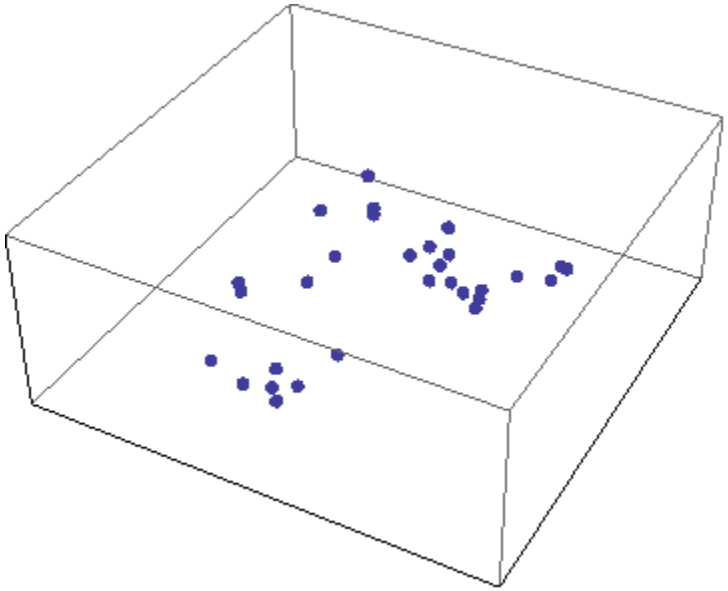
velocities





accelerations

Simulation



And more:

- Virial theorem
- Velocity curve profile
- Pair formation

⋮

Summary

There is a similarity between globular star clusters and midge swarms, stemming from a similar force between their constituents.

- The connection between phenomena allows us to learn about one from the other.
- Astrophysics in the lab
- Universality of the mathematical description

Thank You

Based on:

- D. Gorbonos, James G. Puckett, Kasper van der Vaart, Michael Sinhuber, N. T. Ouellette & N. S. Gov, **Pair formation in Insect Swarms Driven by Adaptive Long-range Interactions**, J. R. Soc. Interface.17 2020 20200367
- D. Gorbonos , M. Sinhuber, J. G. Puckett , N. T. Ouellette & N. S. Gov, **Similarities between Insect Swarms and Globular Clusters**, Physical Review Research 2:013271, 2020
- D. Gorbonos & N. S. Gov, **Stable Swarming Using Adaptive Long-range Interactions**, Phys. Rev. E 95:042405, 2017
- D. Gorbonos, R. Ianconescu, J. G. Puckett, R. Ni, N. T. Ouellette & N. S. Gov, **Long-range Acoustic Interactions in Insect Swarms: An Adaptive Gravity Model**, New Journal of Physics 18, 2016