Title: 13/14 PSI - Student Presentations - 1

Date: Aug 16, 2013 09:00 AM

URL: http://pirsa.org/13080036

Abstract:

Introduction and Motivation

- Why interesting?
- Why does it work?
- Intuition
- Actual Physics
- Optimal Parameters

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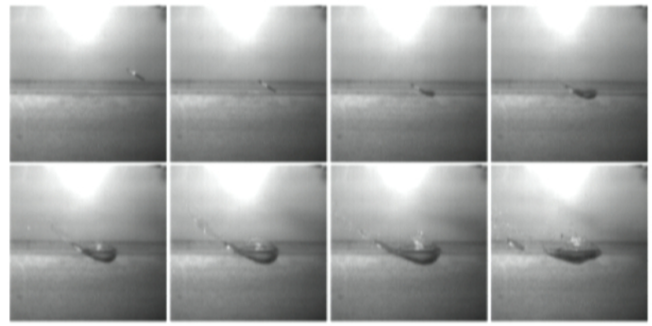
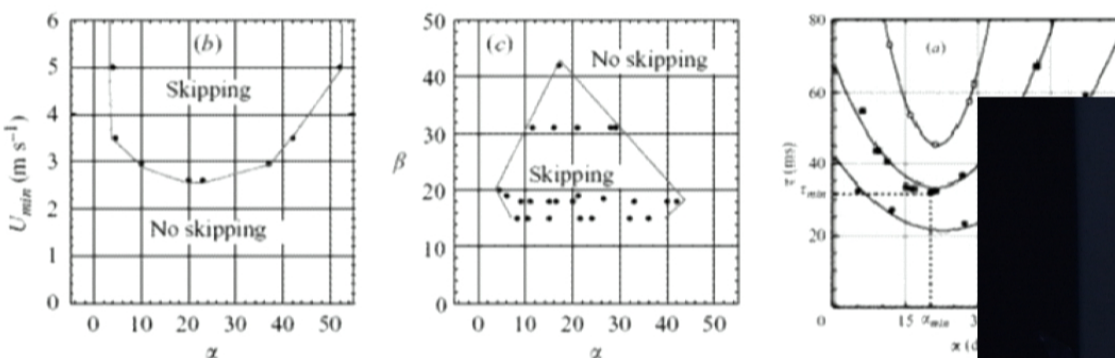
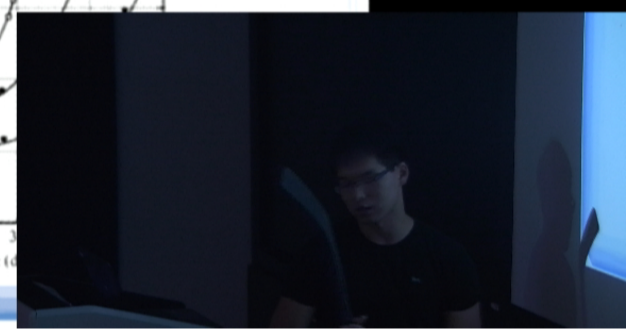
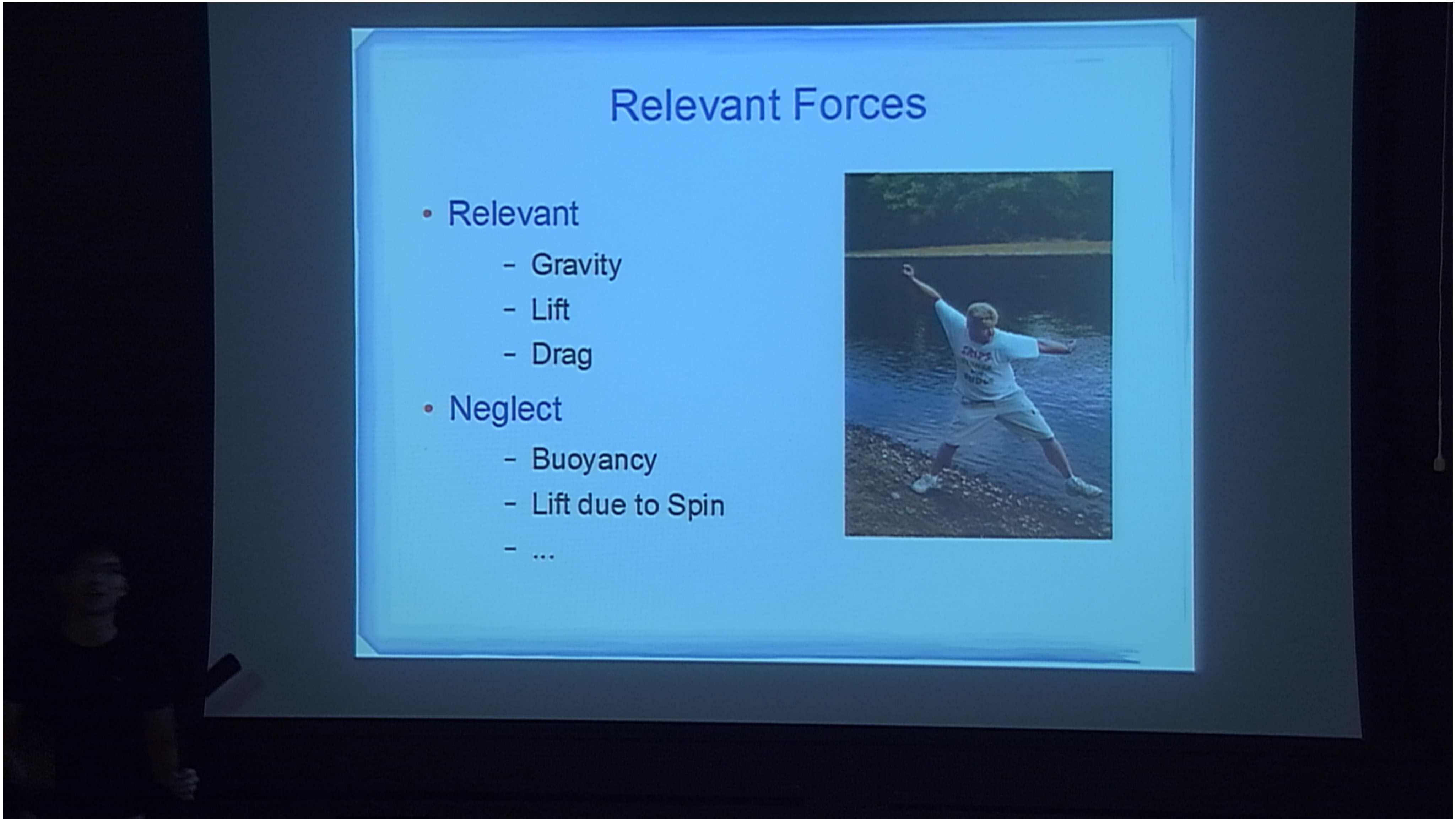
Experiments

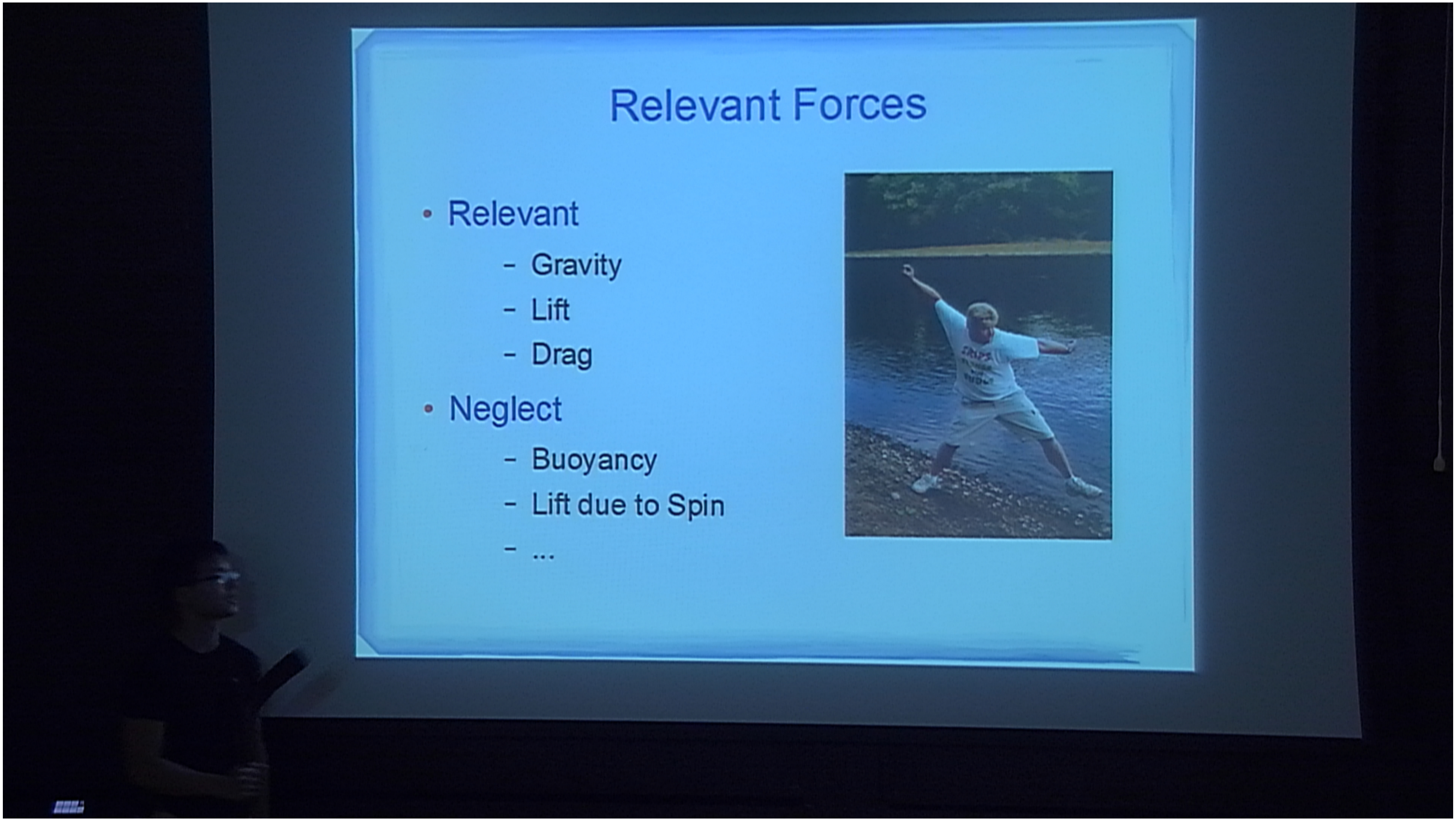
Optimum angle ~ 20°








Relevant Forces
• Relevant
– Gravity
– Lift
– Drag
• Neglect
– Buoyancy
– Lift due to Spin
– ...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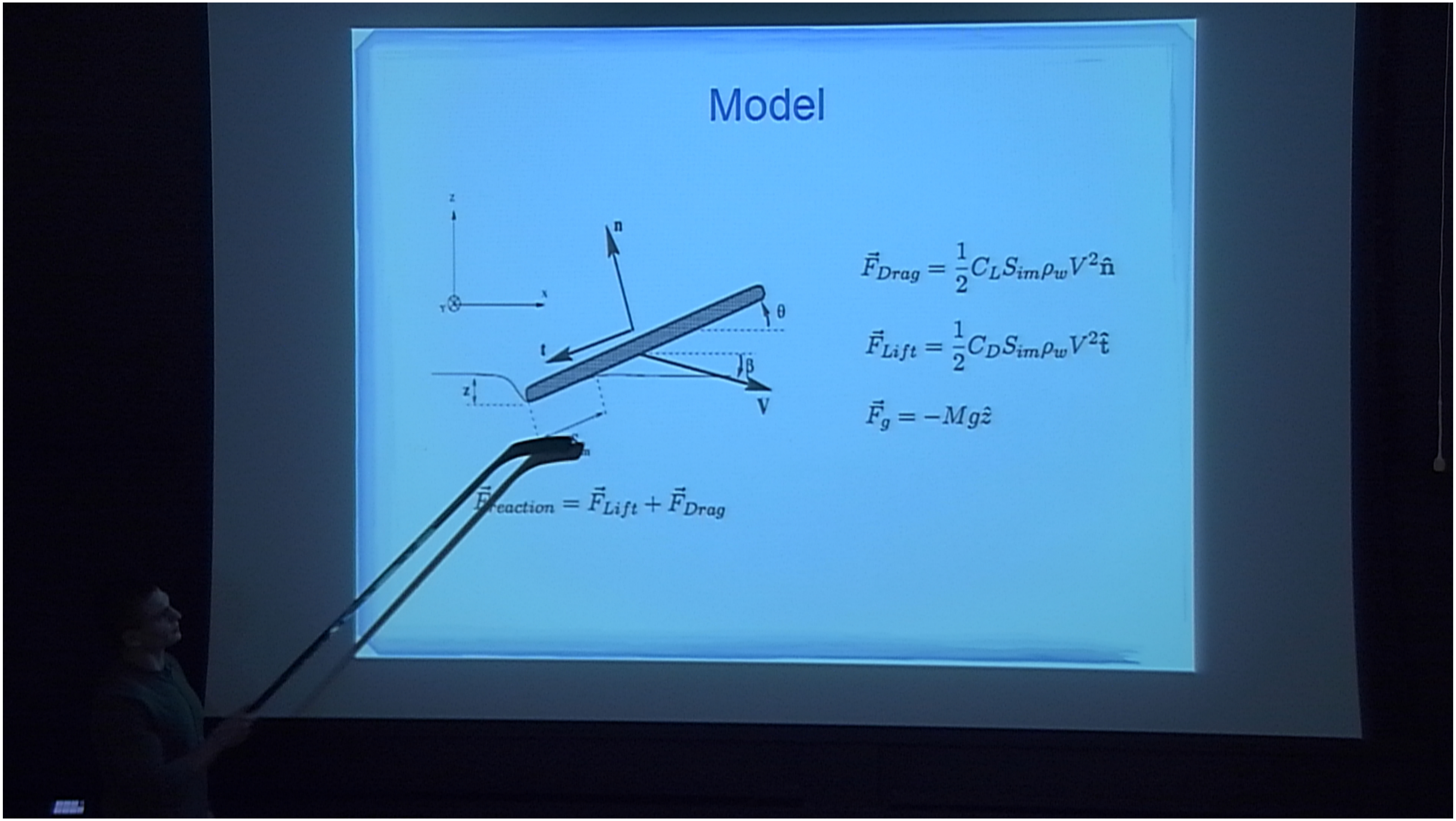
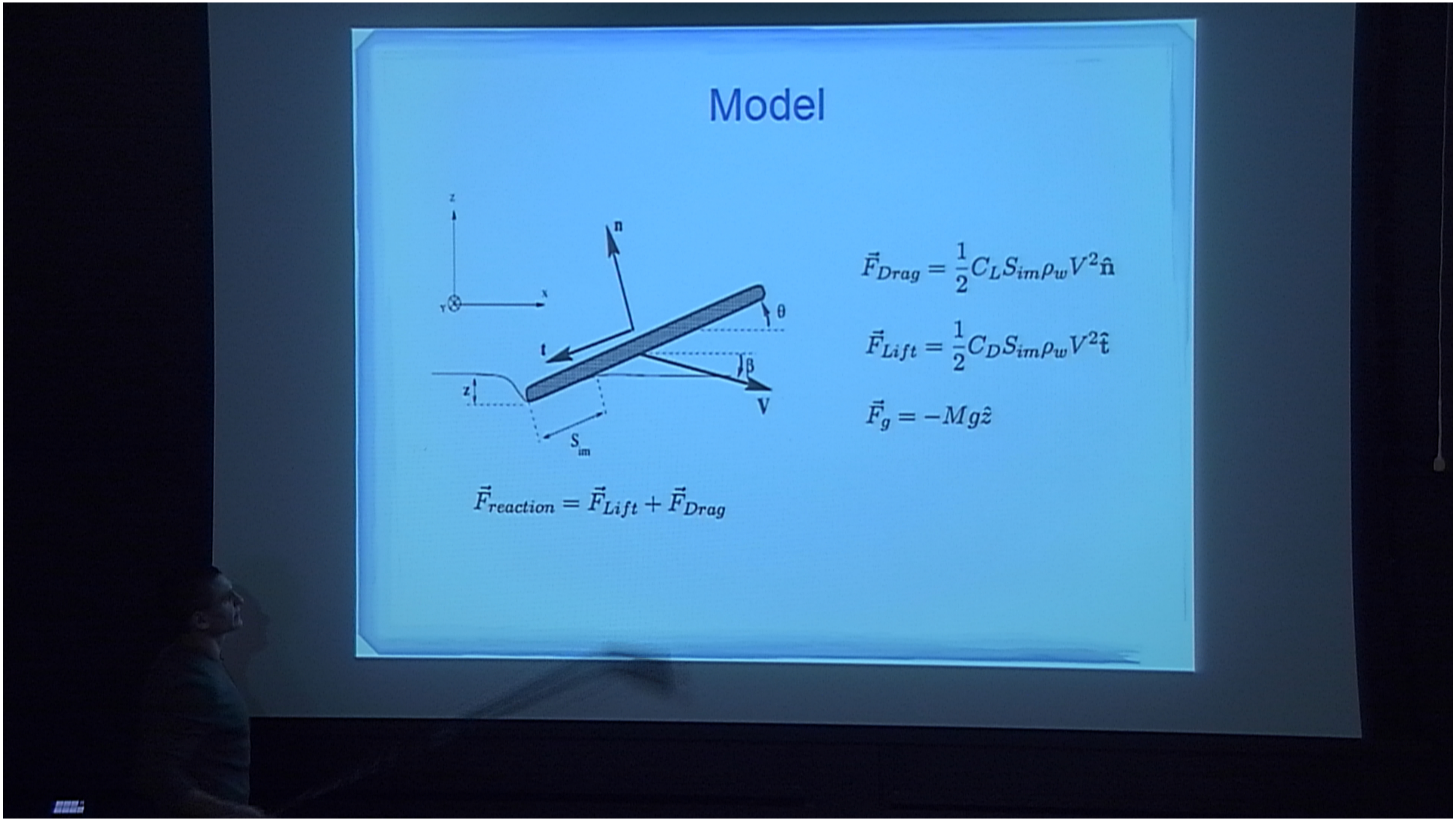

Model
$\vec{F}_{Drag} = \frac{1}{2} C_L S_{im} \rho_w V^2 \hat{\mathbf{n}}$
$\vec{F}_{Lift} = \frac{1}{2} C_D S_{im} \rho_w V^2 \hat{\mathbf{t}}$
$\vec{F}_g = -Mg\hat{z}$
$\vec{F}_{reaction} = \vec{F}_{Lift} + \vec{F}_{Drag}$


Model
z
x
Y
n
t
θ
β
z
V
S_{im}
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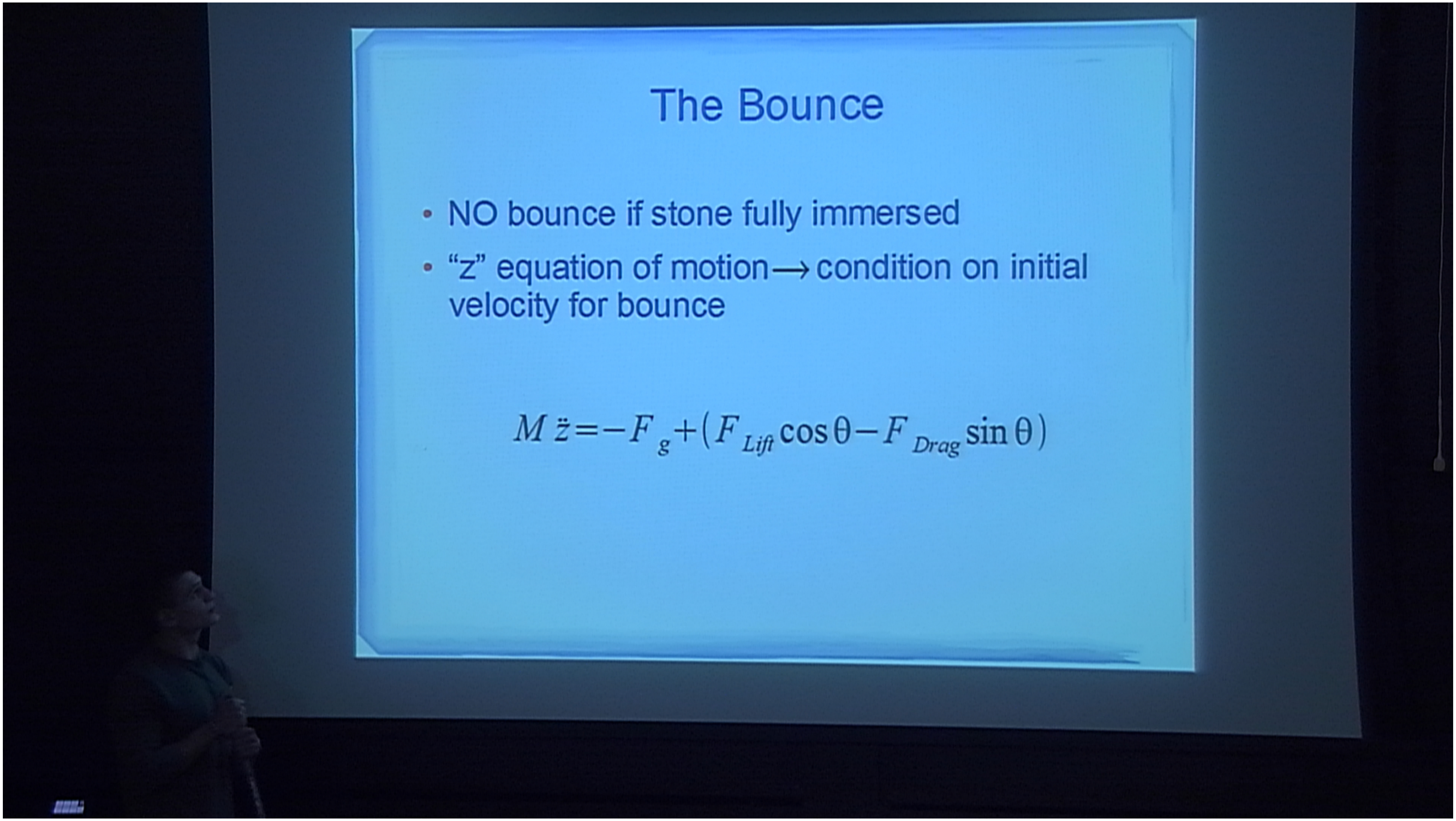
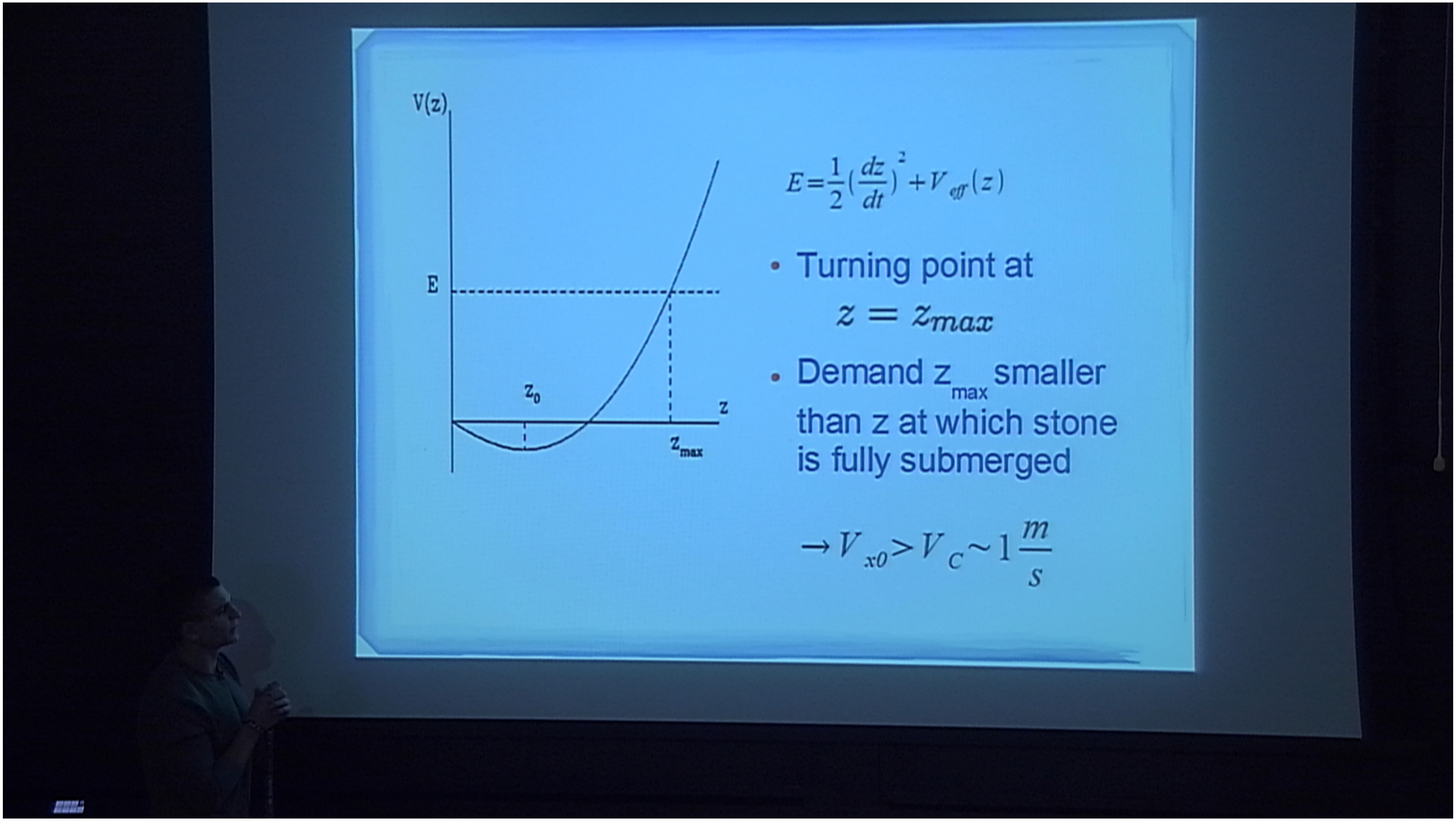
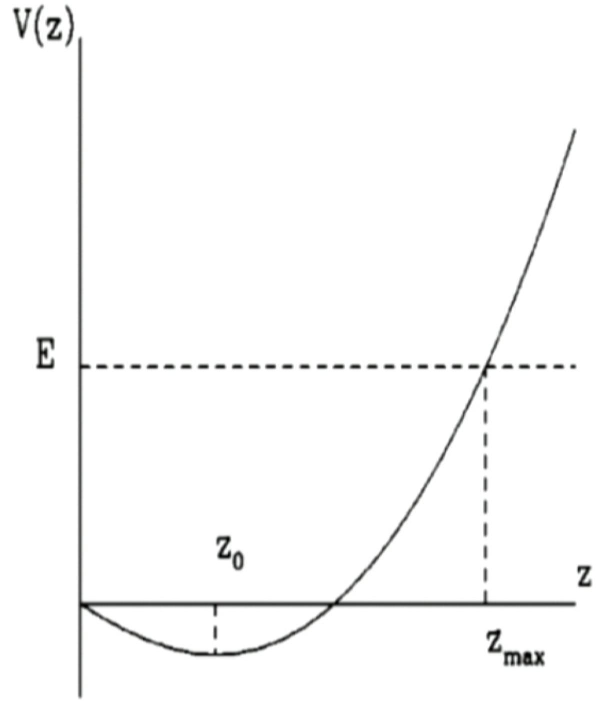

The Bounce
• NO bounce if stone fully immersed
• "z" equation of motion⟶condition on initial velocity for bounce
$M\ddot{z} = -F_g + (F_{Lift}\cos\theta - F_{Drag}\sin\theta)$


V(z)
E
z_0
z
z_{max}
$E = \frac{1}{2}(\frac{dz}{dt})^2 + V_{eff}(z)$
• Turning point at
$z = z_{max}$
• Demand z_{max} smaller than z at which stone is fully submerged
$\rightarrow V_{x0} > V_C \sim 1 \frac{m}{s}$



$$E = \frac{1}{2}\left(\frac{dz}{dt}\right)^2 + V_{eff}(z)$$

- Turning point at

$$z = z_{max}$$

- Demand z_{max} smaller than z at which stone is fully submerged

$$\rightarrow V_{x0} > V_C \sim 1\,\frac{m}{s}$$

Energy Dissipation

- What slows the stone down?
  - Dissipation in x-motion from lift and drag
  - $\langle F_x \rangle = \mu \langle F_z \rangle \approx \mu M g$
  - $W = Fl = \mu M g l$

- $W < \frac{1}{2} V_{x0}^2$ gives new min velocity

$$V_{x0} < V_c = \sqrt{2\mu g l} \approx 2\frac{m}{s}$$

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Spin

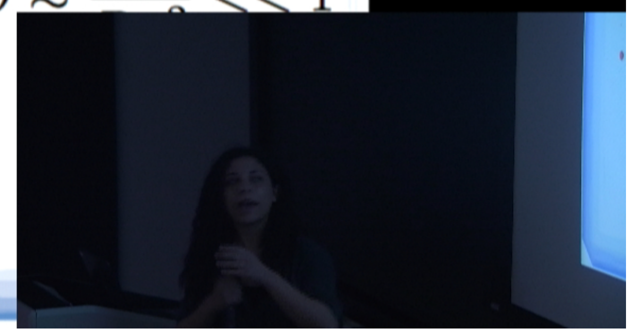
- The torque from lift changes incidence angle (want small, constant)
- Without spin about y-axis, unstable

$$\ddot{\theta} + \omega^2(\theta - \theta_0) = \frac{M_\theta}{I_t}$$

$$\omega = \frac{I_n - I_t}{I_t}\dot{\phi}_0$$

- Gyroscopic effect keeps max deviation $\delta\theta \approx \frac{g}{[illegible]} << 1$ via condition on spin

$$\dot{\phi} \approx \omega >> \sqrt{\frac{g}{R}}$$



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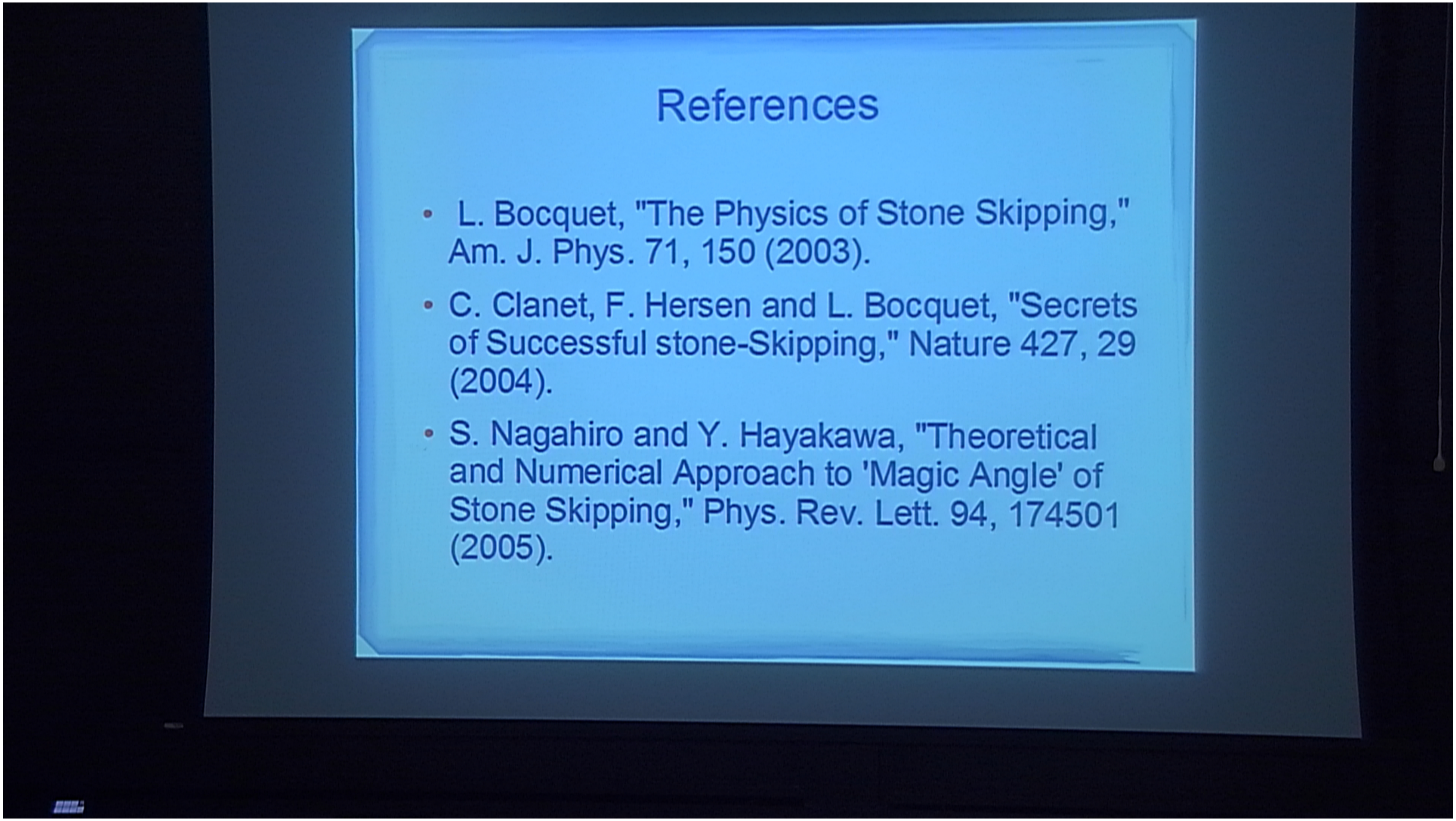
References
L. Bocquet, "The Physics of Stone Skipping," Am. J. Phys. 71, 150 (2003).
C. Clanet, F. Hersen and L. Bocquet, "Secrets of Successful stone-Skipping," Nature 427, 29 (2004).
S. Nagahiro and Y. Hayakawa, "Theoretical and Numerical Approach to 'Magic Angle' of Stone Skipping," Phys. Rev. Lett. 94, 174501 (2005).

How Does Rain Drop?

Lucía Gómez-Córdova, Martin Houde,
Jason Wien

PSI 2013-2014

Raindrop Formation

Cloud Droplets

- Saturation vapor pressure
- Aerosols
- ~10μm

Increasing size → raindrops (~1mm)

Collision & coalescence

Bergeron process

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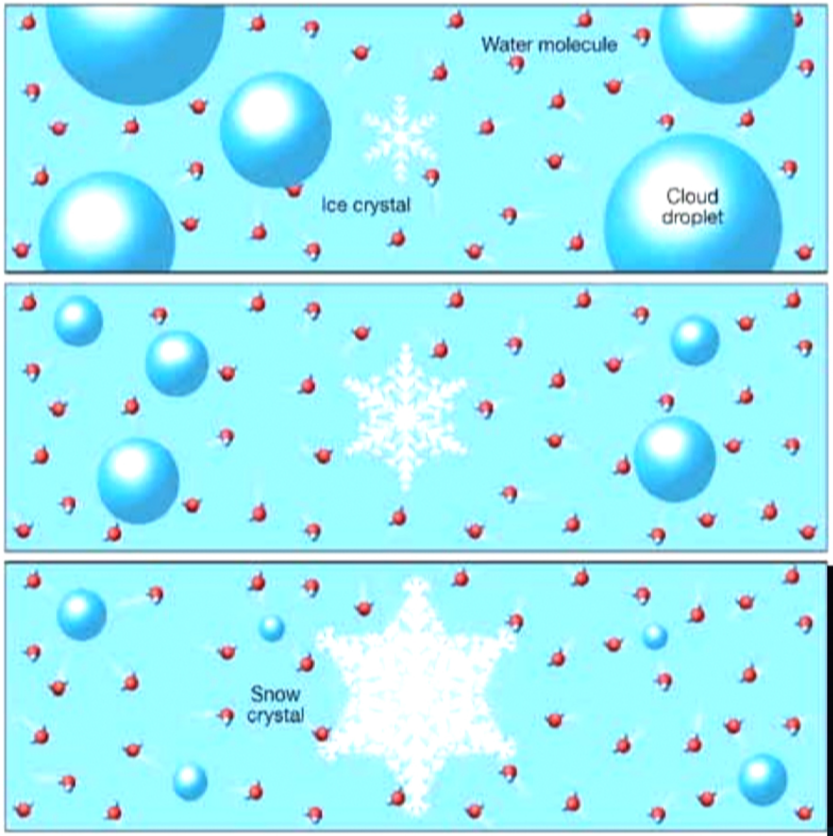
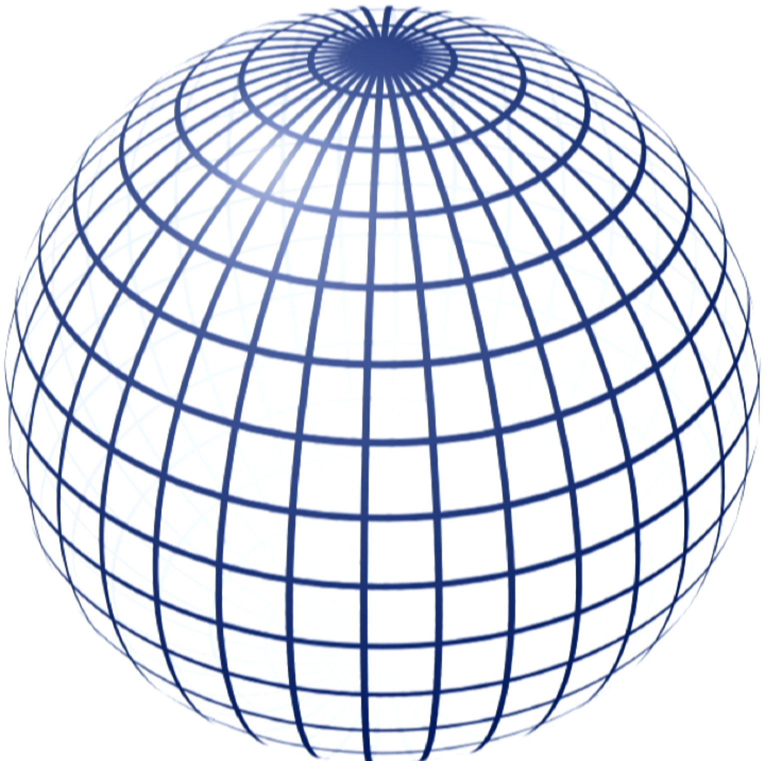
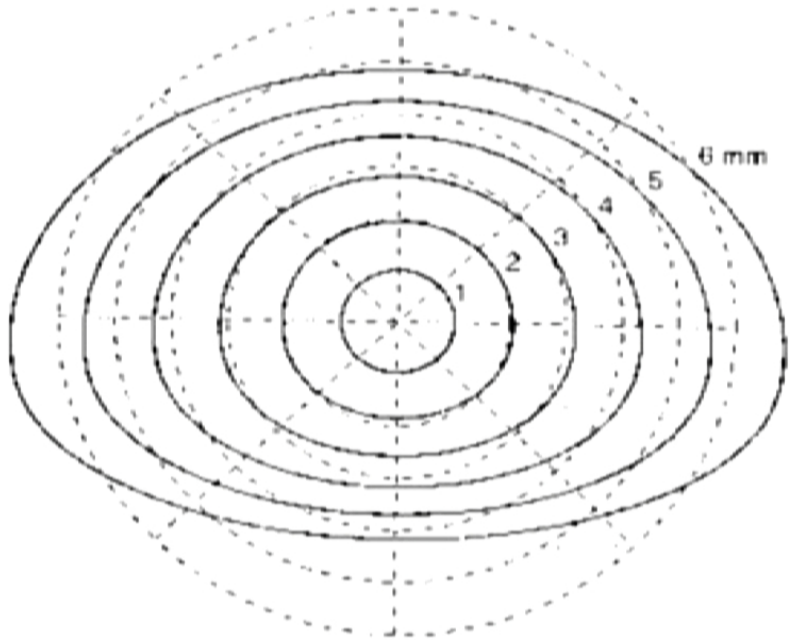


Free Raindrop Shape



$$\Delta P \equiv P_{\text{inside}} - P_{\text{outside}} = \gamma \left(\frac{1}{R_1} + \frac{1}{R_2} \right),$$

Falling Raindrop

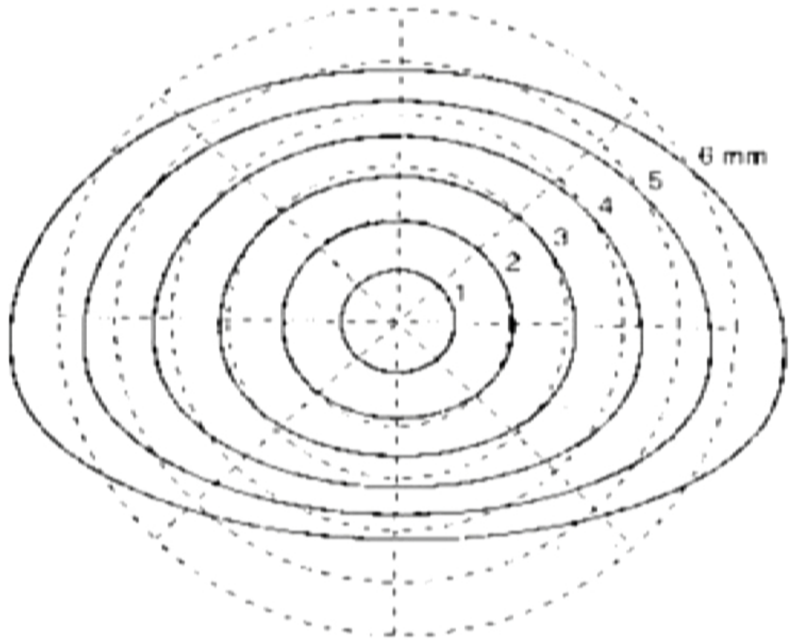


$$\frac{\rho}{2} Re\, \boldsymbol{v} \cdot \boldsymbol{\nabla v} = \boldsymbol{\nabla} \cdot \boldsymbol{T}_l \text{ with } \boldsymbol{T}_l \equiv -p\boldsymbol{I} + \mu[\boldsymbol{\nabla v} + (\boldsymbol{\nabla v})^T], \quad (1)$$

and

$$\frac{1}{2} Re\, \boldsymbol{v} \cdot \boldsymbol{\nabla v} = \boldsymbol{\nabla} \cdot \boldsymbol{T}_g \text{ with } \boldsymbol{T}_g \equiv -p\boldsymbol{I} + \boldsymbol{\nabla v} + (\boldsymbol{\nabla v})^T, \quad (2)$$

Falling Raindrop



$$\frac{\rho}{2} Re\, \boldsymbol{v} \cdot \boldsymbol{\nabla} \boldsymbol{v} = \boldsymbol{\nabla} \cdot \boldsymbol{T}_l \text{ with } \boldsymbol{T}_l \equiv -p\boldsymbol{I} + \mu[\boldsymbol{\nabla}\boldsymbol{v} + (\boldsymbol{\nabla}\boldsymbol{v})^T], \quad (1)$$

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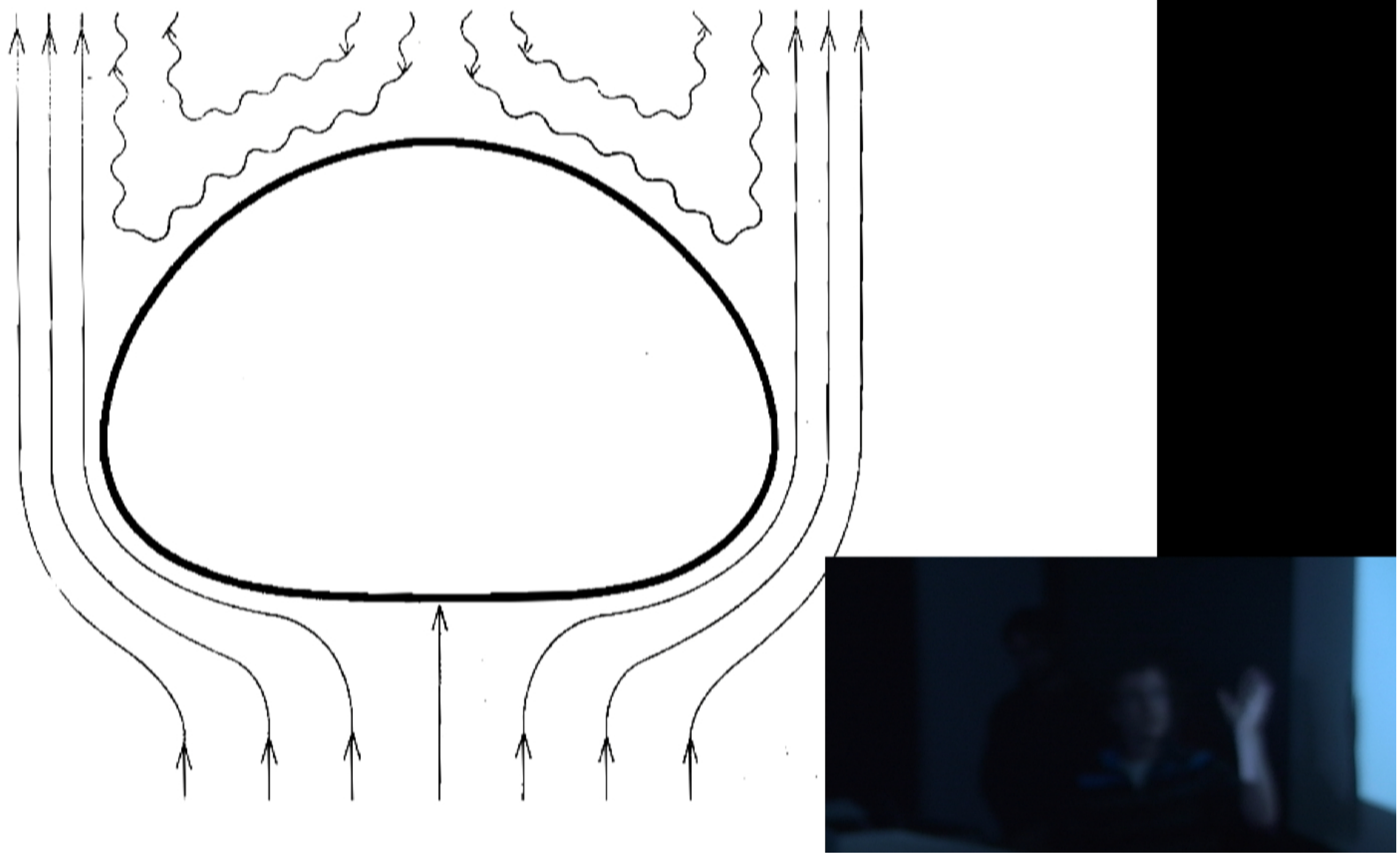
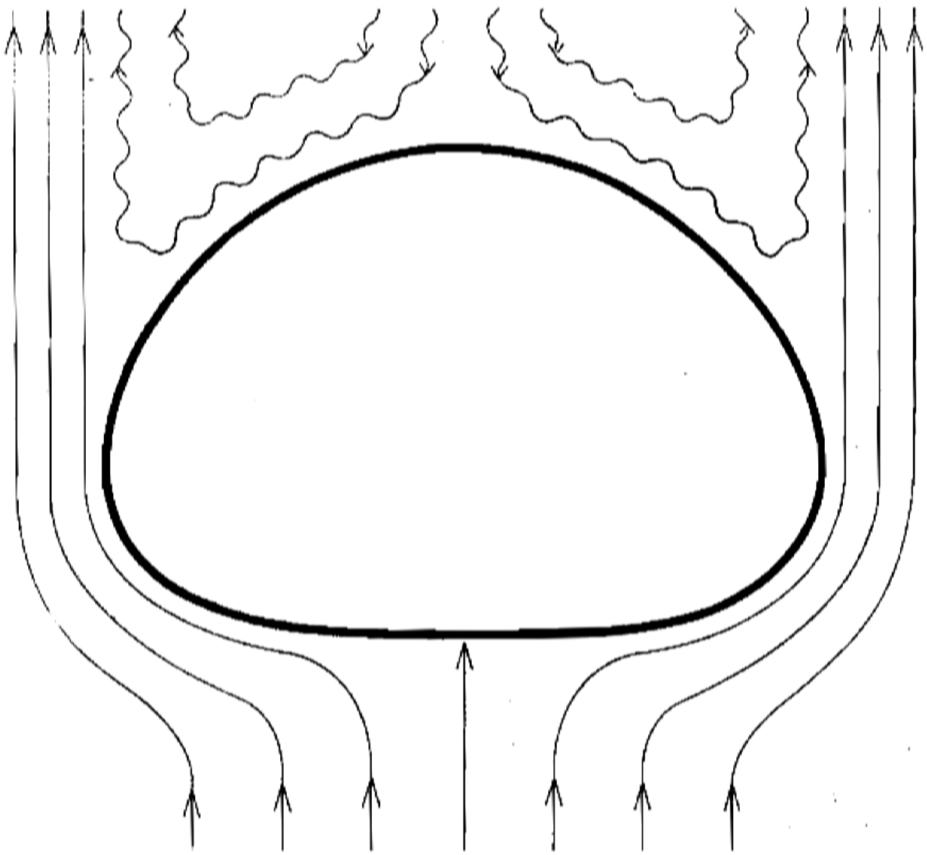
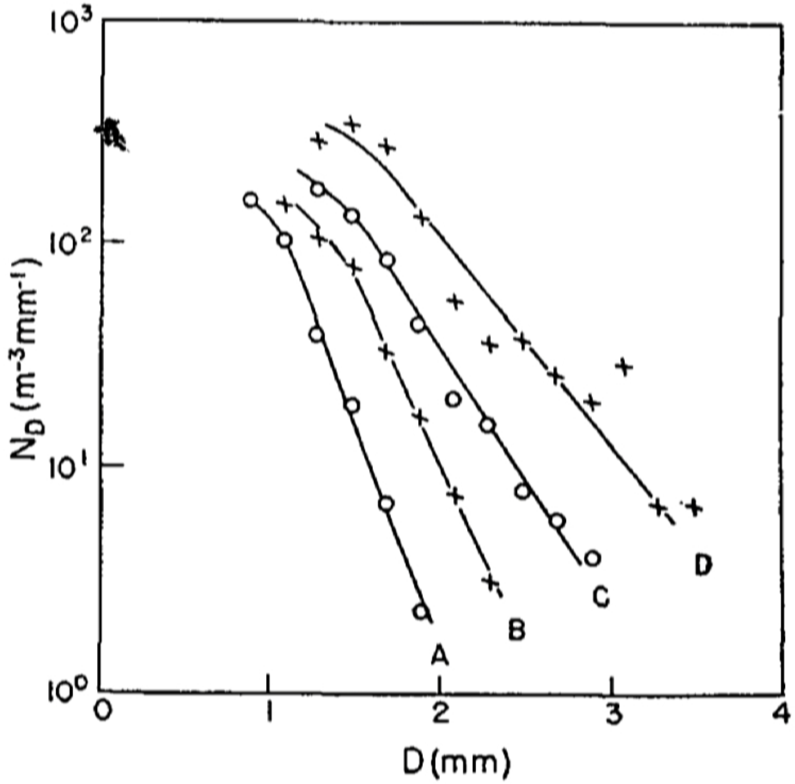


Falling Raindrop



Raindrop Size:
Marshall-Palmer Distribution (1948)



N_D δD: the density of drops with diameter between D and D + δD

Exponential Model:

$N_D = N_0 \, e^{-\Lambda D}$

$N_0 = 0.08$ cm^{-4}, $\Lambda = 41 \, R^{-0.21}$ cm^{-1}, and R is the rate of rainfall in mm/hr.

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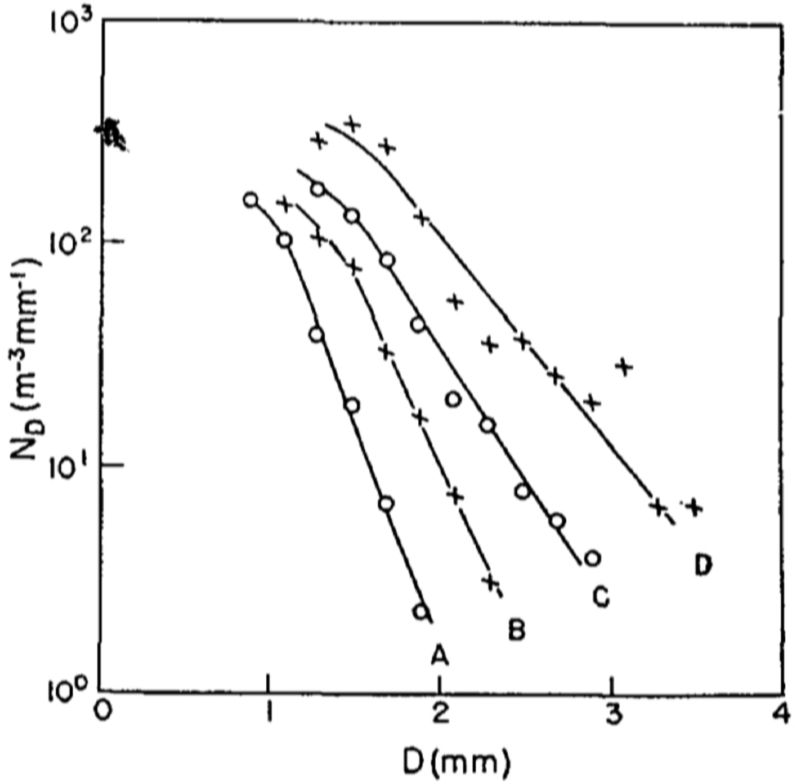

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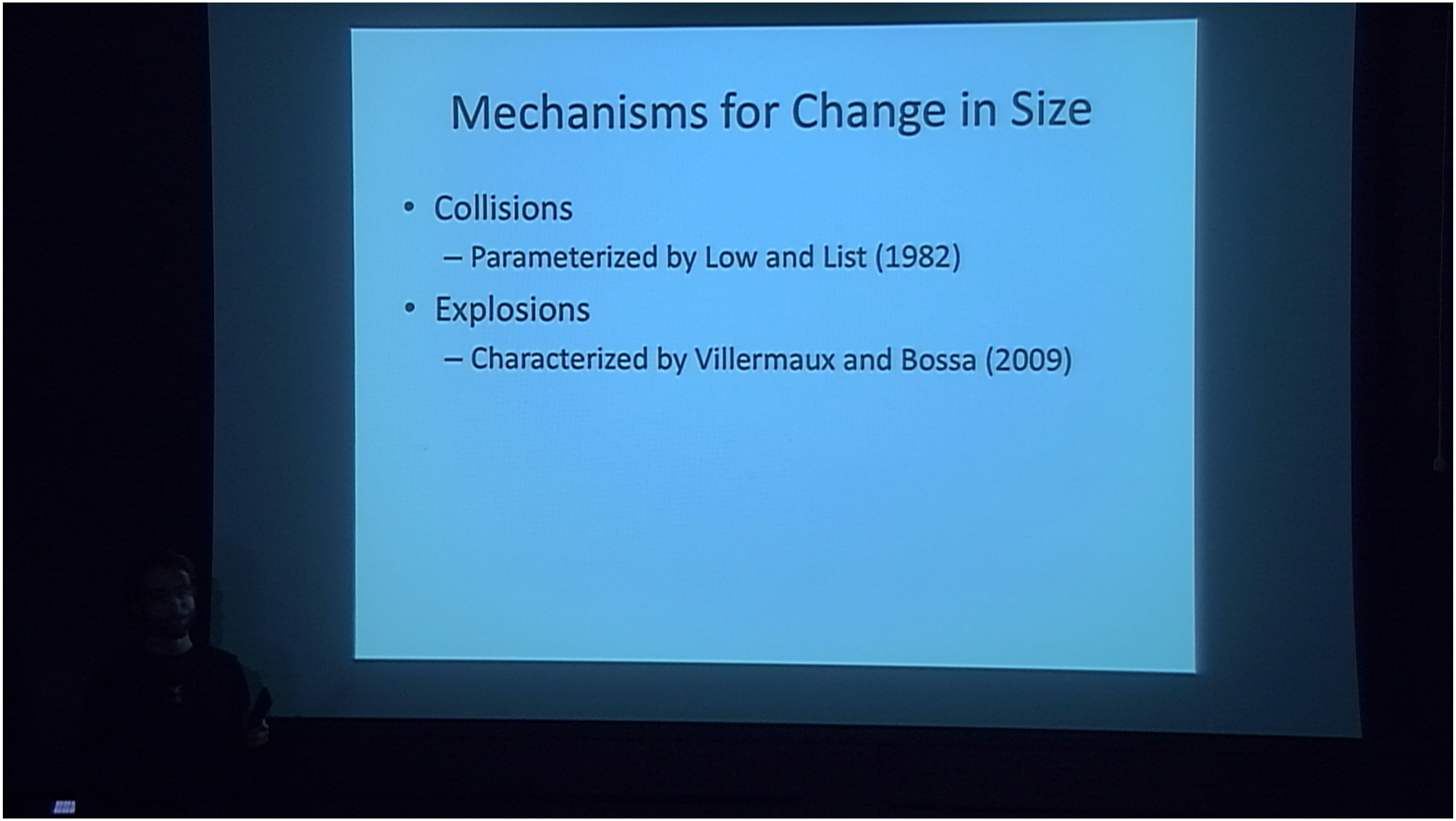
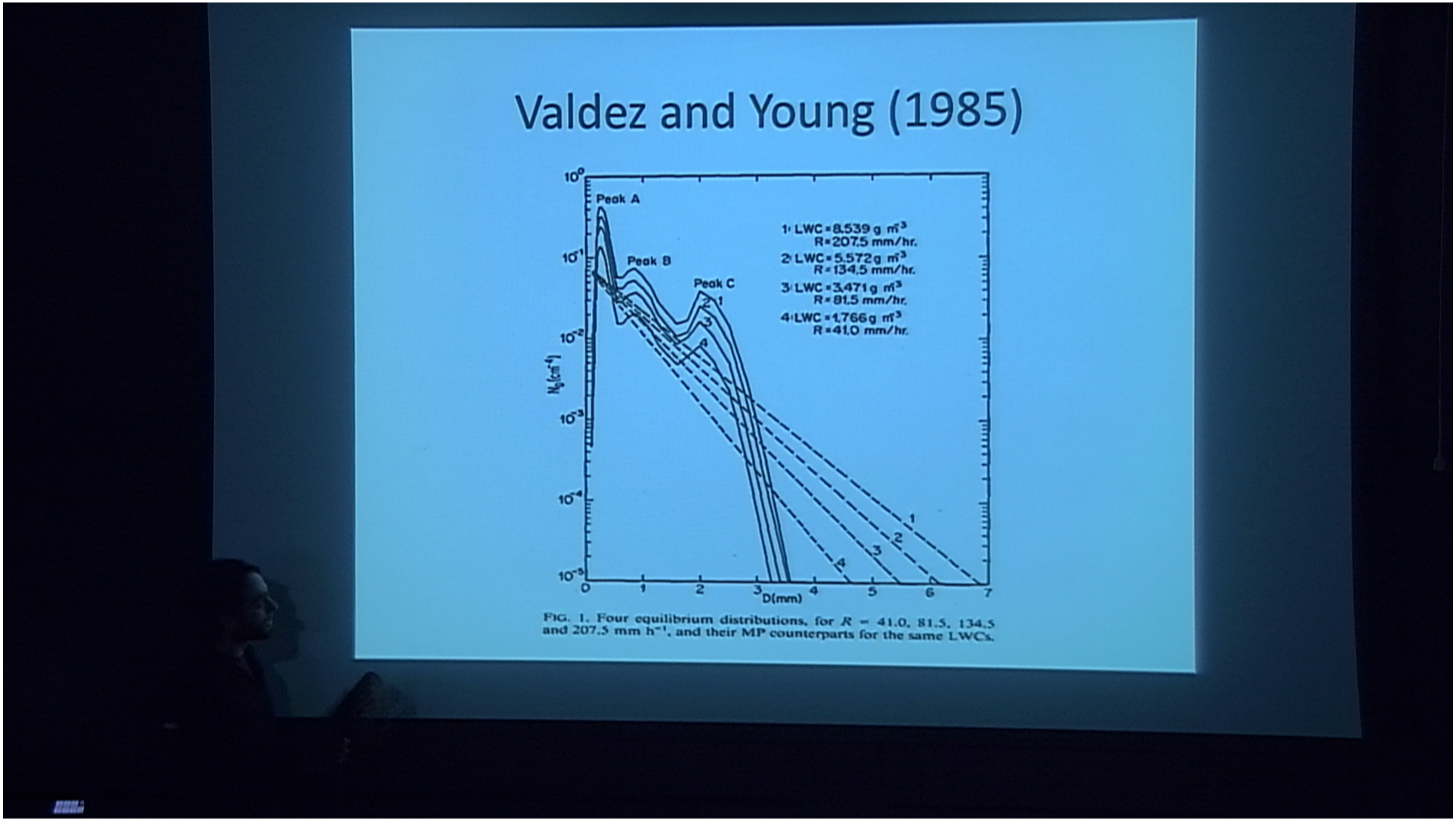
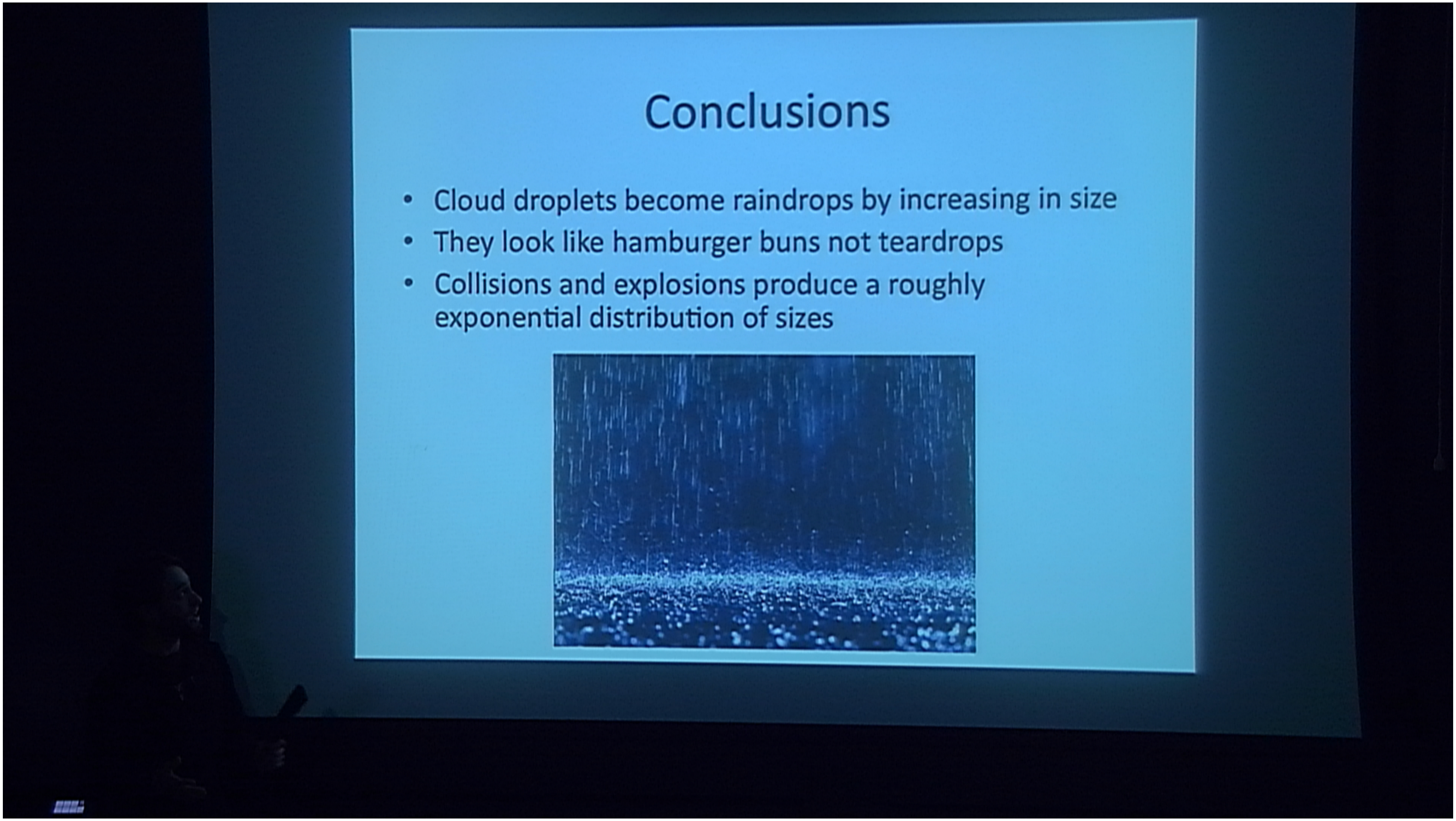
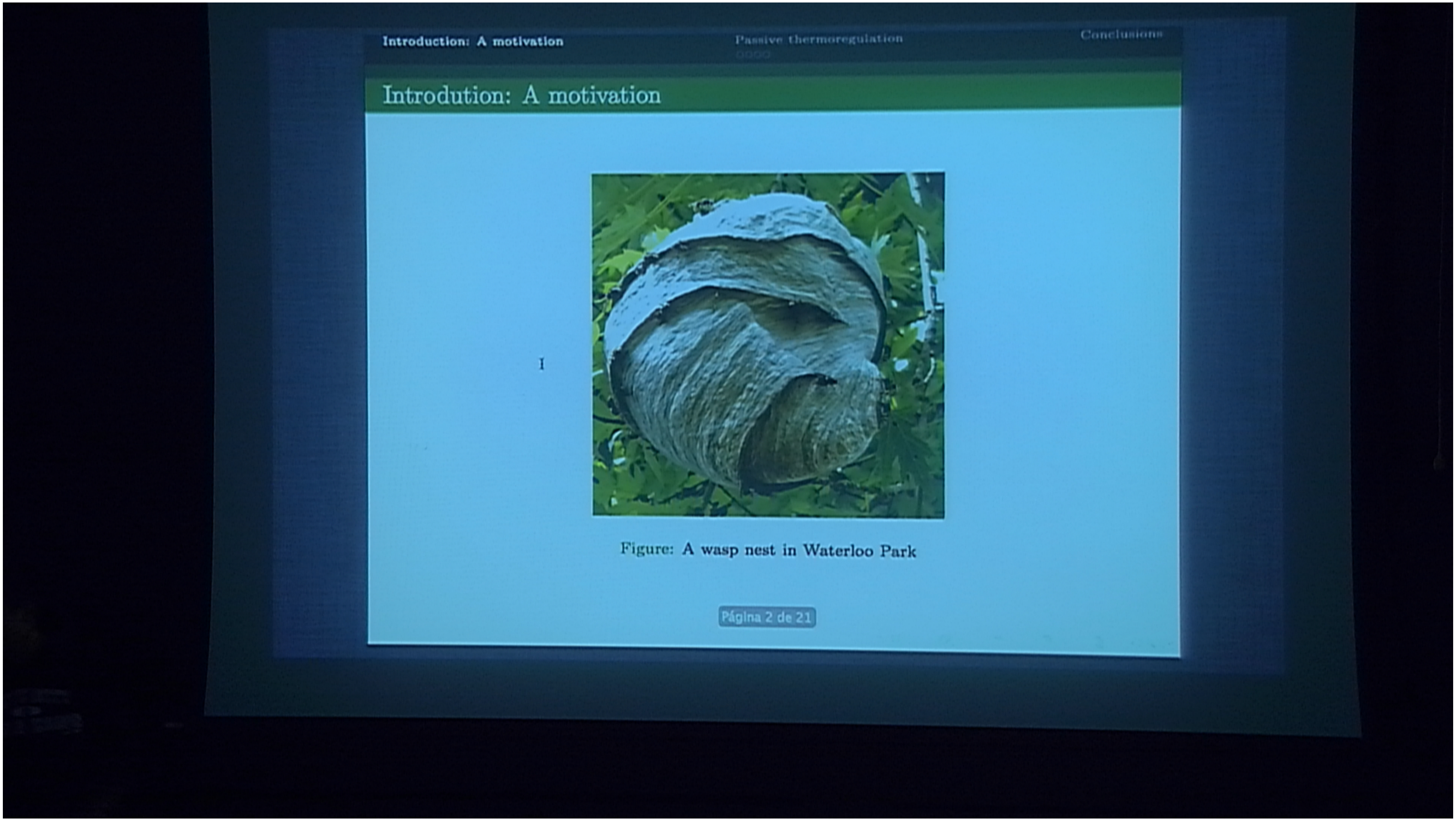

Mechanisms for Change in Size
• Collisions
– Parameterized by Low and List (1982)
• Explosions
– Characterized by Villermaux and Bossa (2009)



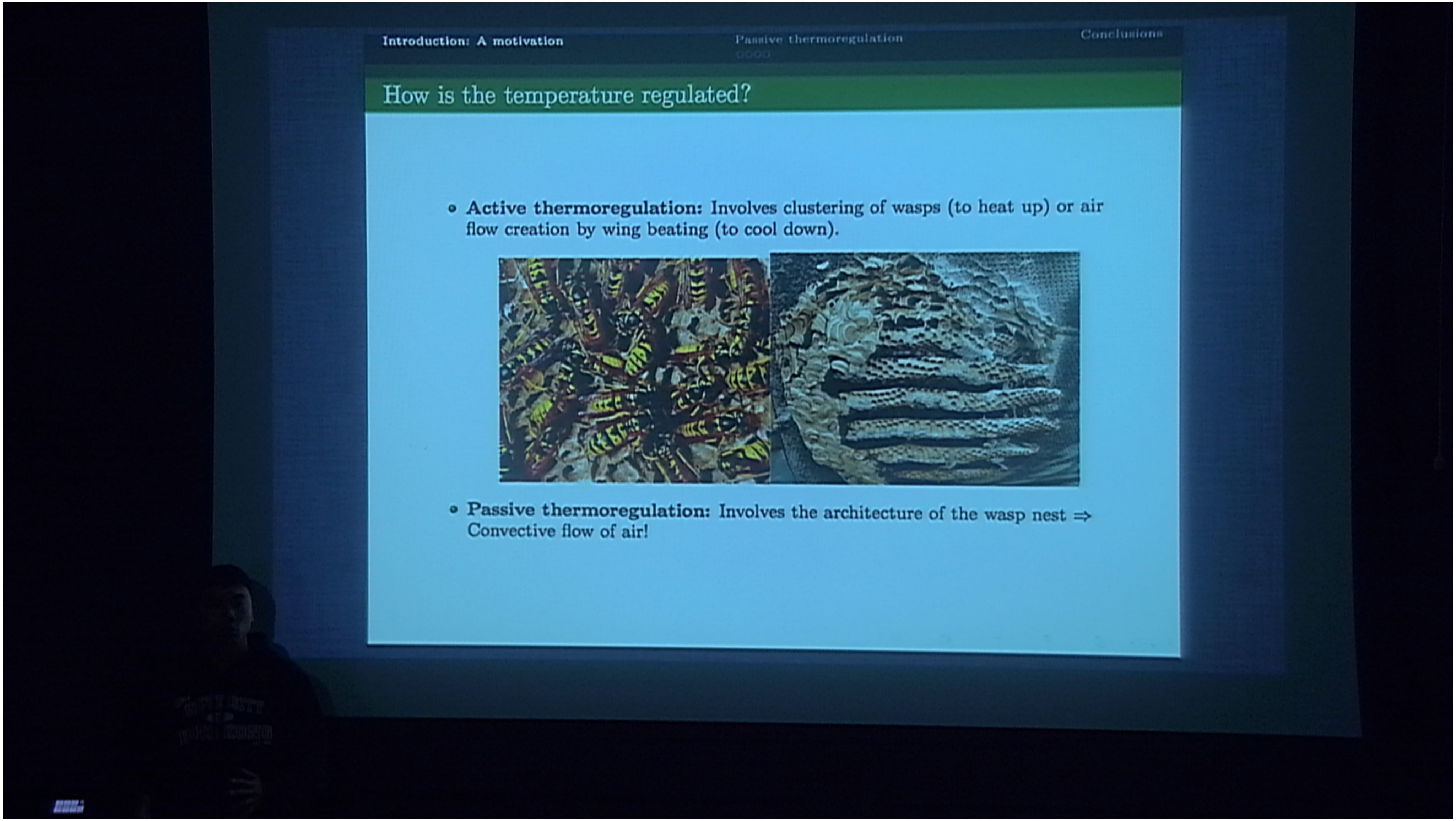
Valdez and Young (1985)
Peak A
Peak B
Peak C
1: LWC = 8.539 g m⁻³ R = 207.5 mm/hr.
2: LWC = 5.572 g m⁻³ R = 134.5 mm/hr.
3: LWC = 3.471 g m⁻³ R = 81.5 mm/hr.
4: LWC = 1.766 g m⁻³ R = 41.0 mm/hr.
N_D (cm⁻⁴)
D(mm)
FIG. 1. Four equilibrium distributions, for R = 41.0, 81.5, 134.5 and 207.5 mm h⁻¹, and their MP counterparts for the same LWCs.


Exploding Raindrops
Villermaux and Bossa (2009)


Conclusions
• Cloud droplets become raindrops by increasing in size
• They look like hamburger buns not teardrops
• Collisions and explosions produce a roughly exponential distribution of sizes


Introduction: A motivation
Passive thermoregulation
Conclusions
Introdution: A motivation
Figure: A wasp nest in Waterloo Park
Página 2 de 21


Introduction: A motivation
Passive thermoregulation
Conclusions
Why is the hive's thermoregulation important?


Introduction: A motivation
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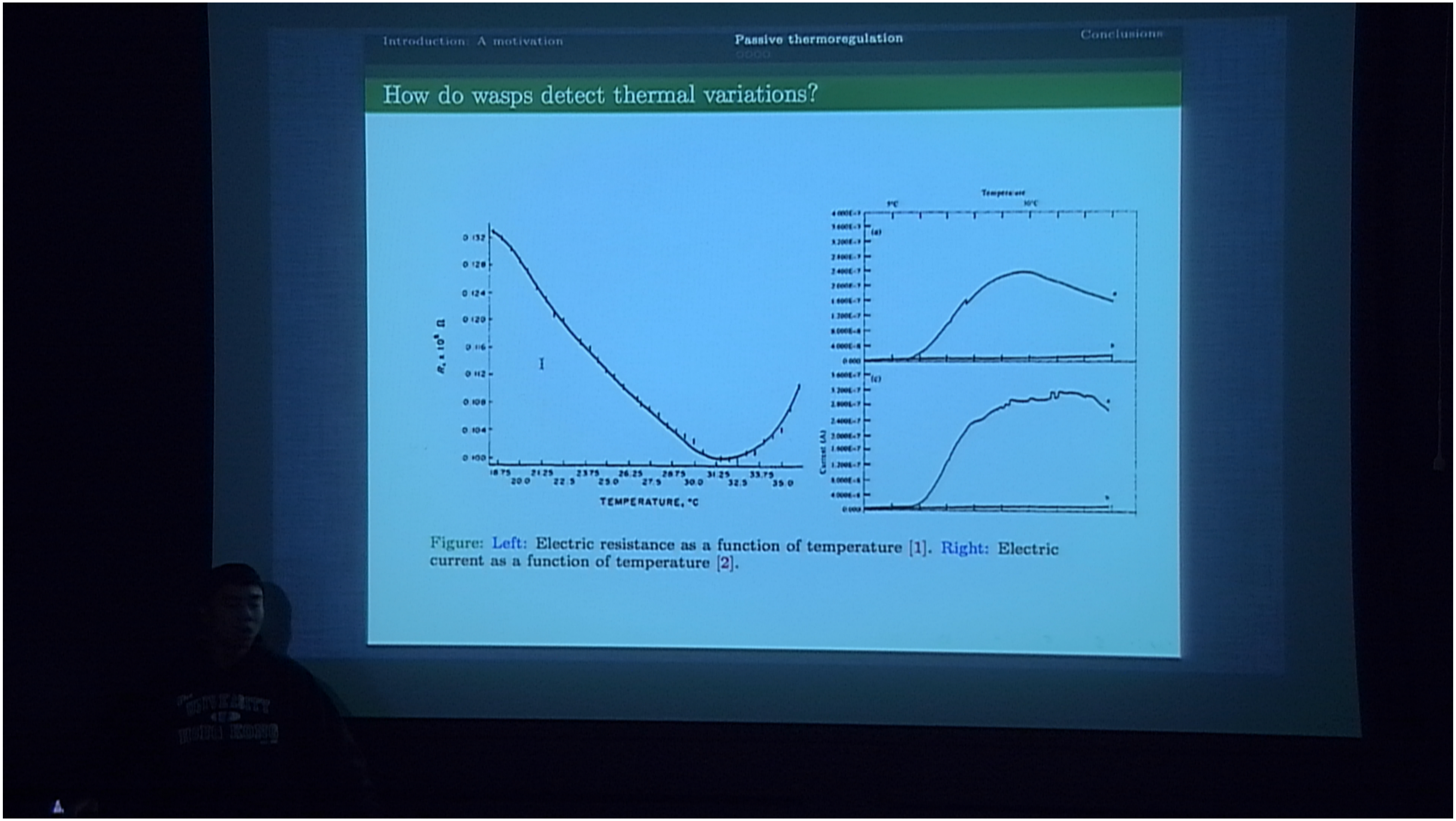
Conclusions
How is the temperature regulated?
Active thermoregulation: Involves clustering of wasps (to heat up) or air flow creation by wing beating (to cool down).
Passive thermoregulation: Involves the architecture of the wasp nest ⇒ Convective flow of air!


Introduction: A motivation
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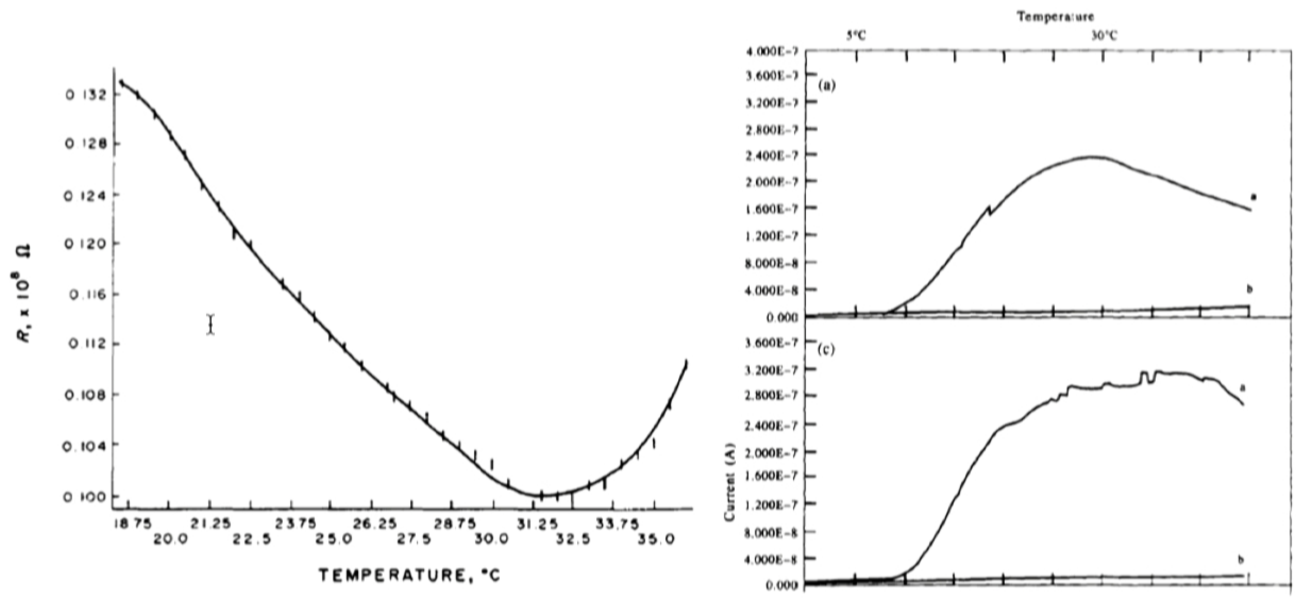
How do wasps detect thermal variations?
TEMPERATURE, °C
Figure: Left: Electric resistance as a function of temperature [1]. Right: Electric current as a function of temperature [2].

How do wasps detect thermal variations?



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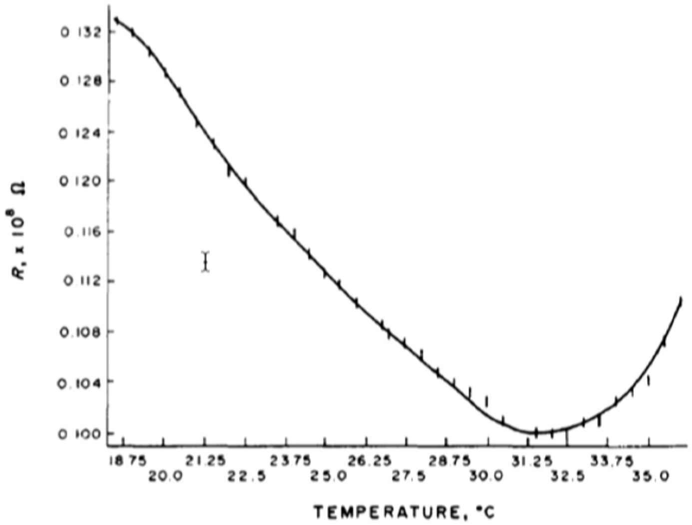

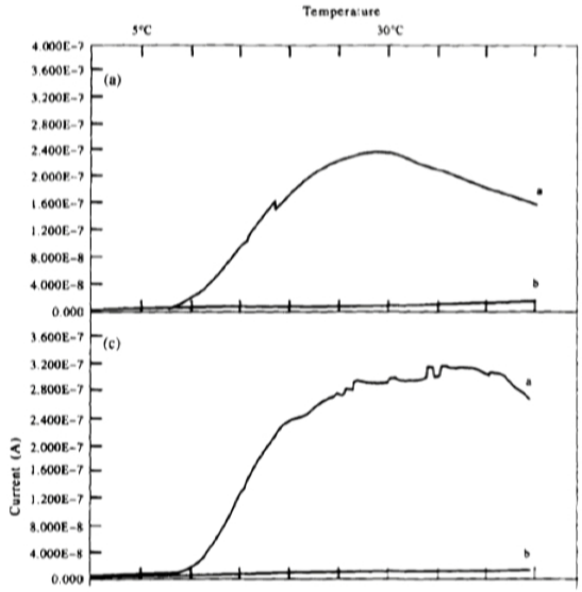

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Polybia spinifex Richards hive model

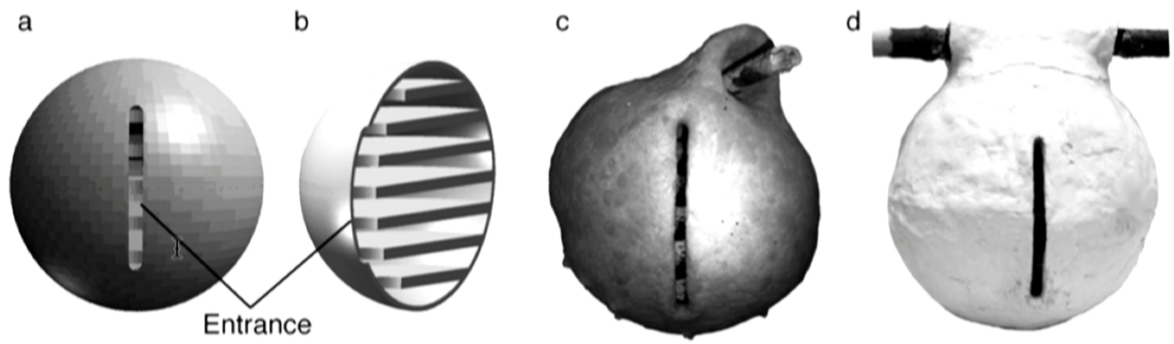


Figure: (*a*) Spherical model, (*b*) Inside hive model, (*c*) and (*d*) Real *Polybia spinifex* Richards hives [3].

Physics background: Fluid Dynamics

- **Mass Equation:**

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{u}) = 0.$$

- **Energy Equation:**

$$\frac{\partial E}{\partial t} + \nabla \cdot (\mathbf{u}(E + p)) = 0.$$

- **Momentum Equation:**

$$\frac{\partial (\rho \mathbf{u})}{\partial t} + \nabla \cdot (\mathbf{u} \otimes (\rho \mathbf{u})) + \nabla p = 0.$$

These equations combine into:

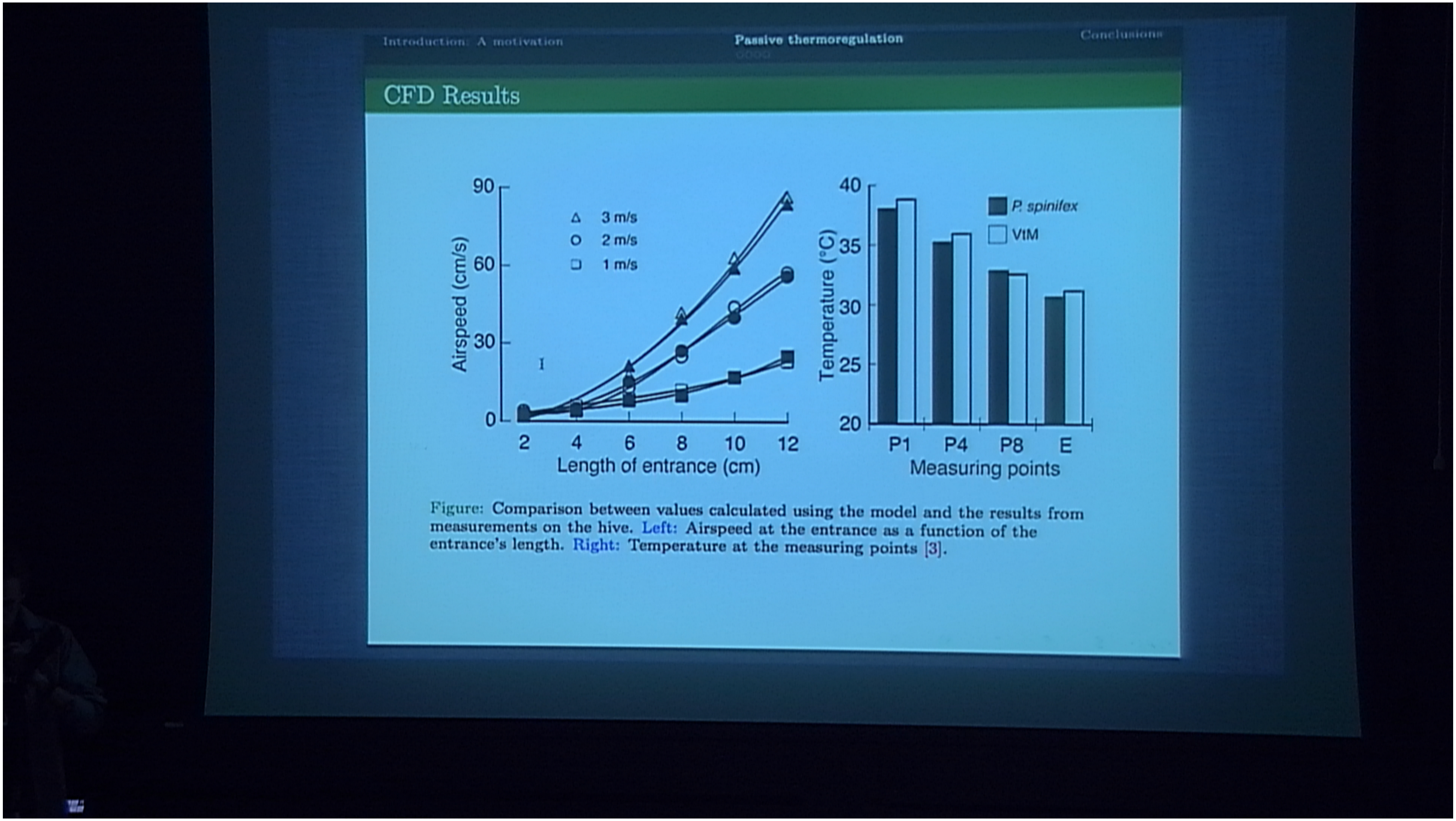
- **Navier Stokes equation:**

$$\rho \left(\frac{\partial \mathbf{u}}{\partial t} + \mathbf{u} \cdot \nabla \mathbf{u} \right) + \nabla p = 0.$$

With the boundary conditions:

- **Inflow/Outflow:**

$$\mathbf{u} \cdot \mathbf{n}|_{\partial M} = u_0 = 0$$


Introduction: A motivation
Passive thermoregulation
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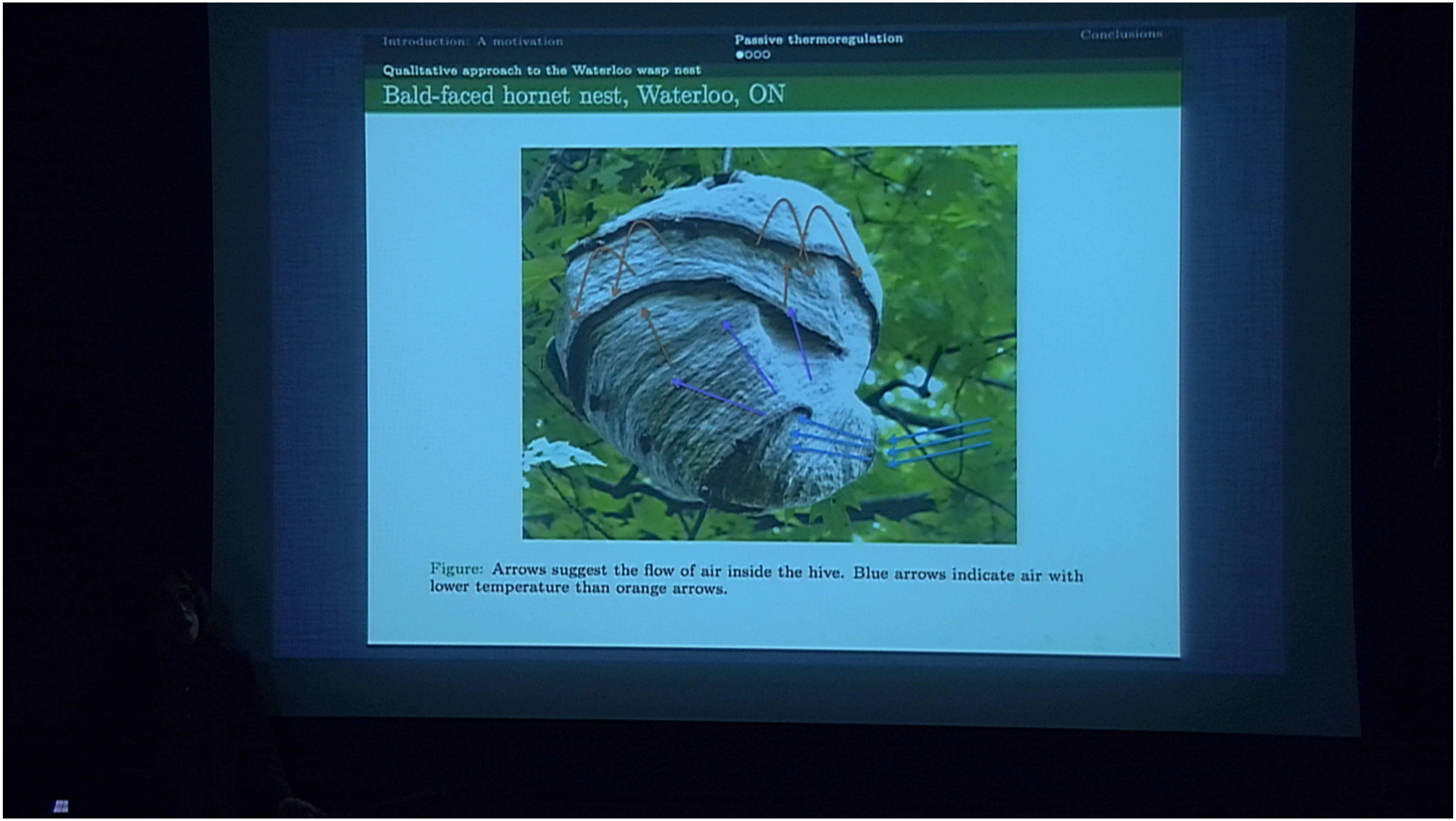
CFD Results
90
60
30
0
Airspeed (cm/s)
3 m/s
2 m/s
1 m/s
2 4 6 8 10 12
Length of entrance (cm)
40
35
30
25
20
Temperature (°C)
P. spinifex
VtM
P1 P4 P8 E
Measuring points
Figure: Comparison between values calculated using the model and the results from measurements on the hive. Left: Airspeed at the entrance as a function of the entrance's length. Right: Temperature at the measuring points [3].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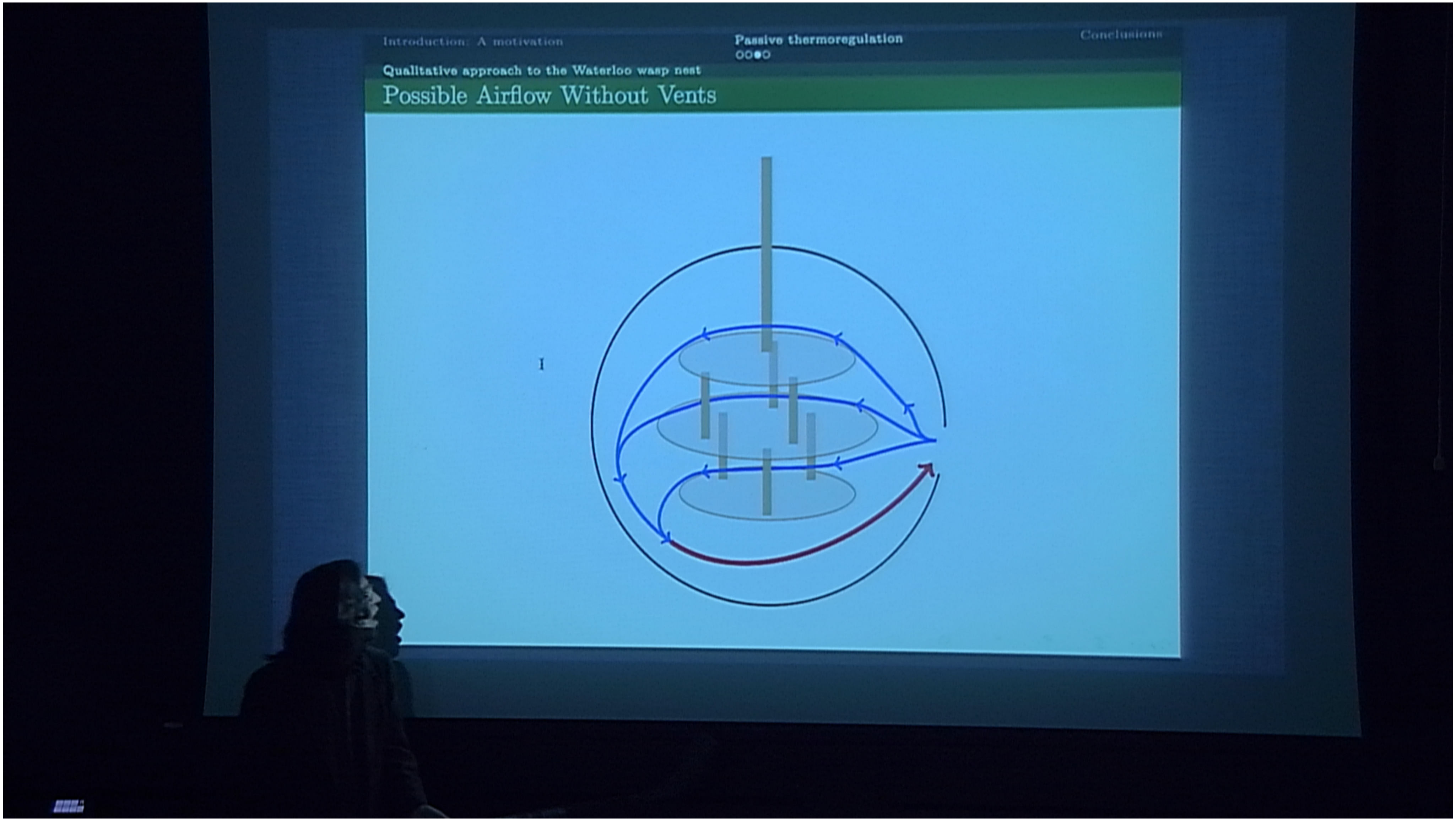
Qualitative approach to the Waterloo wasp nest
Bald-faced hornet nest, Waterloo, ON
Figure: Arrows suggest the flow of air inside the hive. Blue arrows indicate air with lower temperature than orange arrows.


Introduction: A motivation
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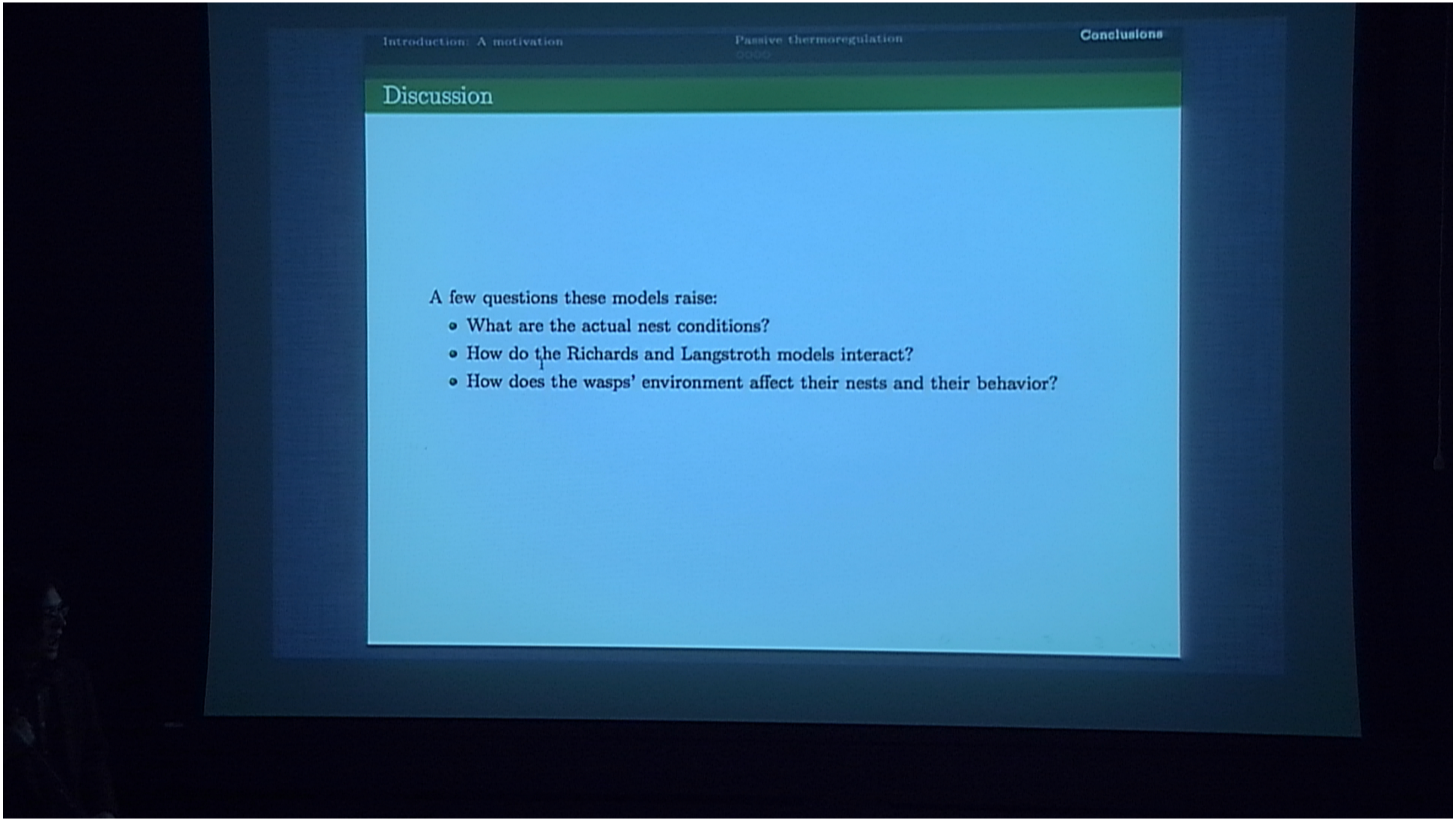
Qualitative approach to the Waterloo wasp nest
Possible Airflow Without Vents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What are the actual nest conditions?
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