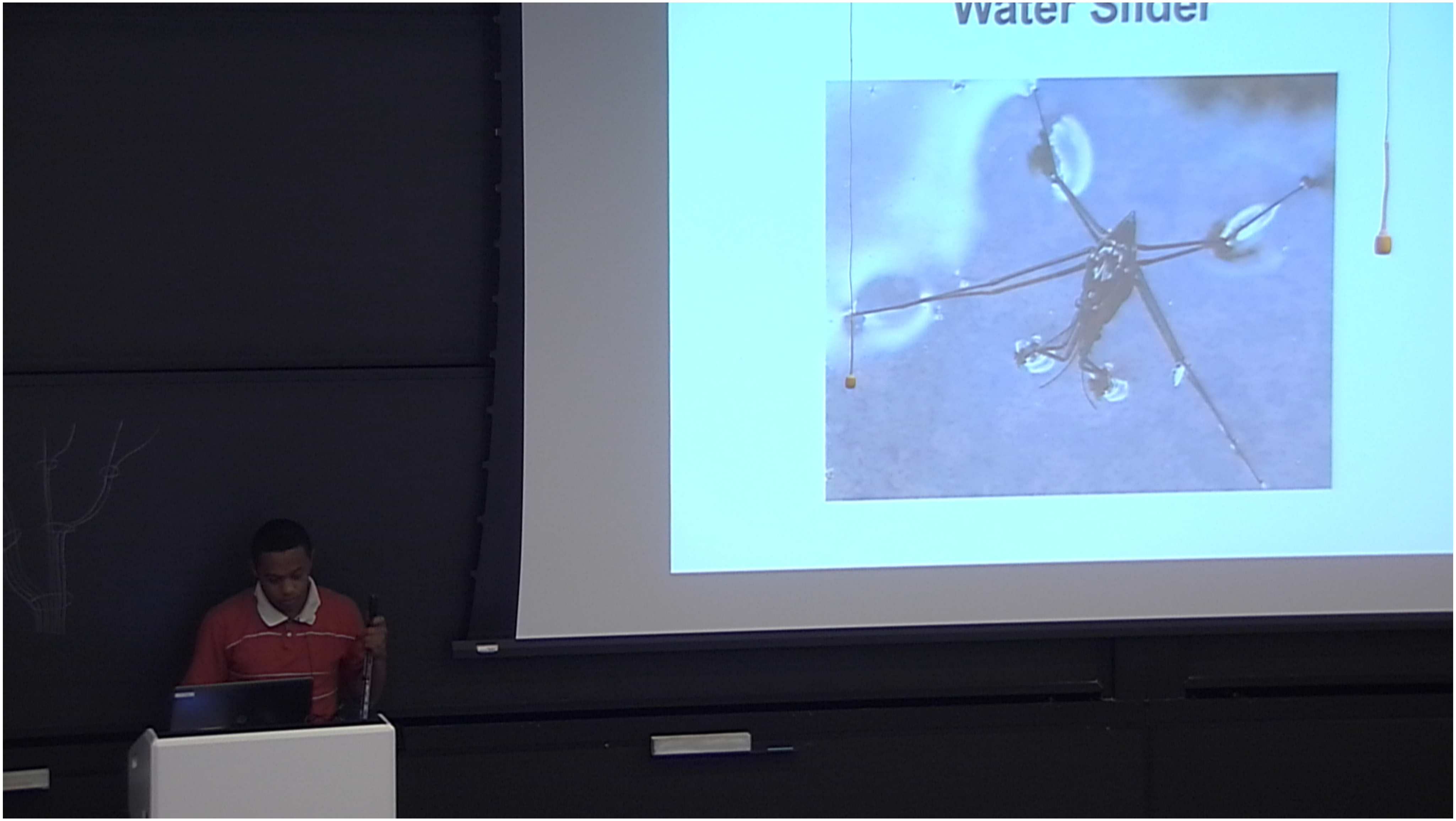
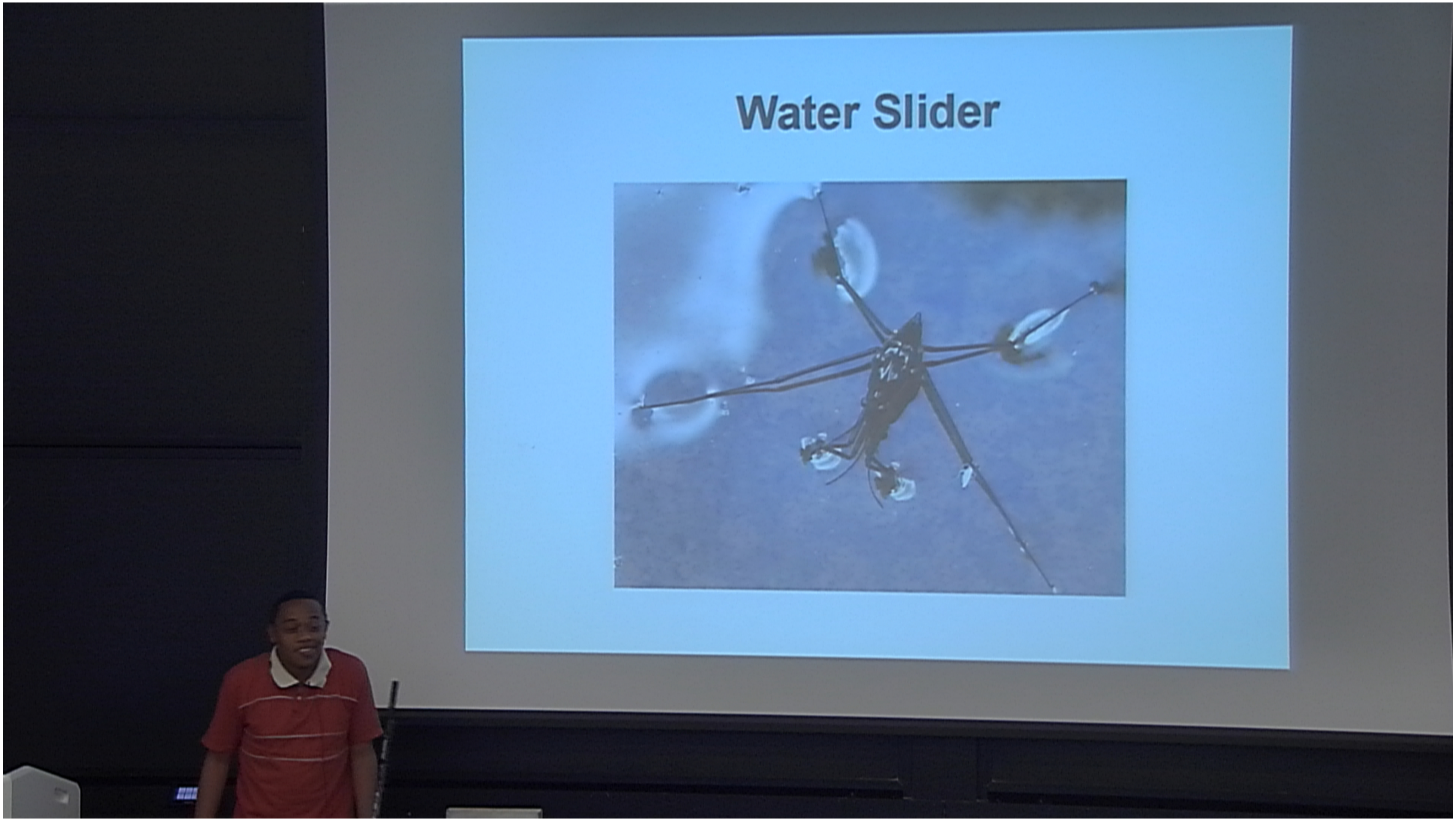
Title: 13/14 PSI - Student Presentations - 3

Date: Aug 16, 2013 02:00 PM

URL: http://pirsa.org/13080038

Abstract:

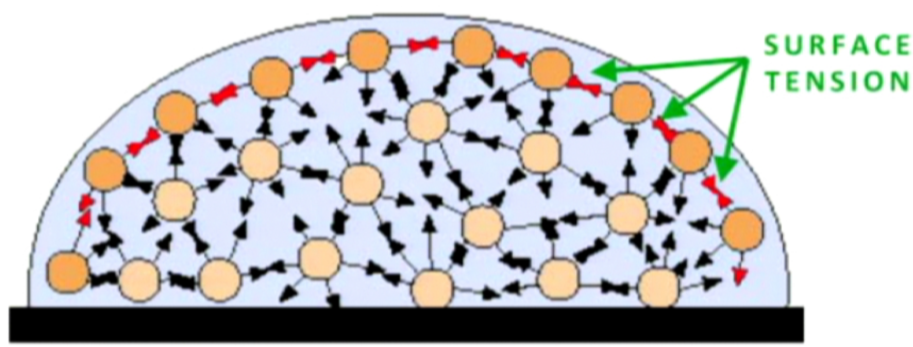



Water Slider

Surface Tension γ

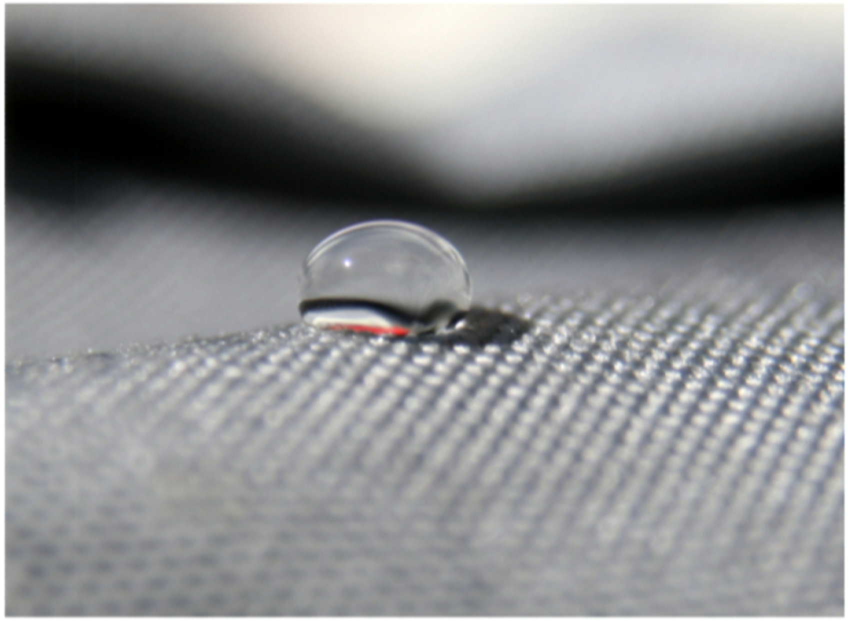
•Property of the surface of a liquid to resist an external force.

•Caused by the attraction of molecules in the surface layer of the liquid.

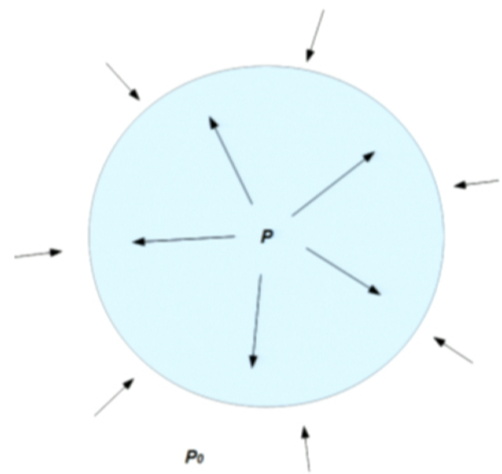


1.Liquid droplets

ɣ provides the necessary wall tension for the formation of liquid droplets.

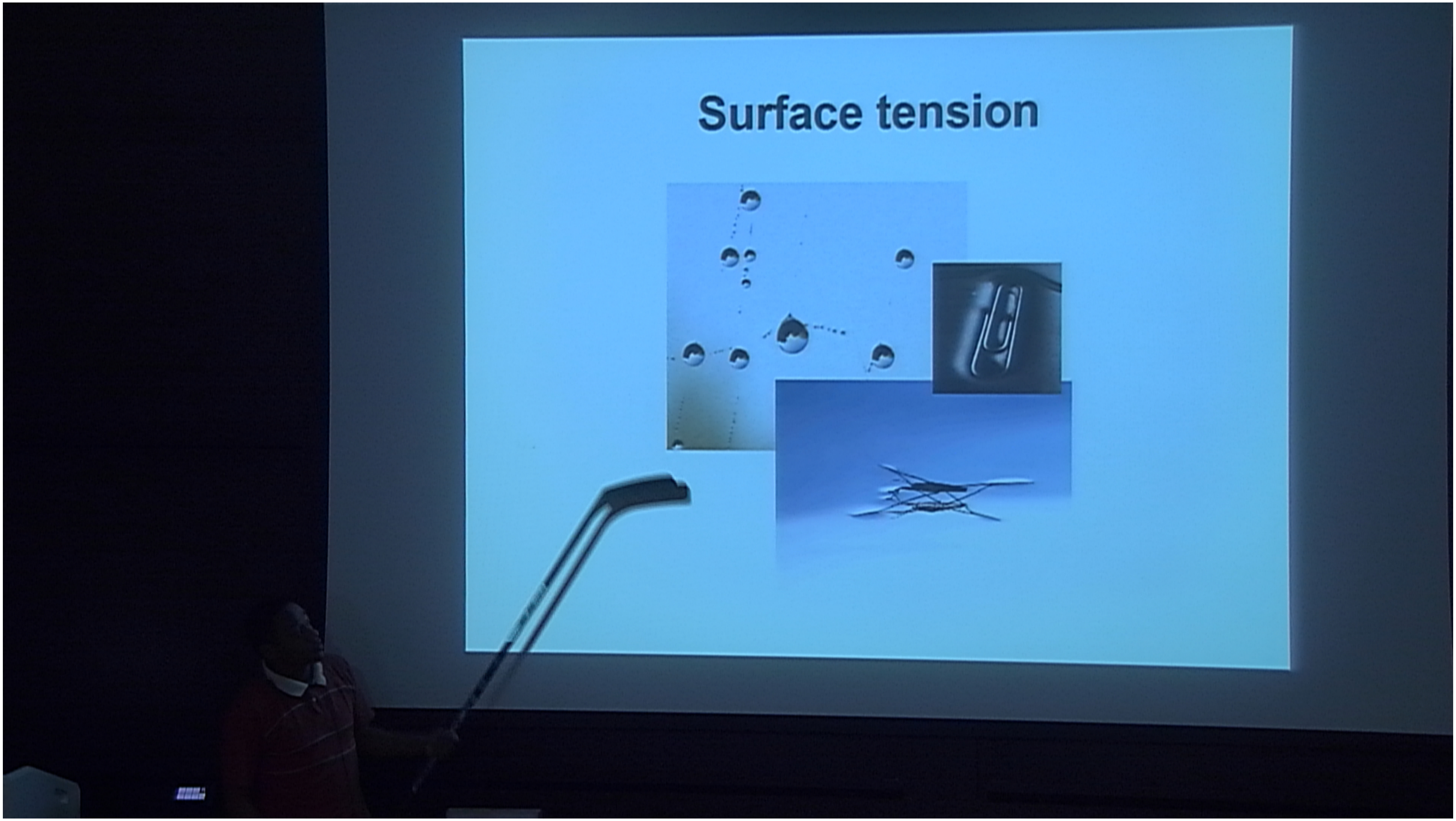


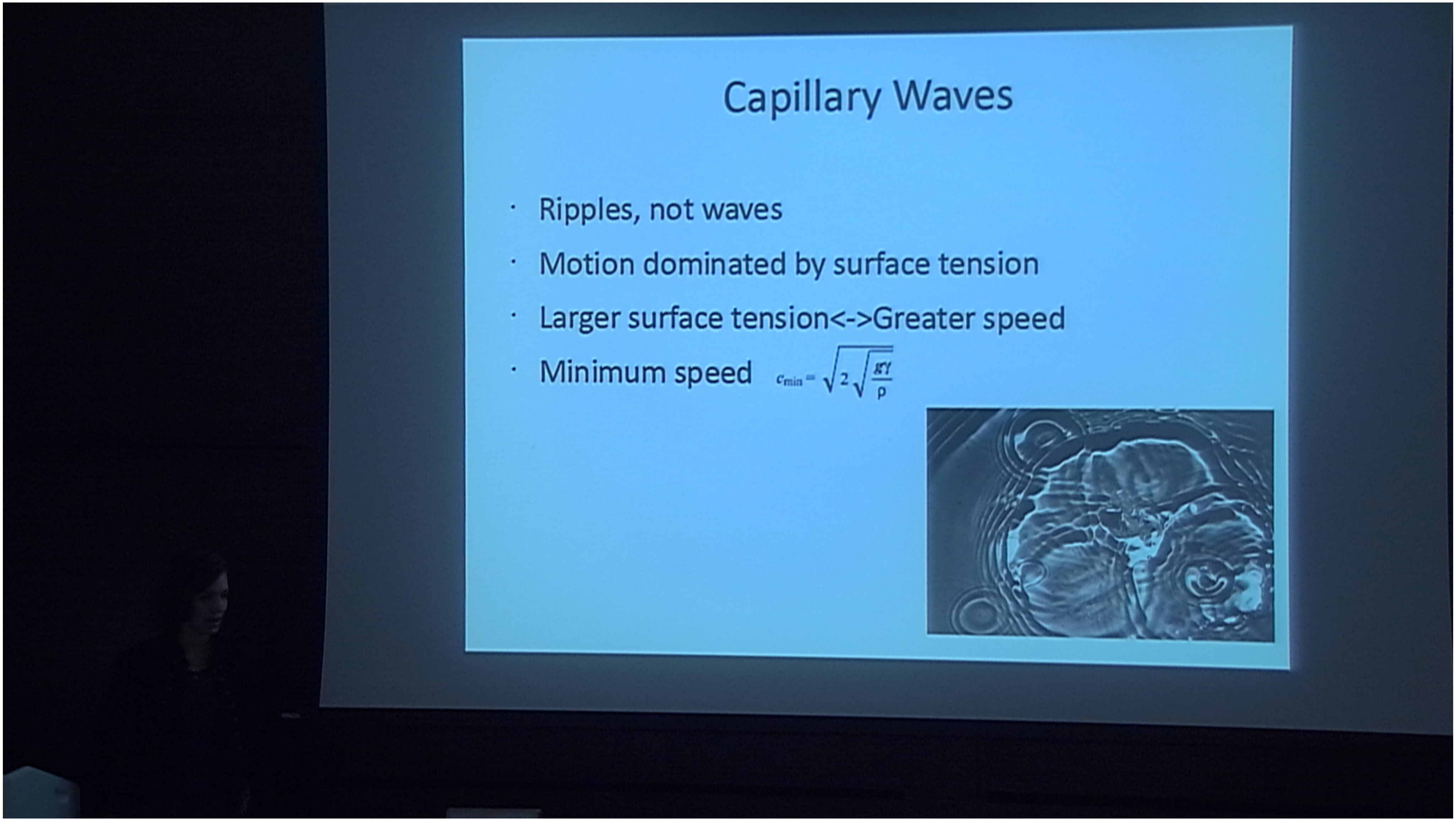
1.Liquid droplets

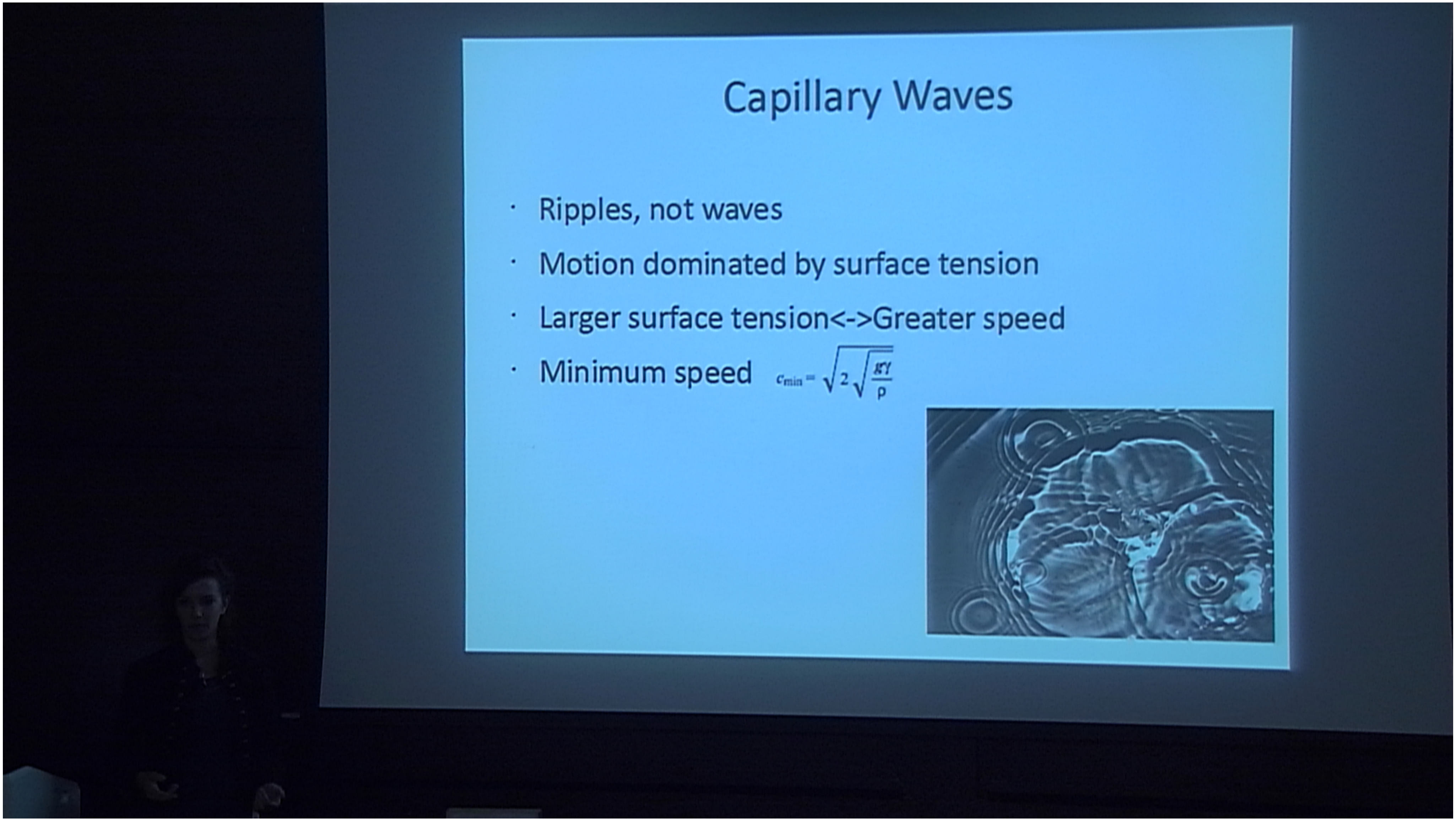


$$dW = \gamma\, dA - \Delta p\, dV$$

$$\Longrightarrow \Delta p = \frac{2\gamma}{R}$$


Surface tension


Capillary Waves
Ripples, not waves
Motion dominated by surface tension
Larger surface tension<->Greater speed
Minimum speed $c_{min} = \sqrt{2\sqrt{\frac{g\gamma}{\rho}}}$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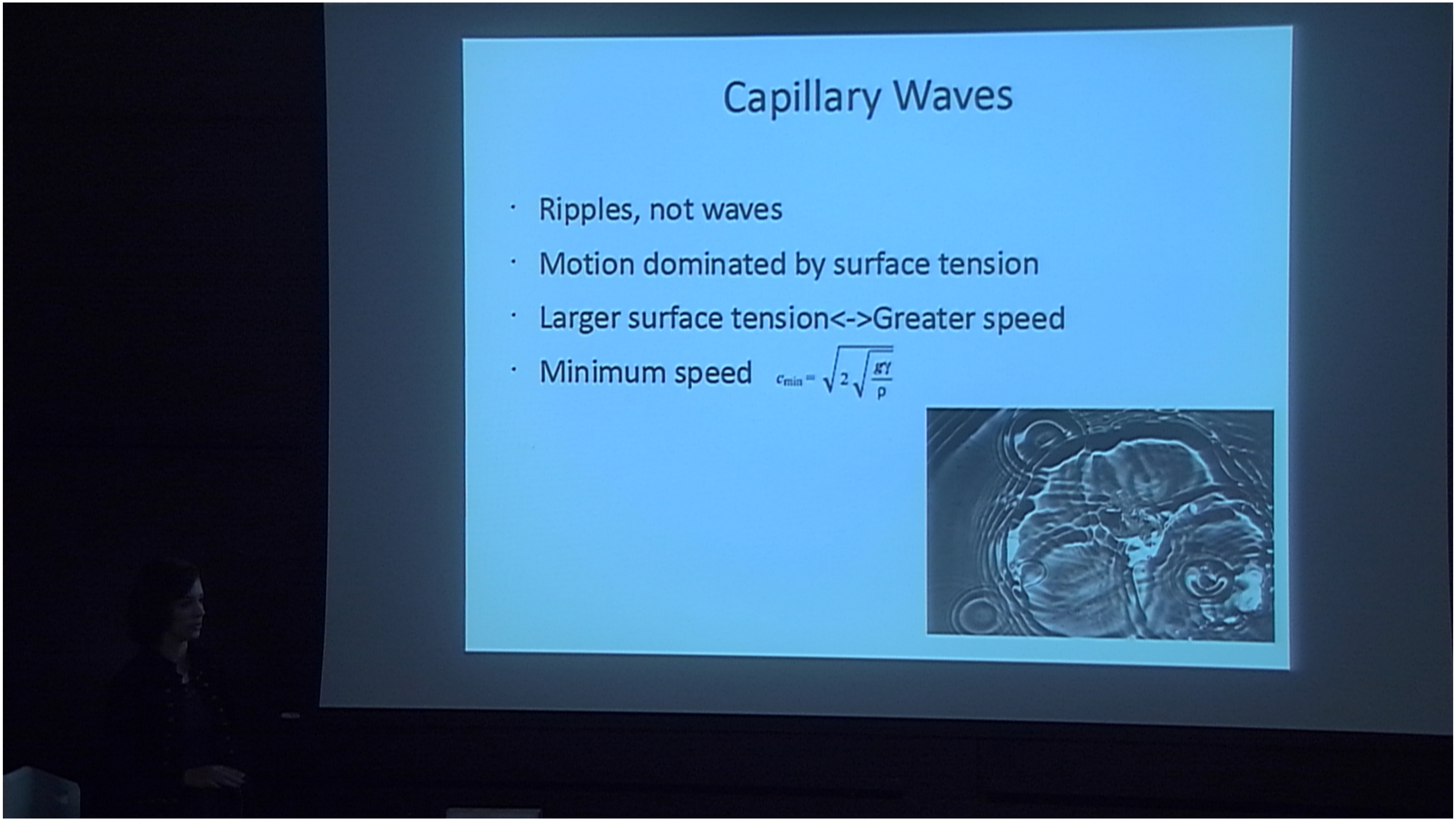
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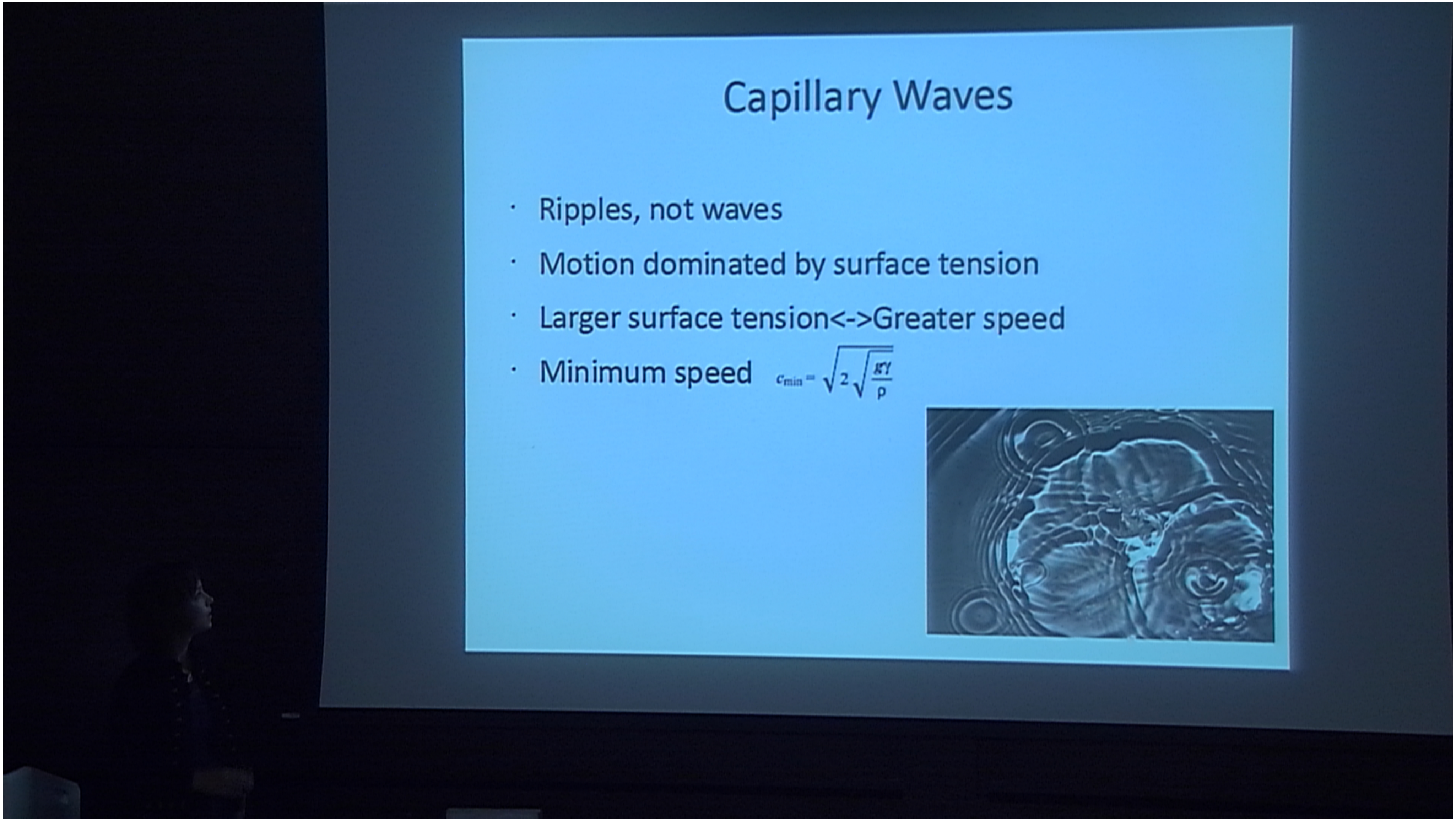
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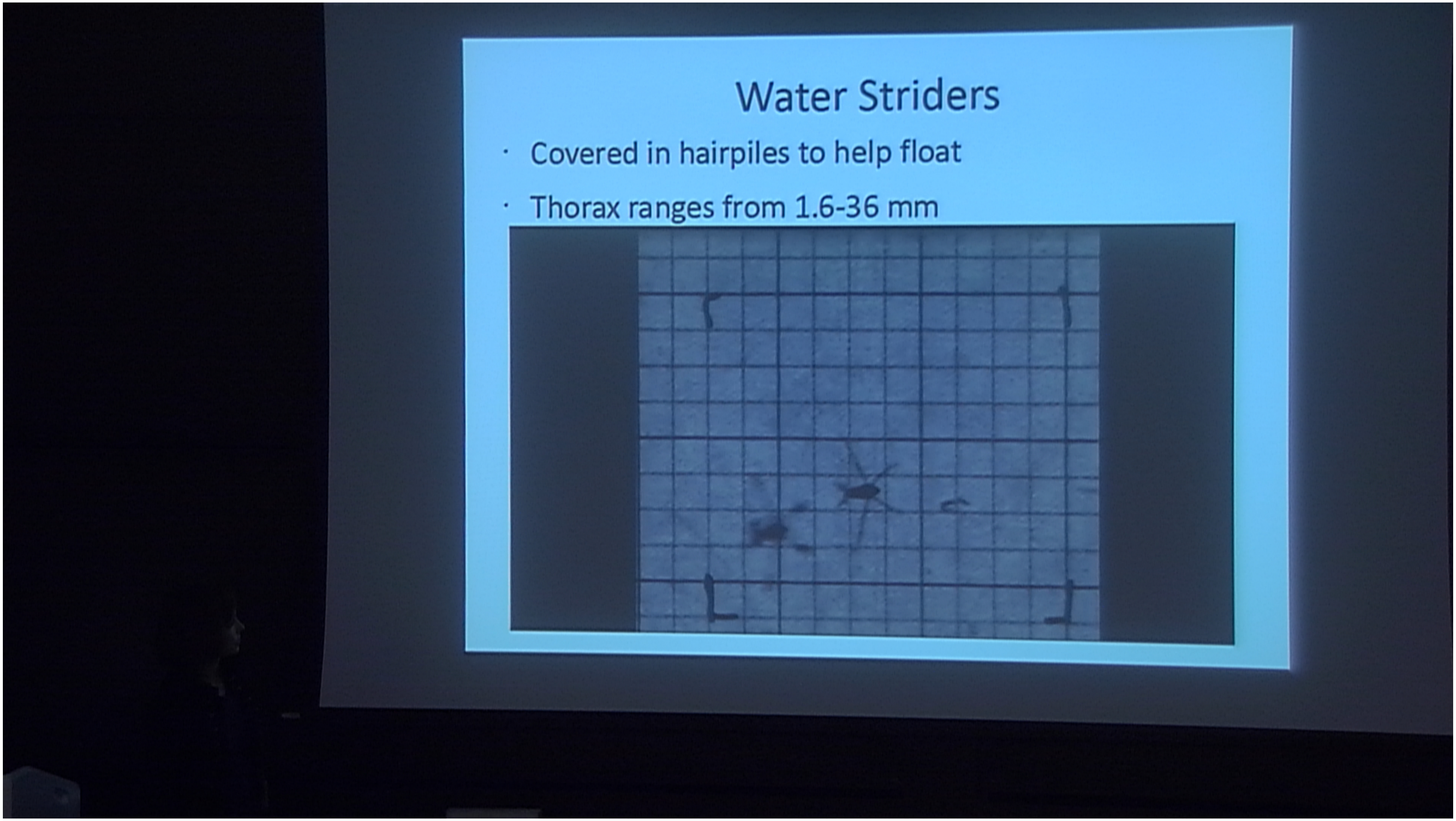
Water Striders
Covered in hairpiles to help float
Thorax ranges from 1.6-36 mm

Water Striders and Capillary Waves

- Similar to bow waves created by boats
- Cannot produce while infants
- Waxy legs reduce friction
- Momentum transfer to capillary wave about 1/10 of total momentum

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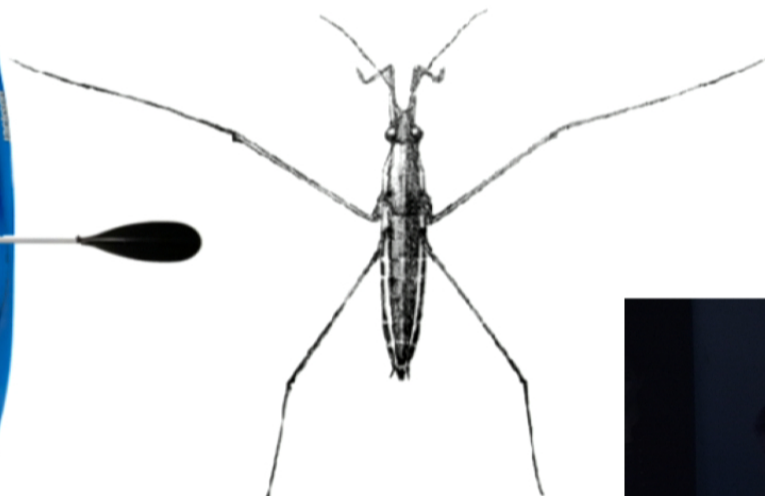
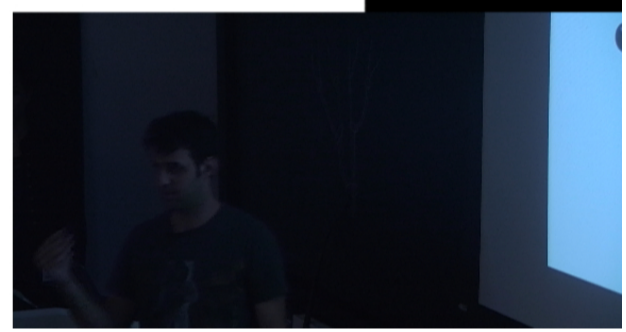
Do water striders row on water

- Diameter of water strider legs ~40 μm

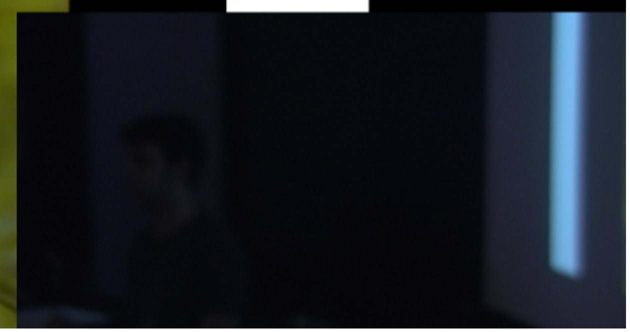
=> Rowing a kayak using a twig with diameter of 1cm





Do water striders row on water

- Based on the trajectory
  =>the force applied by the insect ~0.5mN
- Given the length of the part of the leg in contact with water force per unit length on the water surface~0.8mN/cm
- At 20 C, the maximum force per unit length before penetrating the water~1.4 mN/cm
- So the legs do not break the surface tension



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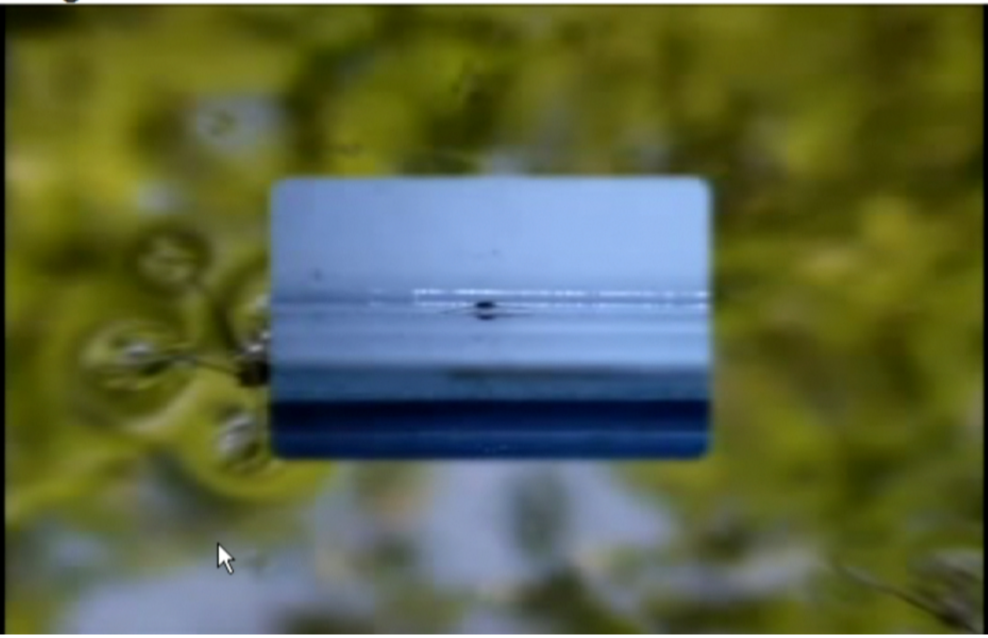
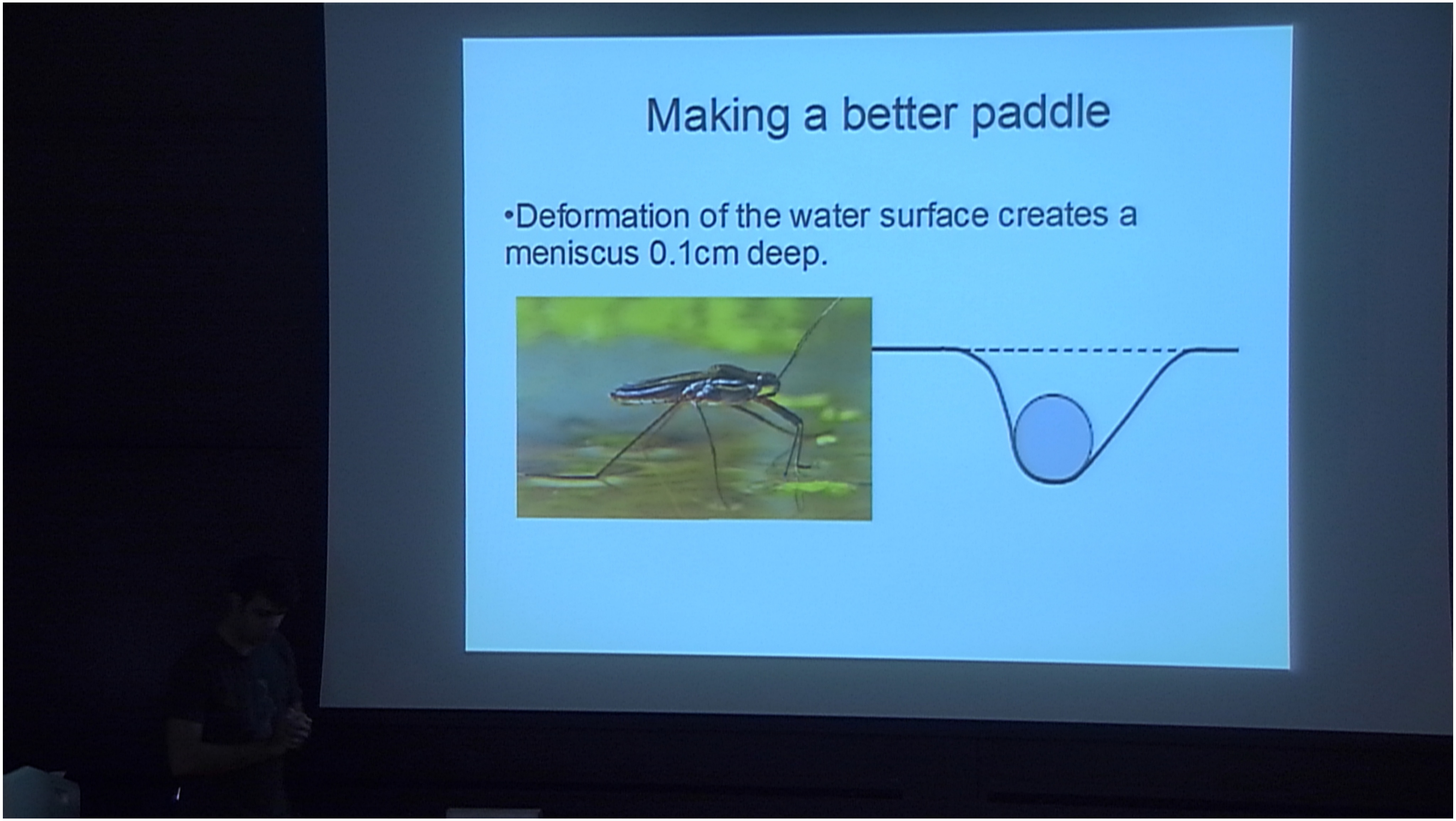
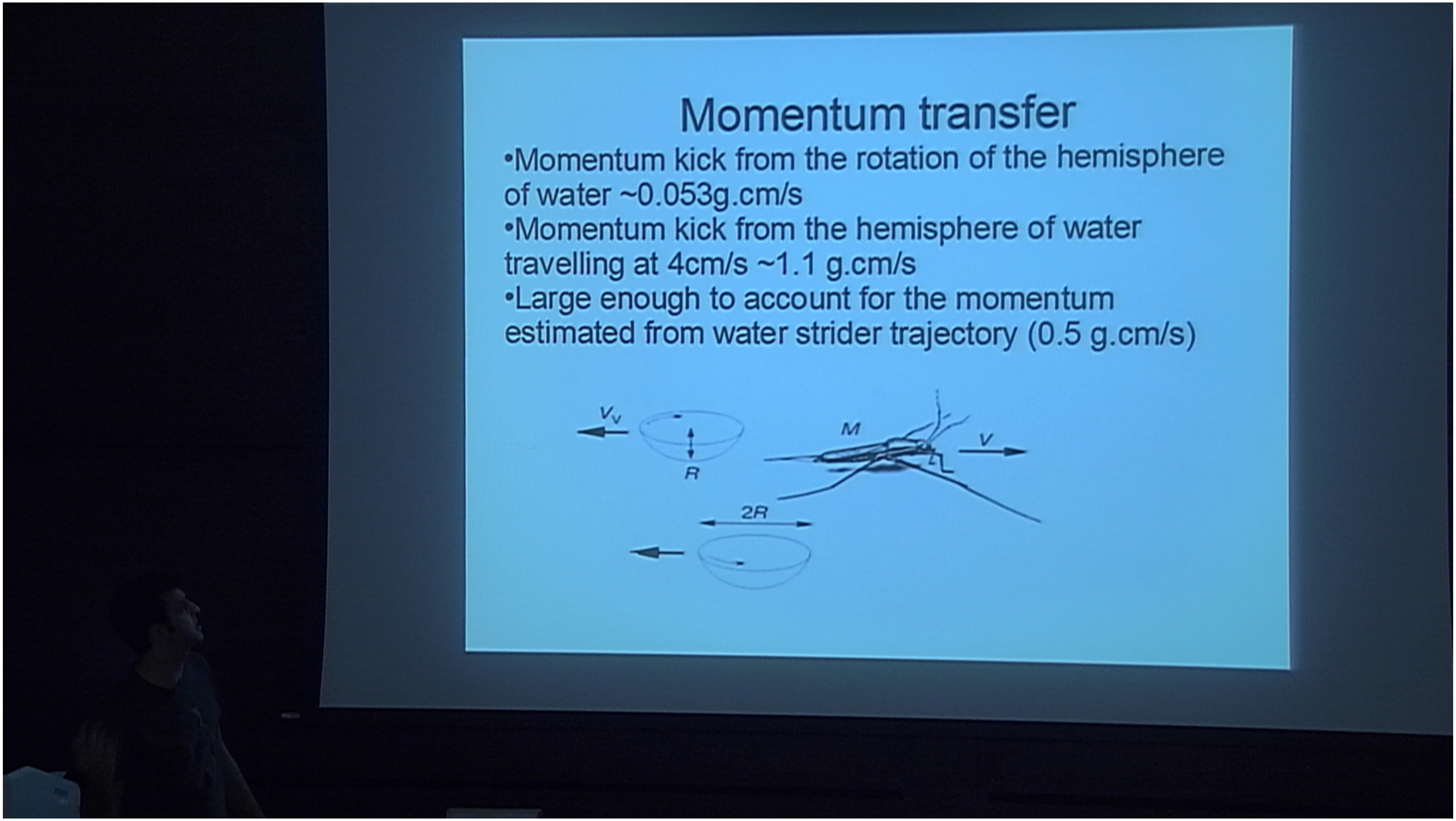


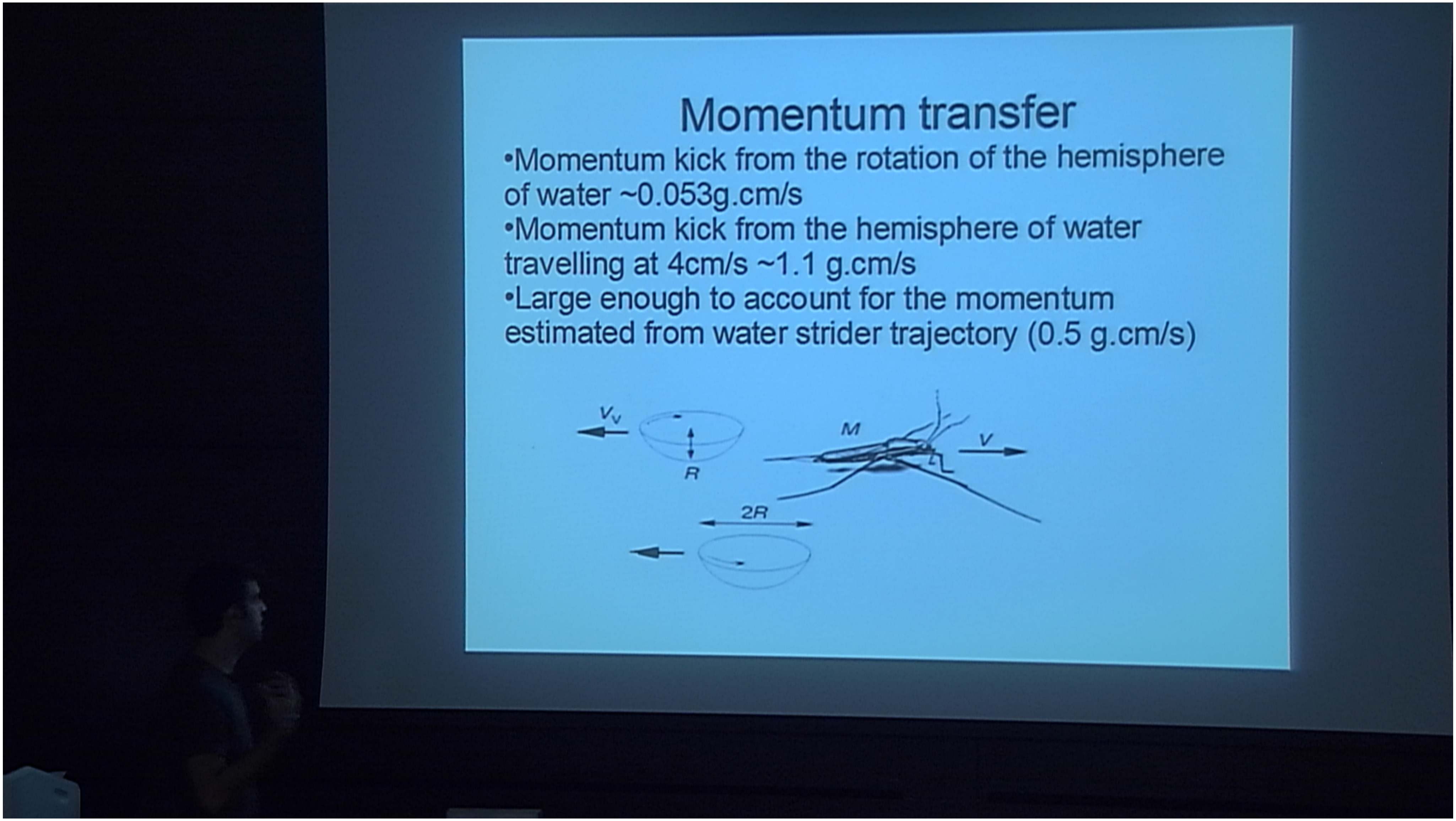
The kick

- The average duration of a leg stroke~0.01s

=>momentum transfer of 0.5 g.cm/s


Making a better paddle
•Deformation of the water surface creates a meniscus 0.1cm deep.


Momentum transfer
•Momentum kick from the rotation of the hemisphere of water ~0.053g.cm/s
•Momentum kick from the hemisphere of water travelling at 4cm/s ~1.1 g.cm/s
•Large enough to account for the momentum estimated from water strider trajectory (0.5 g.cm/s)
Vv
R
M
V
2R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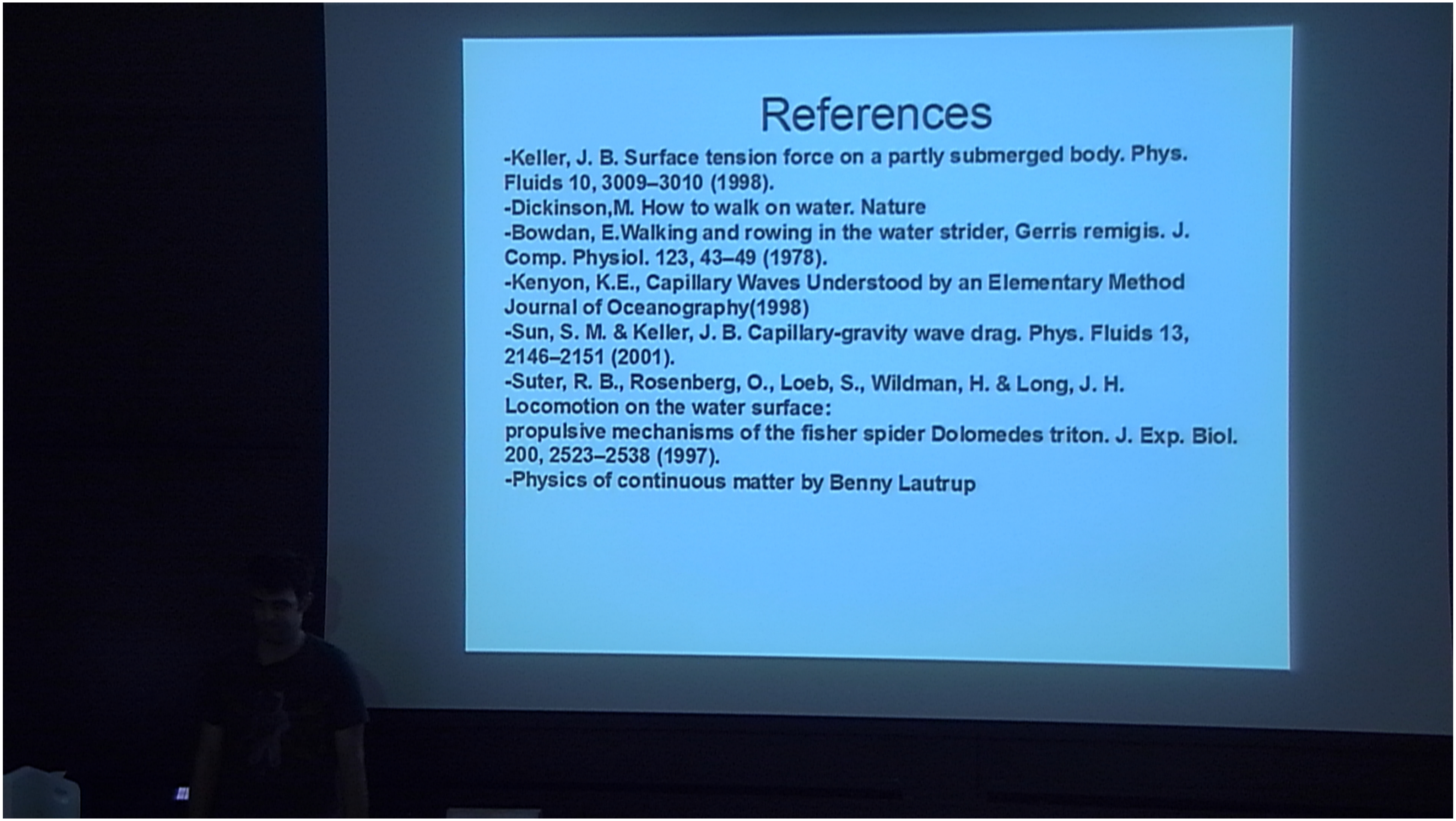
References
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Fluids 10, 3009–3010 (1998).
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-Kenyon, K.E., Capillary Waves Understood by an Elementary Method
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-Sun, S. M. & Keller, J. B. Capillary-gravity wave drag. Phys. Fluids 13,
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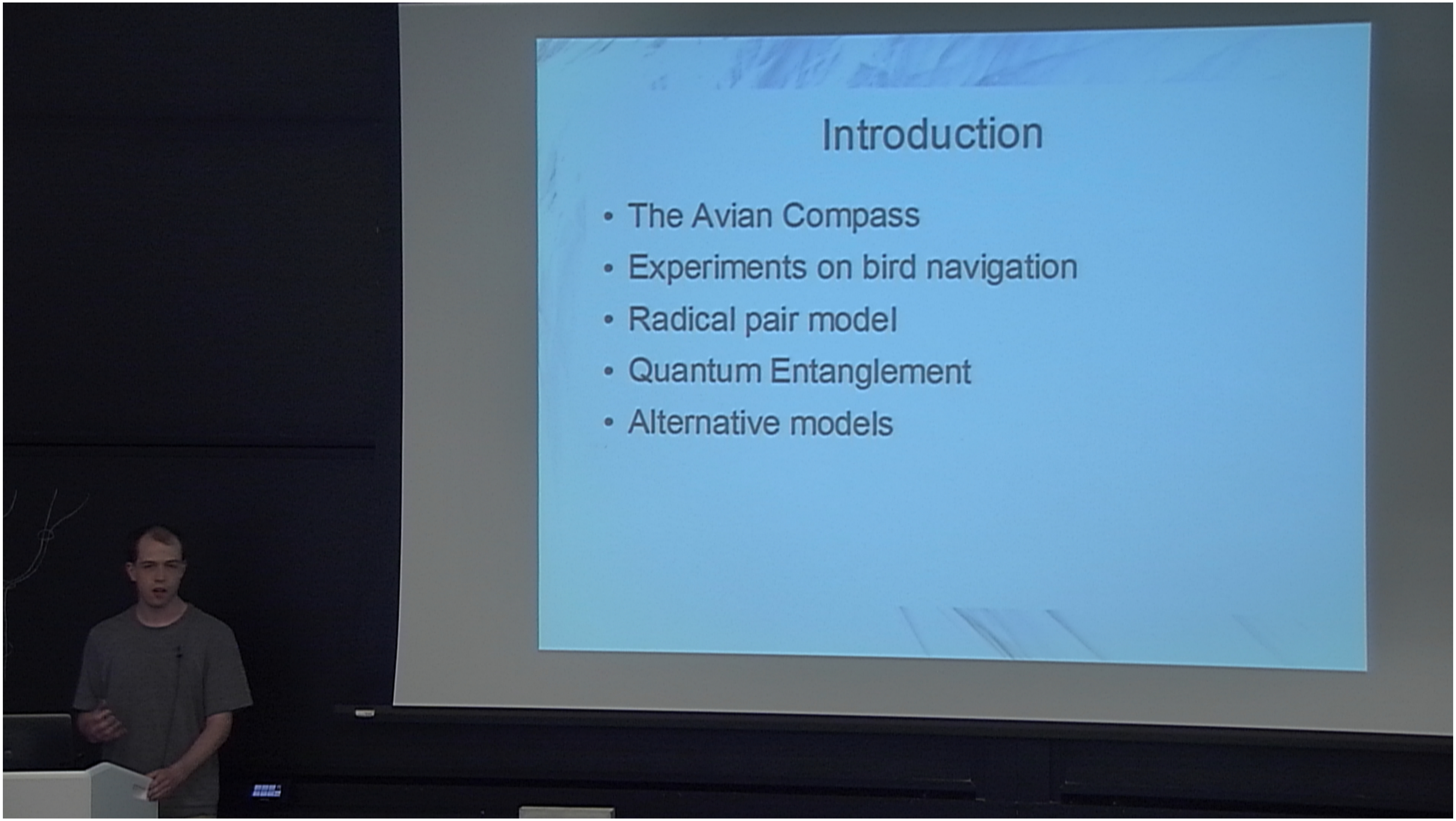
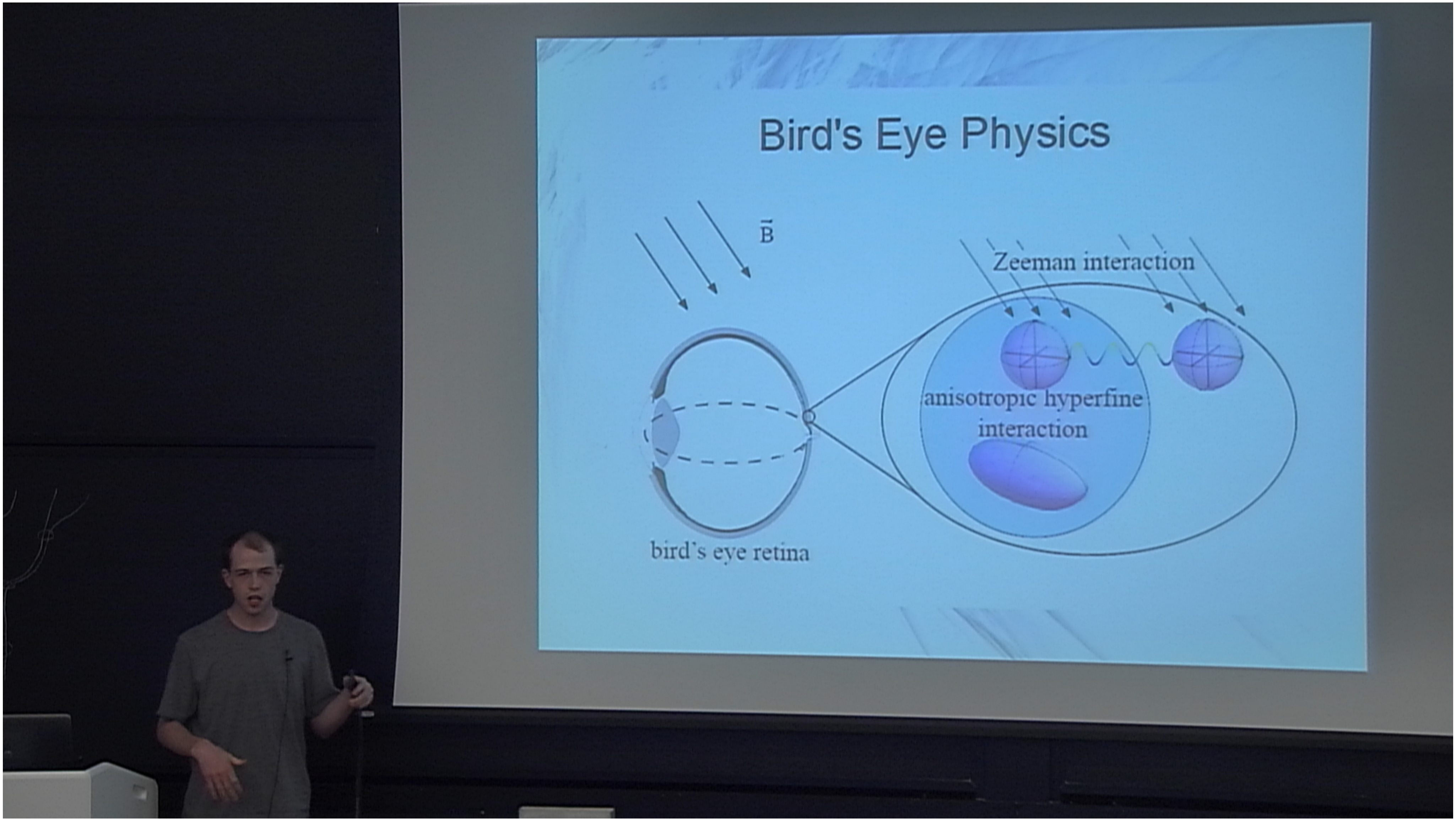
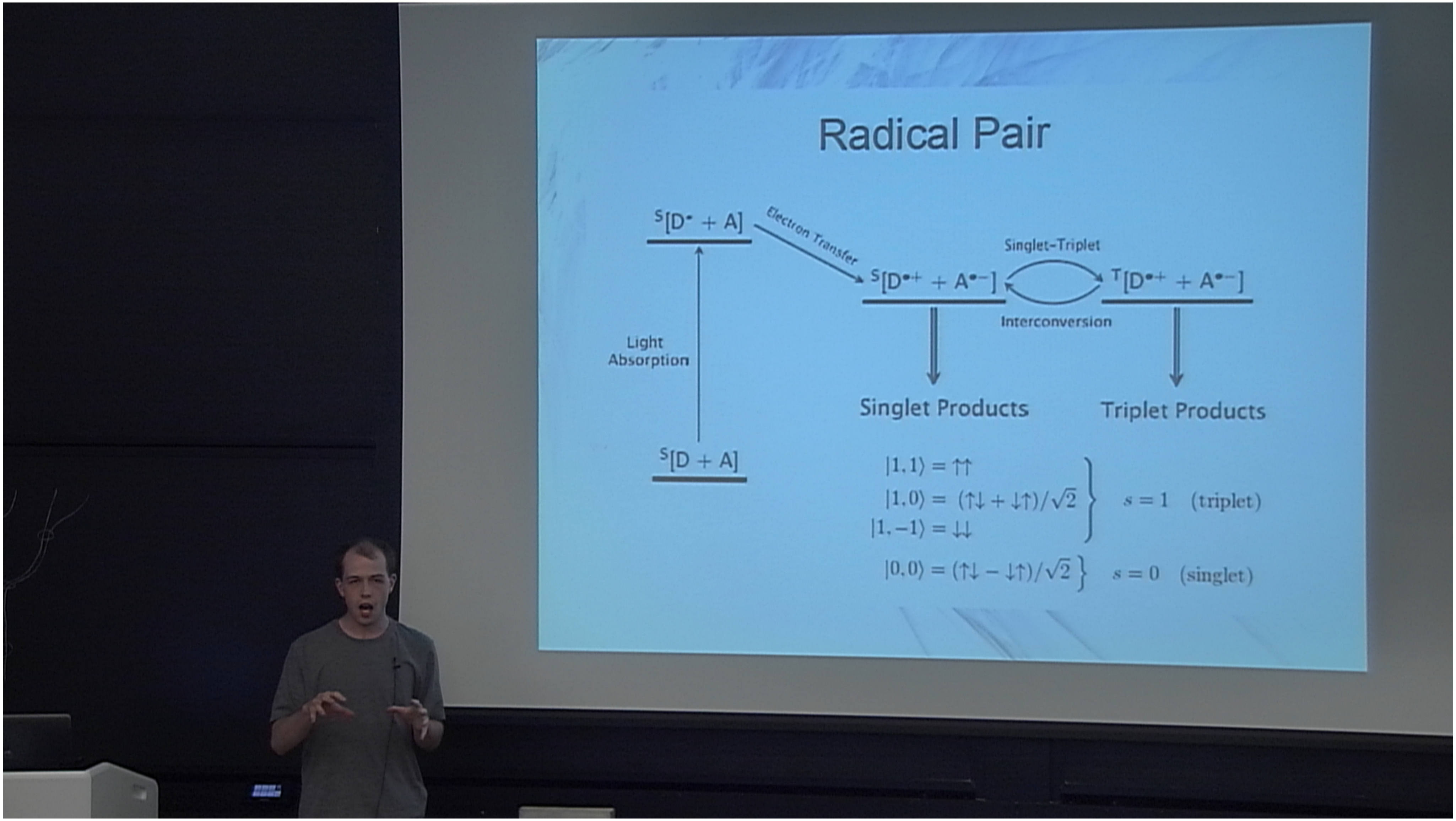
-Suter, R. B., Rosenberg, O., Loeb, S., Wildman, H. & Long, J. H.
Locomotion on the water surface:
propulsive mechanisms of the fisher spider Dolomedes triton. J. Exp. Biol.
200, 2523–2538 (1997).
-Physics of continuous matter by Benny Lautrup

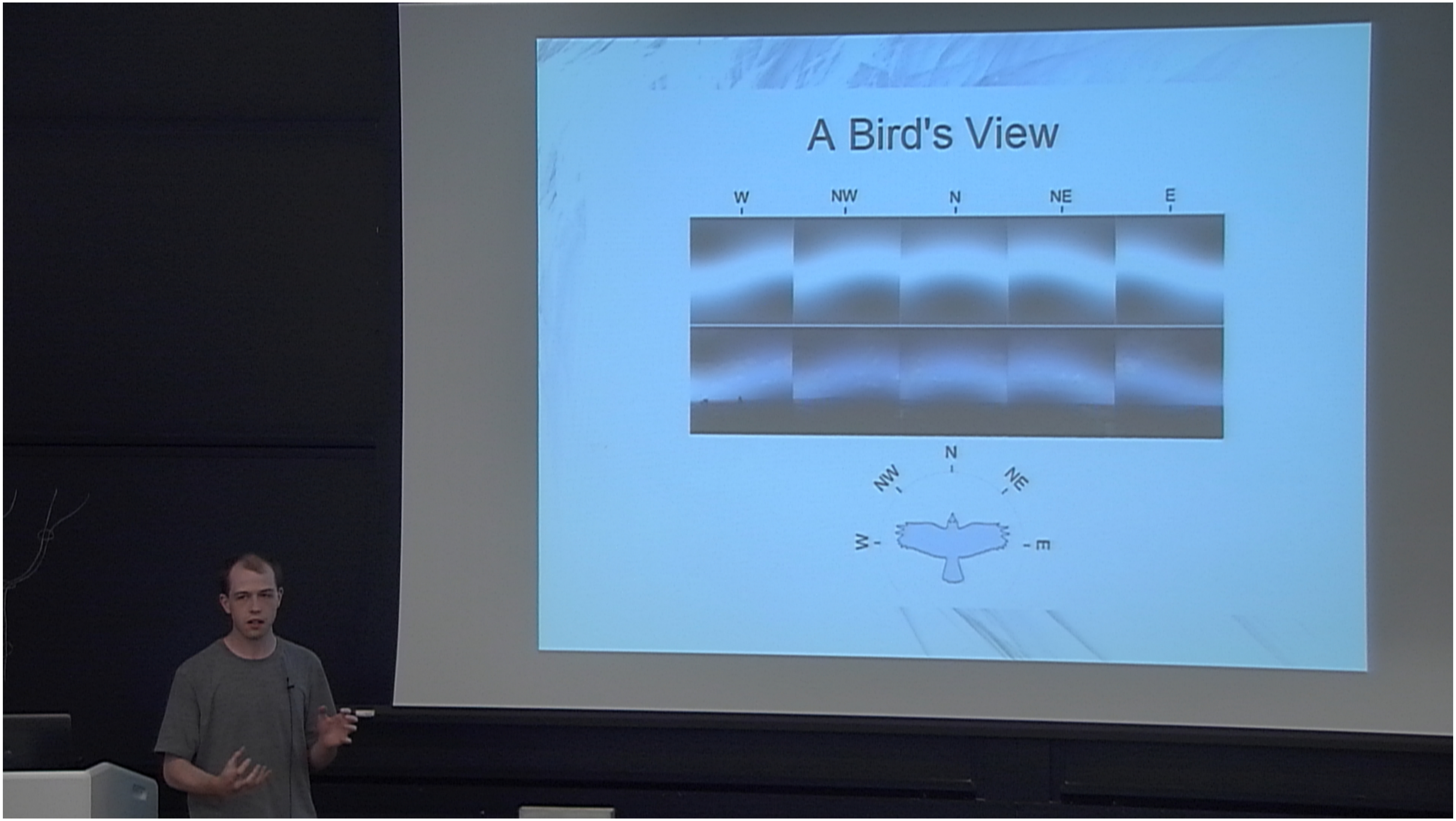

Introduction
• The Avian Compass
• Experiments on bird navigation
• Radical pair model
• Quantum Entanglement
• Alternative models

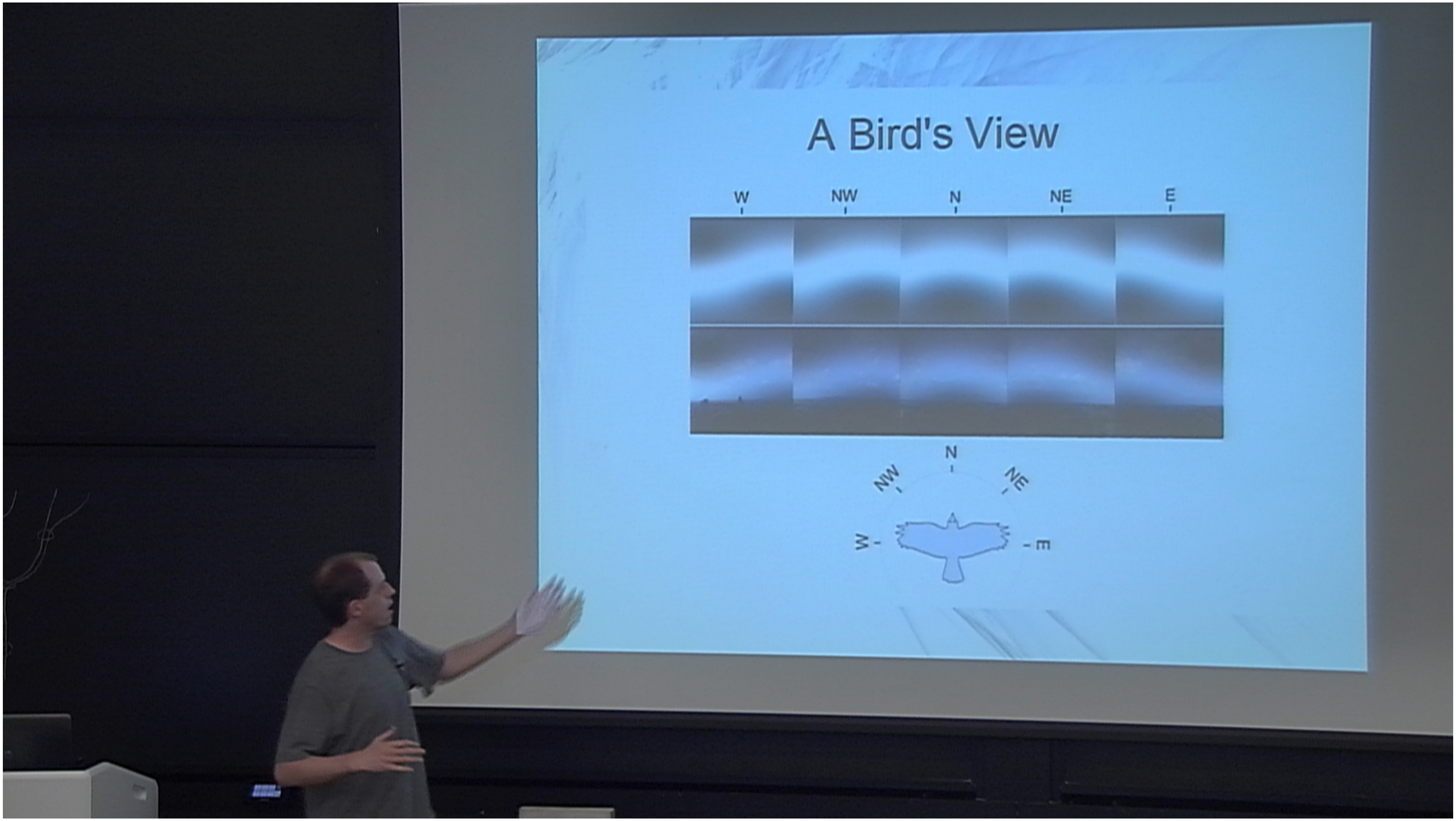

The Avian Compass

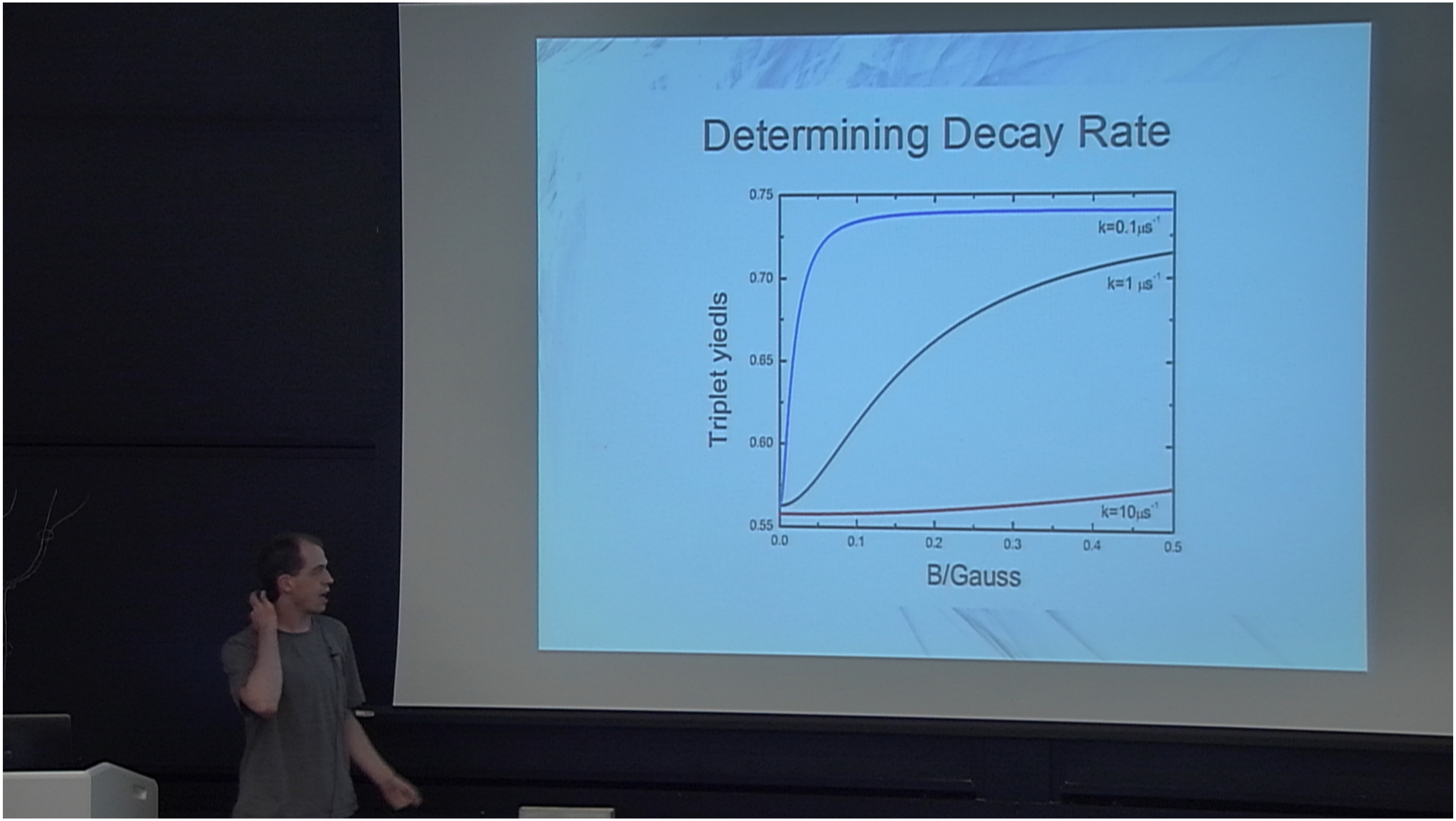


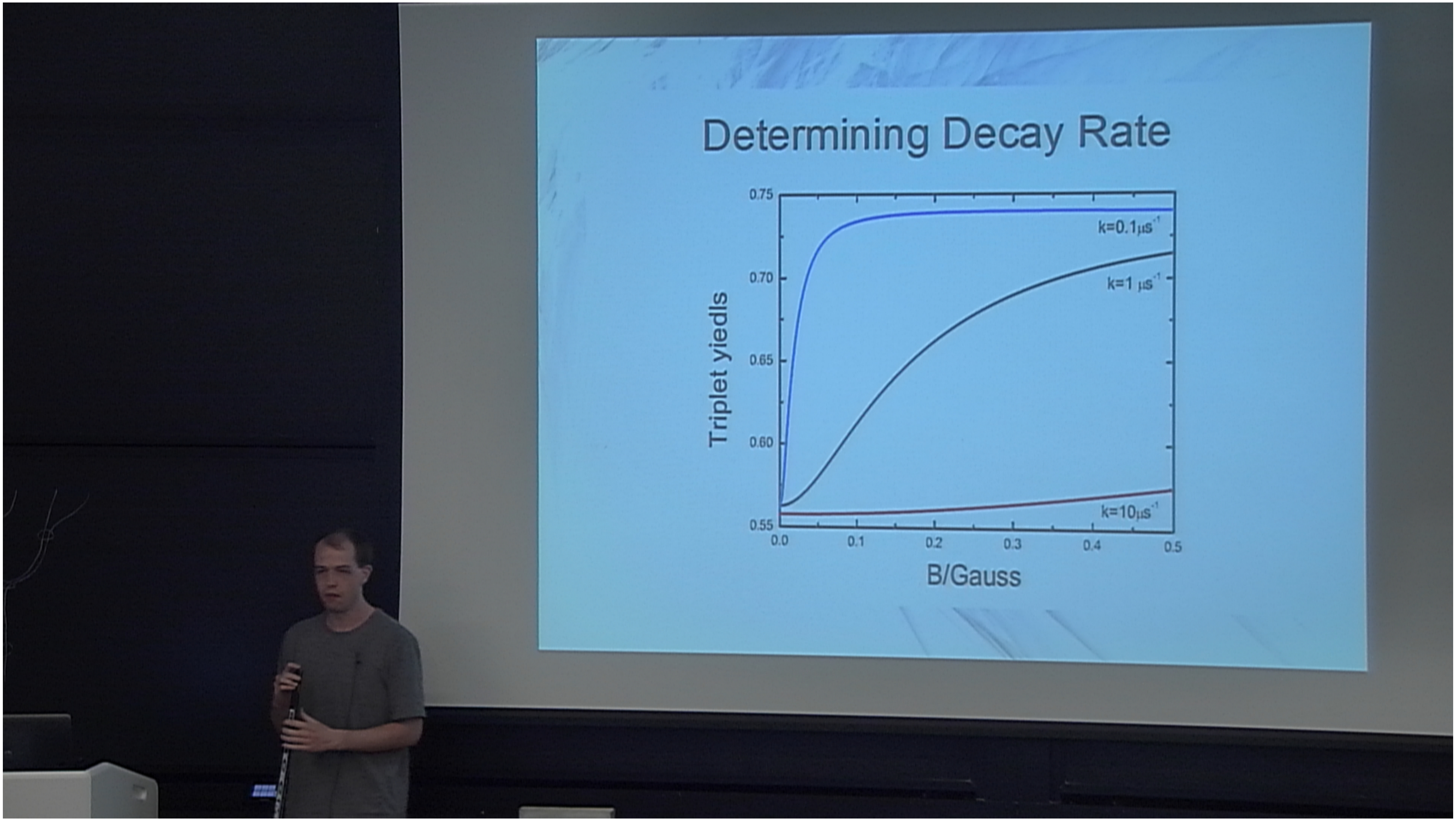
Bird's Eye Physics
B
Zeeman interaction
anisotropic hyperfine interaction
bird's eye retina

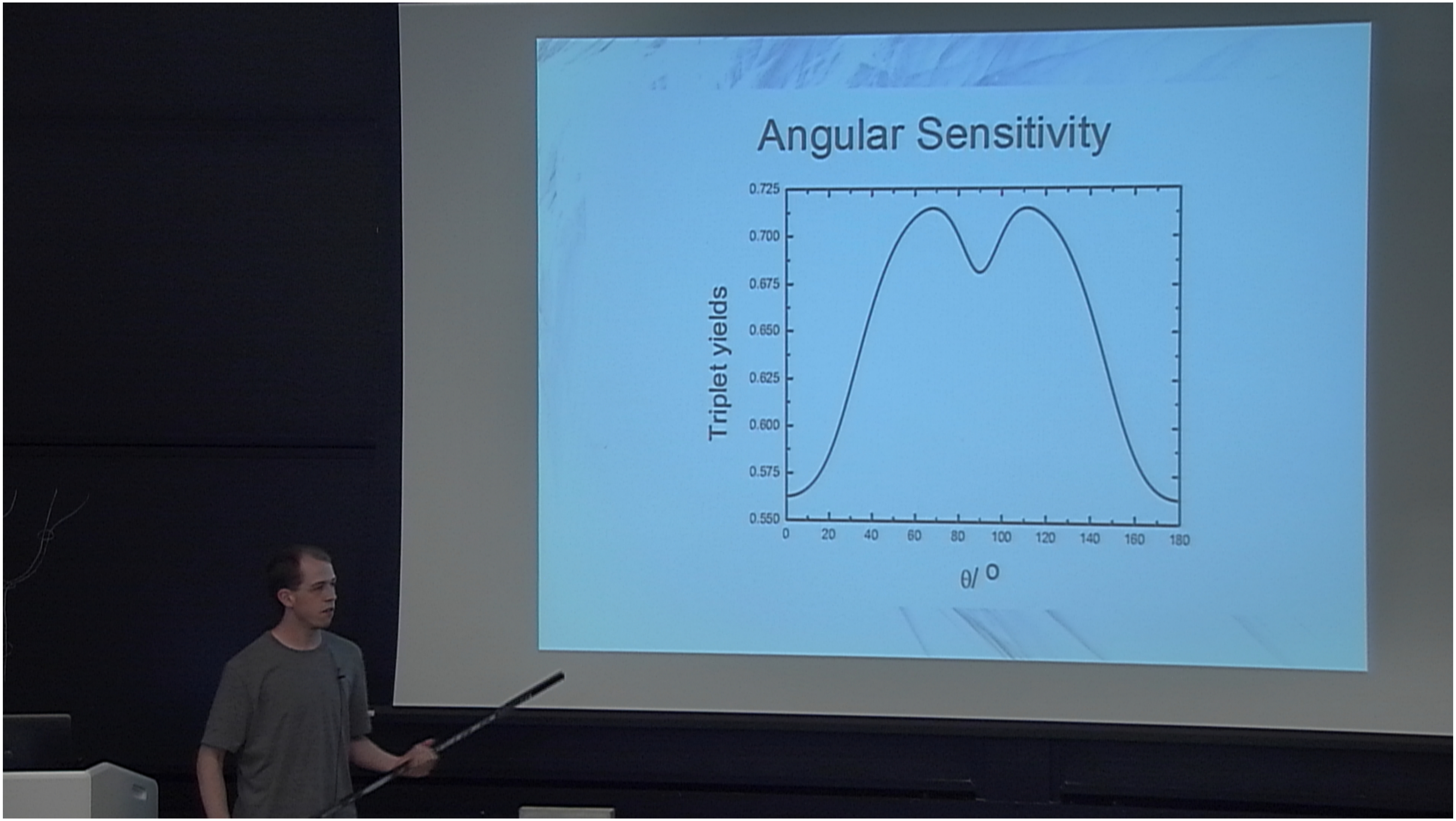

Radical Pair
S[D* + A]
Electron Transfer
Singlet-Triplet
S[D•+ + A•−]
T[D•+ + A•−]
Interconversion
Light
Absorption
Singlet Products
Triplet Products
S[D + A]
|1,1⟩ = ↑↑
|1,0⟩ = (↑↓ + ↓↑)/√2
|1,−1⟩ = ↓↓
s = 1 (triplet)
|0,0⟩ = (↑↓ − ↓↑)/√2
s = 0 (singlet)

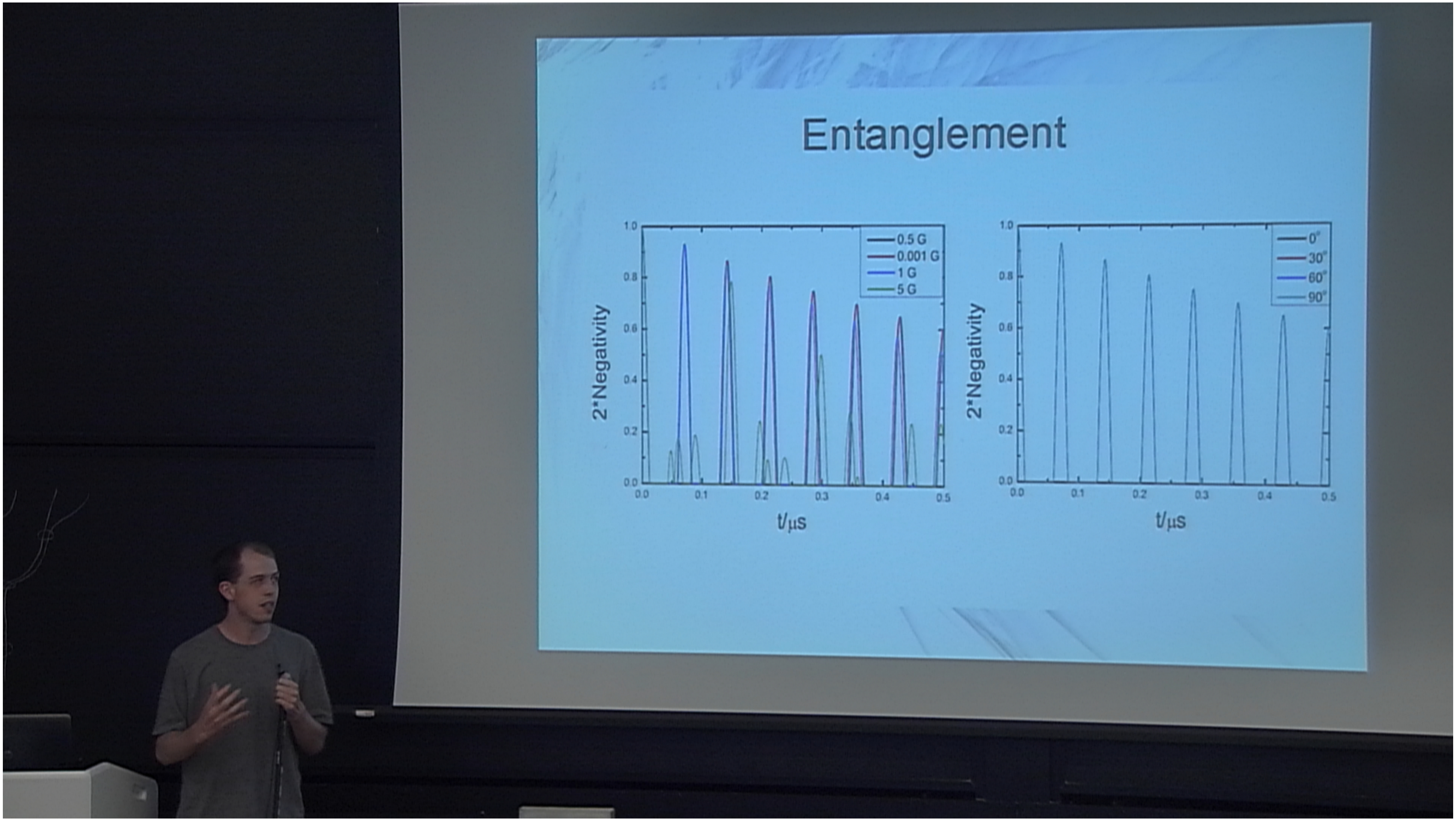

A Bird's View
W
NW
N
NE
E
N
NW
NE
W
E


A Bird's View
W
NW
N
NE
E
N
NW
NE
W
E

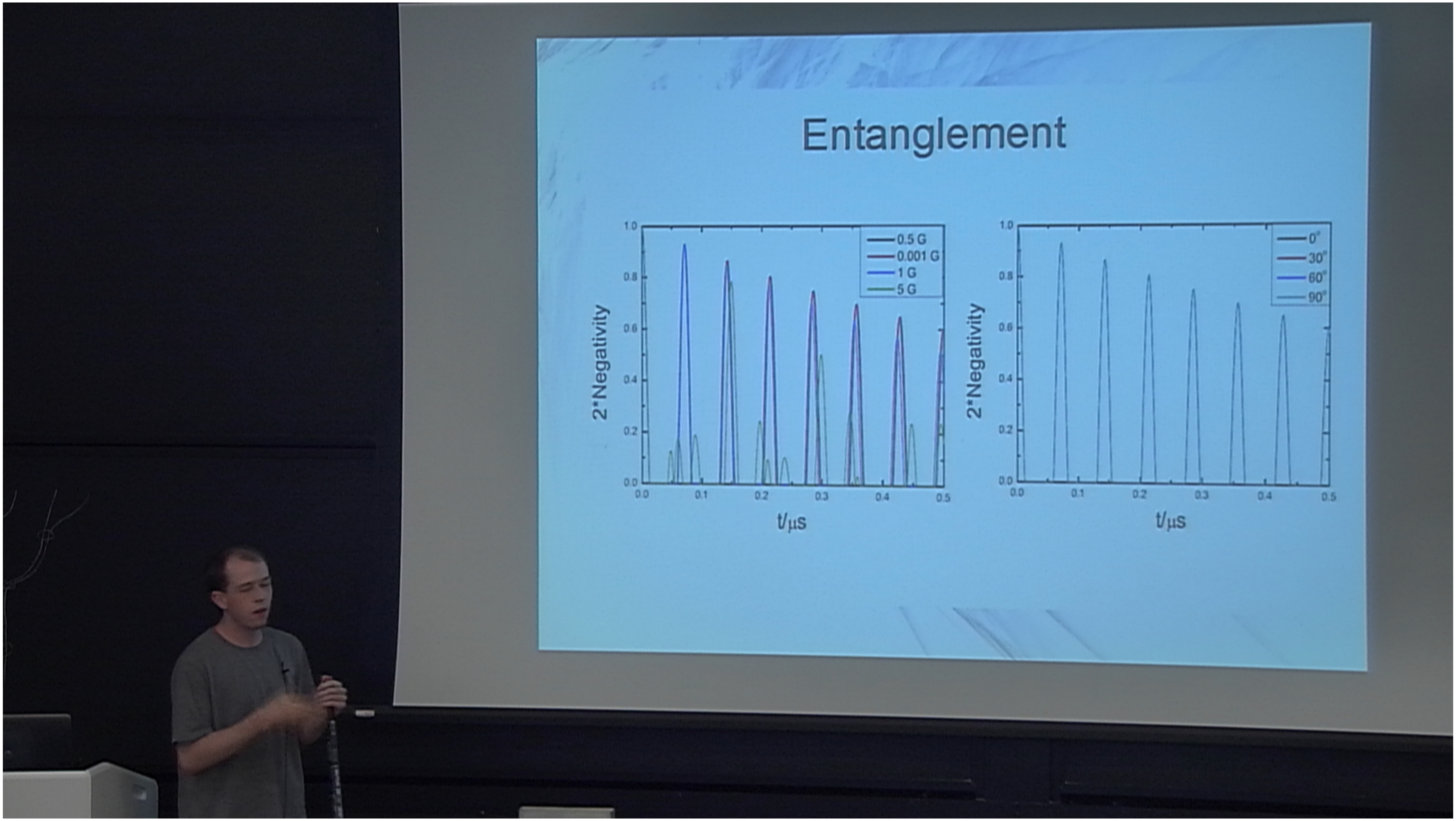

Determining Decay Rate
0.75
0.70
0.65
0.60
0.55
Triplet yiedls
k=0.1μs⁻¹
k=1 μs⁻¹
k=10μs⁻¹
0.0
0.1
0.2
0.3
0.4
0.5
B/Gauss


Determining Decay Rate
Triplet yiedls
B/Gauss
k=0.1μs⁻¹
k=1 μs⁻¹
k=10μs⁻¹
0.75
0.70
0.65
0.60
0.55
0.0
0.1
0.2
0.3
0.4
0.5

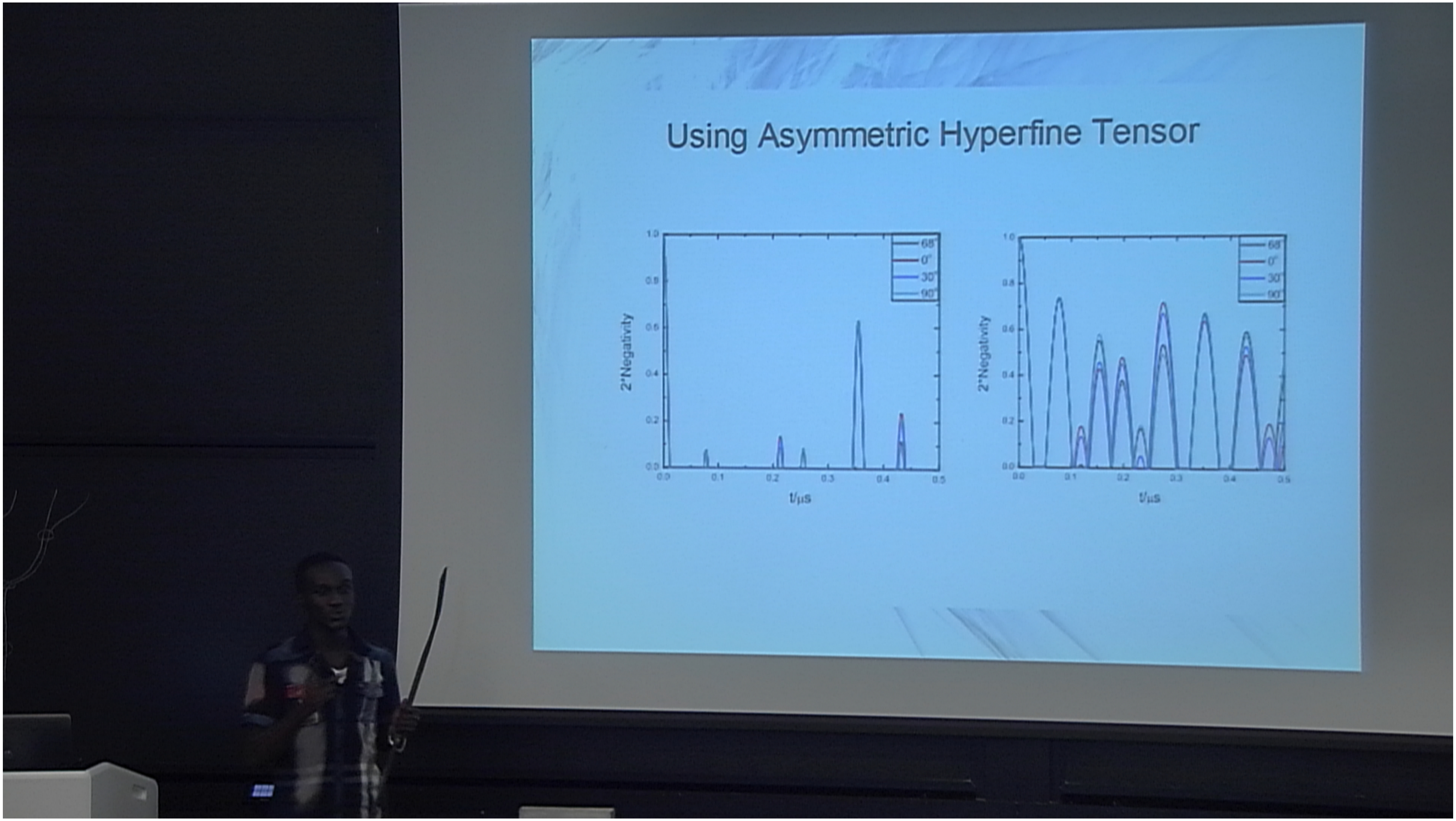

Angular Sensitivity
Triplet yields
0.725
0.700
0.675
0.650
0.625
0.600
0.575
0.550
0
20
40
60
80
100
120
140
160
180
θ/ o

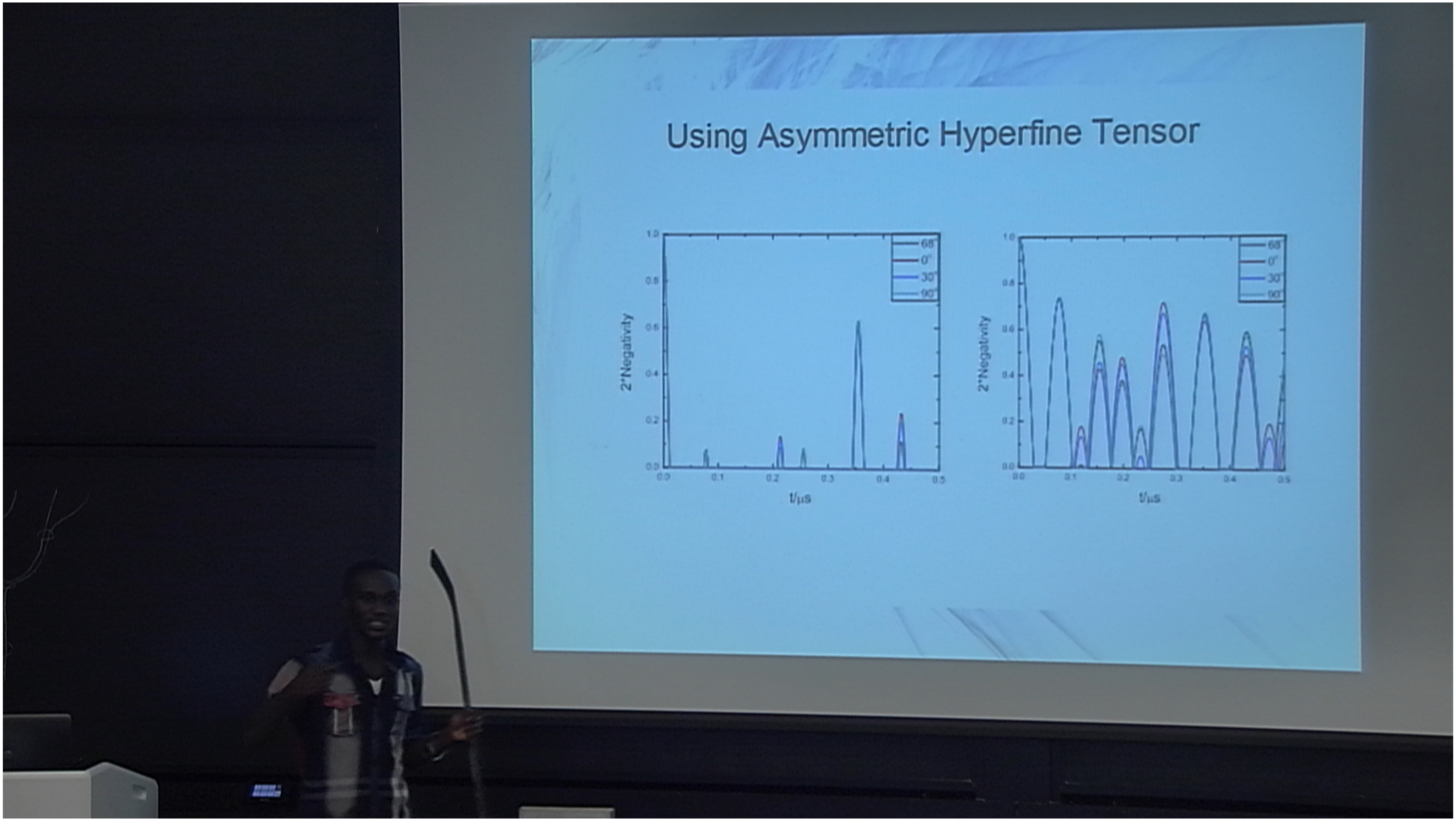


Entanglement
2*Negativity
0.5 G
0.001 G
1 G
5 G
t/μs
2*Negativity
0°
30°
60°
90°
t/μs



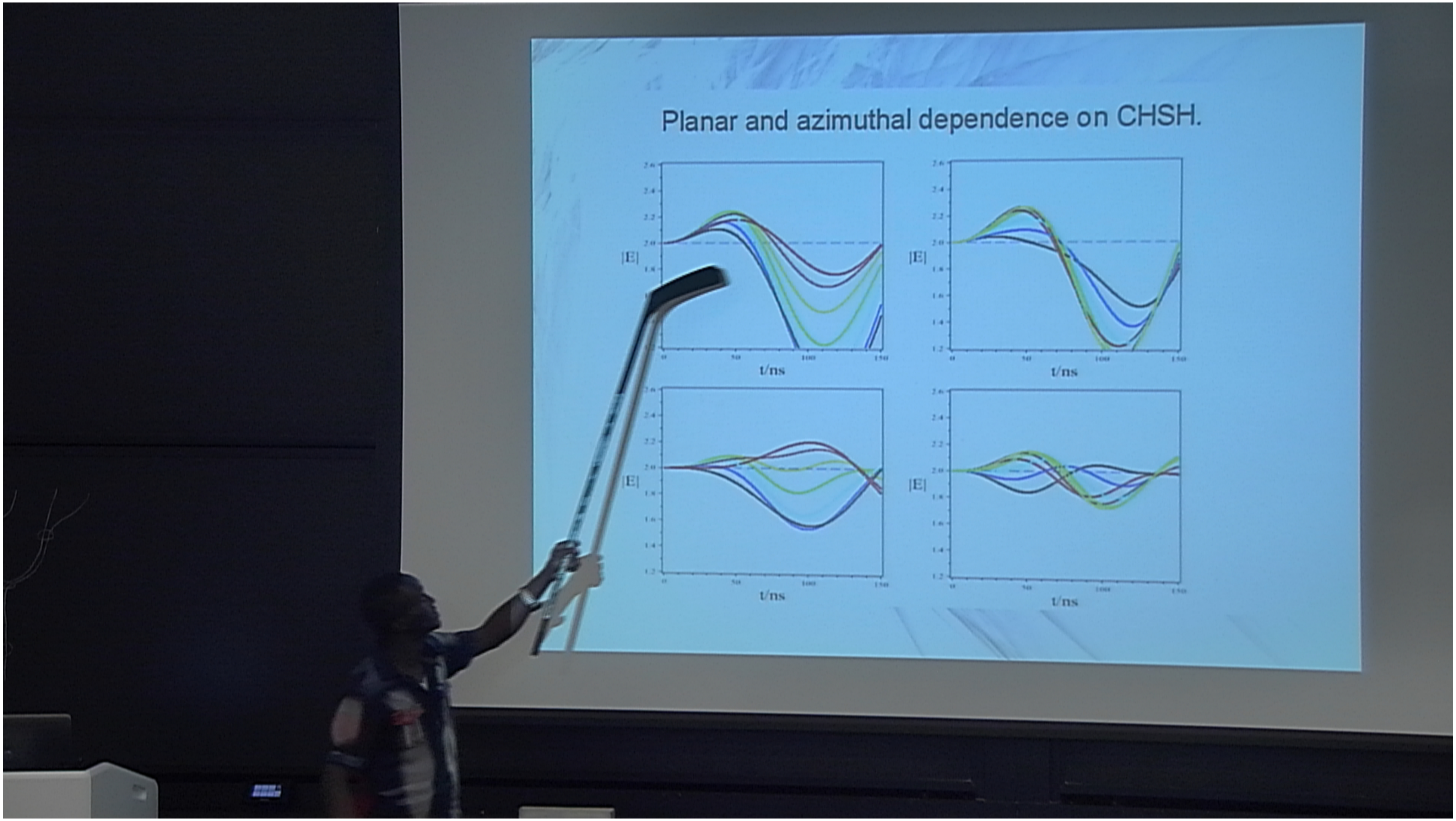
Entanglement
2*Negativity
t/μs
0.5 G
0.001 G
1 G
5 G
0°
30°
60°
90°

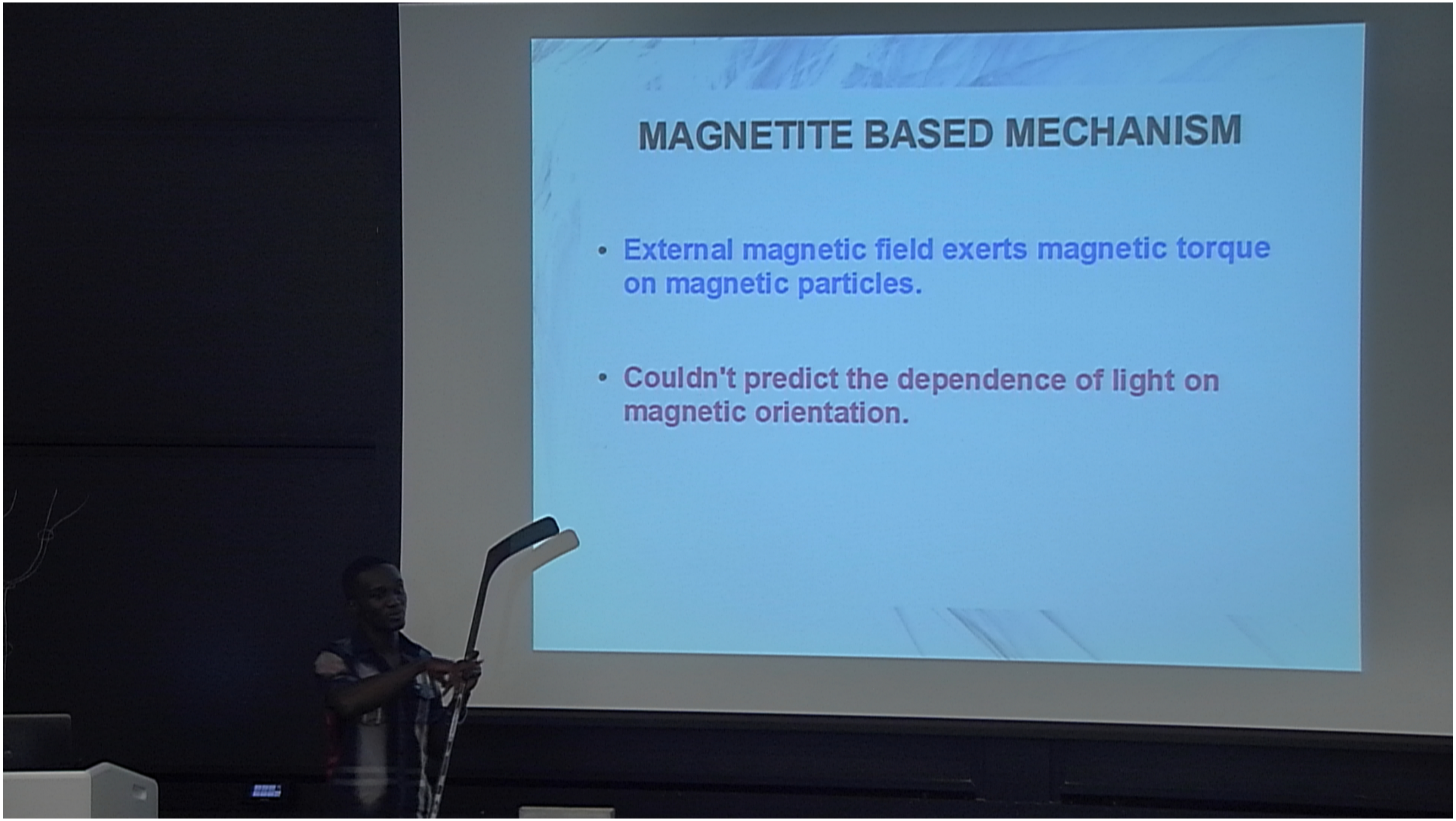

Using Asymmetric Hyperfine Tensor
2*Negativity
t/μs
68°
0°
30°
90°
2*Negativity
t/μs
68°
0°
30°
90°

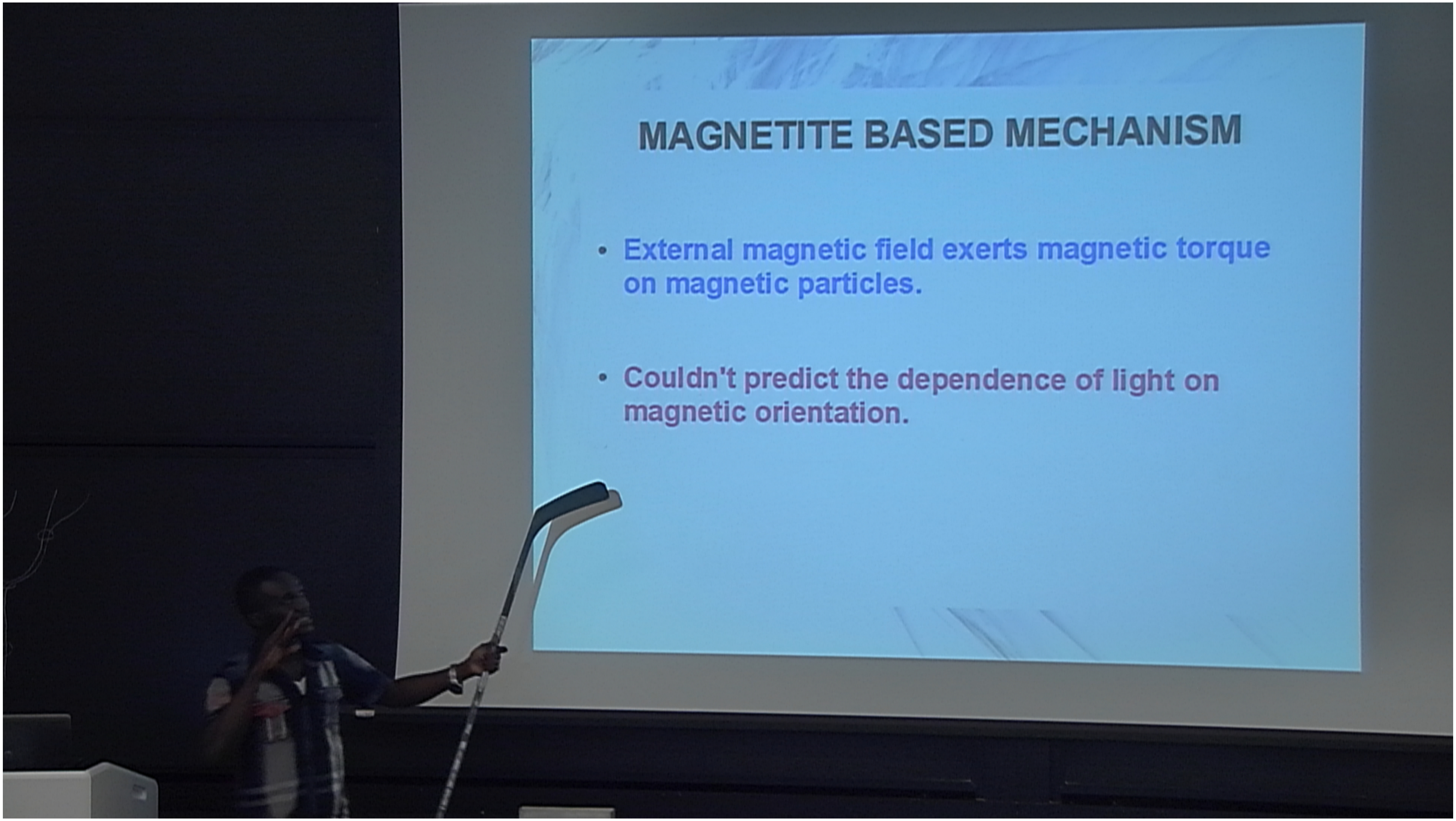


Using Asymmetric Hyperfine Tensor
2*Negativity
t/μs
68°
0°
30°
90°


New Model
• Proposed each electron interacts with additional local magnetic field.
•CHSH (Clausier, Home, Shimony, Holt) inequality,
|E|≤ 2λmax2


Planar and azimuthal dependence on CHSH.
|E|
t/ns
|E|
t/ns
|E|
t/ns
|E|
t/ns


MAGNETITE BASED MECHANISM
• External magnetic field exerts magnetic torque on magnetic particles.
• Couldn't predict the dependence of light on magnetic orientation.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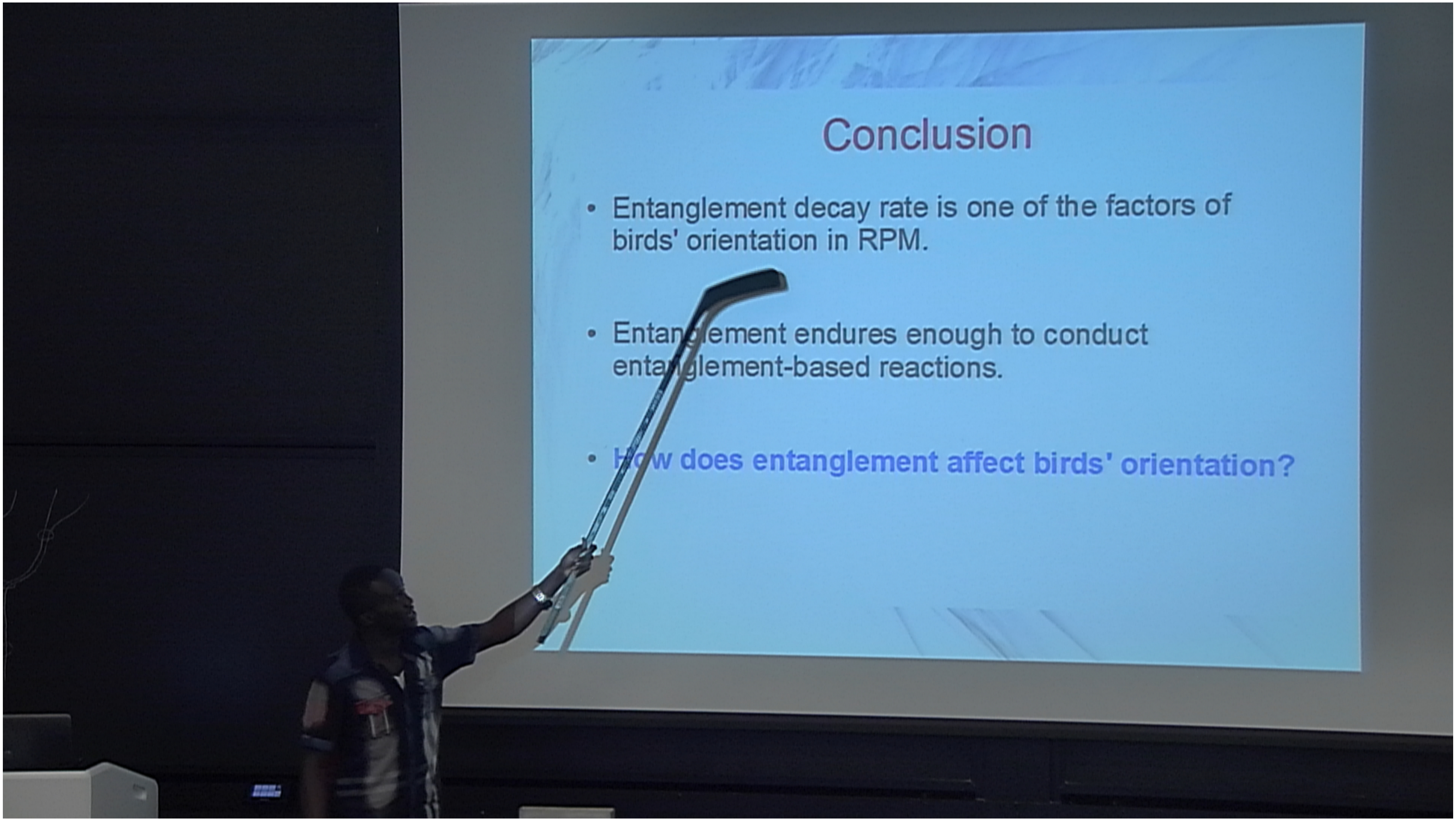
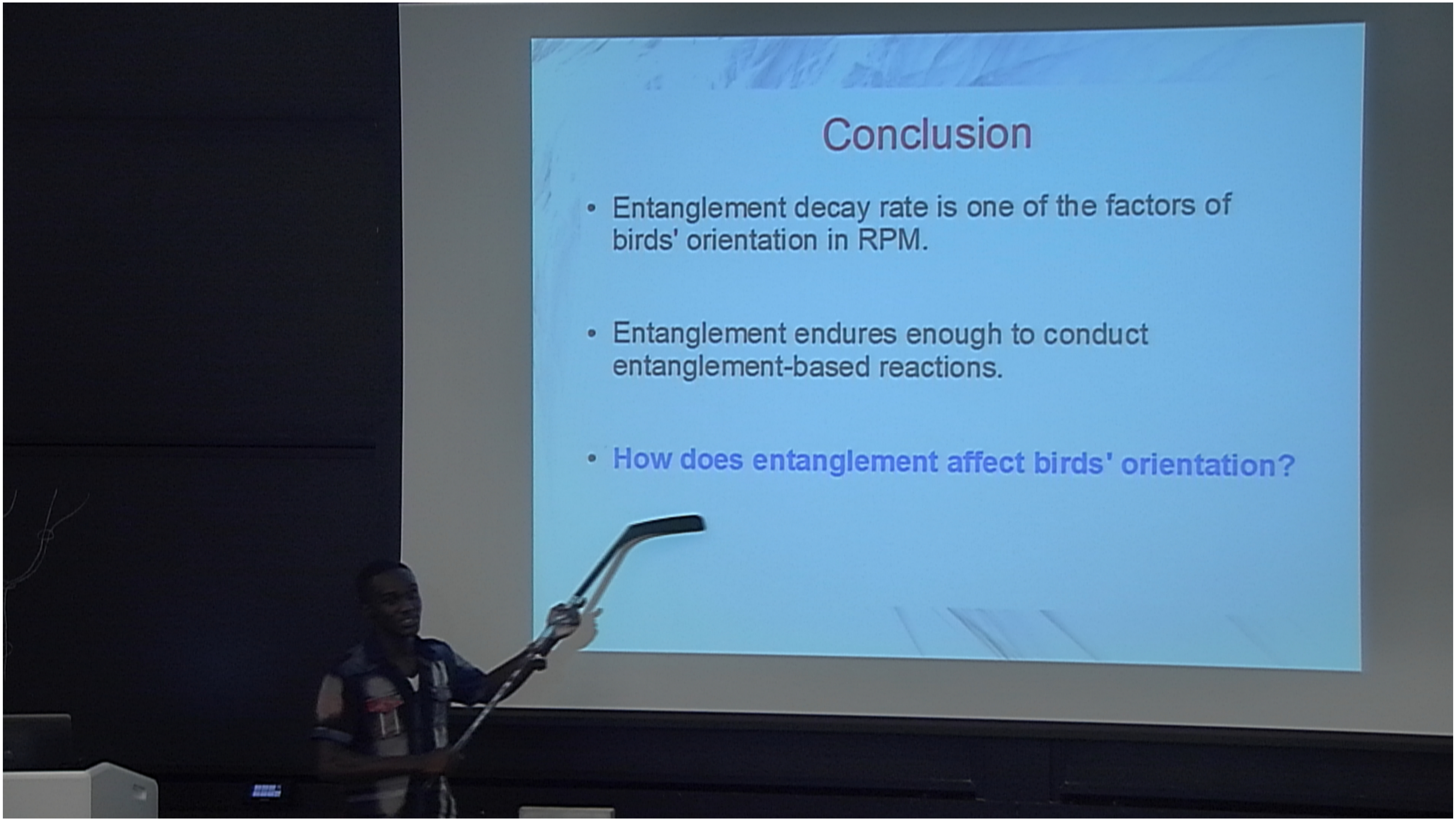

Conclusion
• Entanglement decay rate is one of the factors of birds' orientation in RPM.
• Entanglement endures enough to conduct entanglement-based reactions.
• How does entanglement affect birds' orientation?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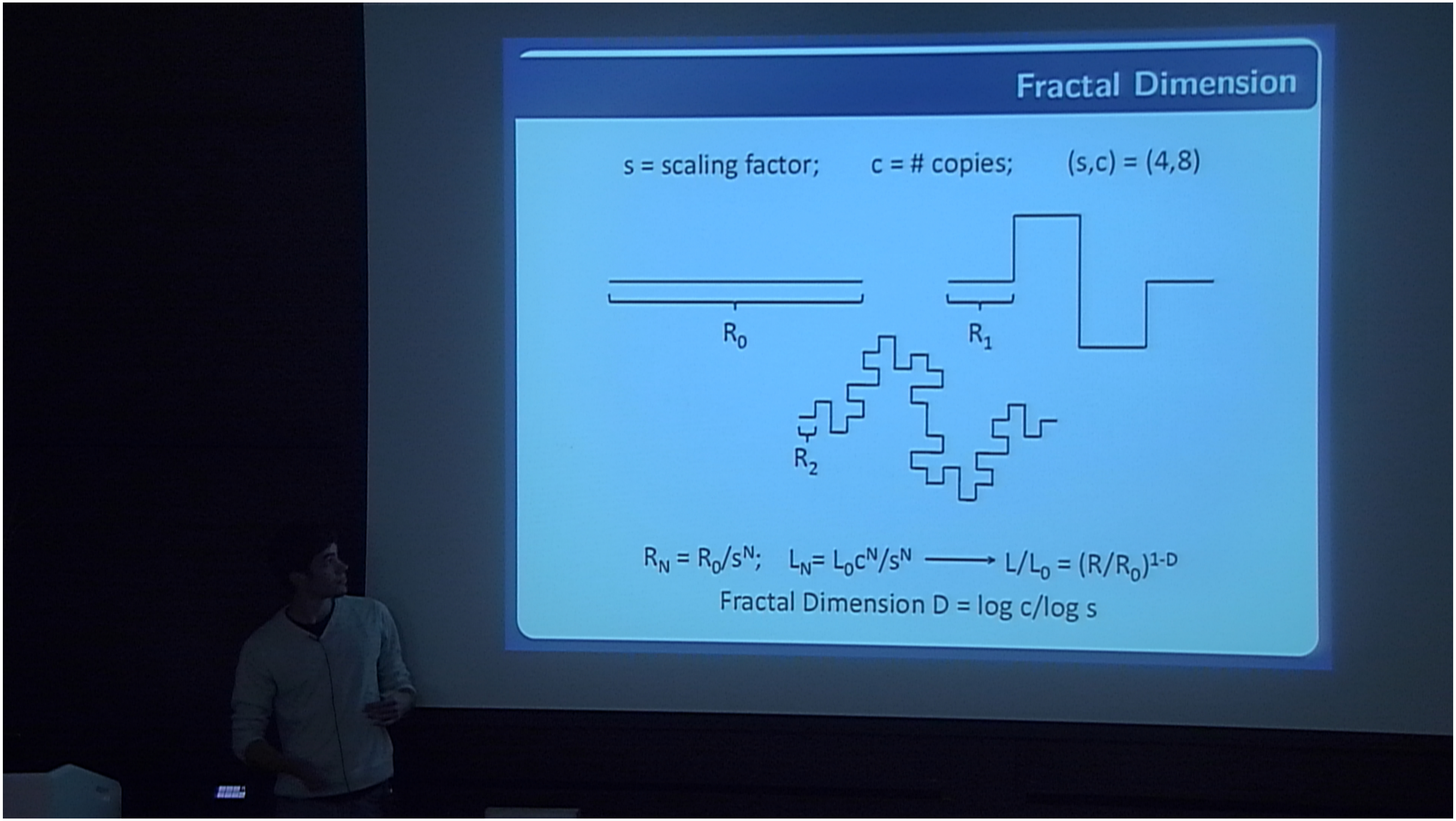
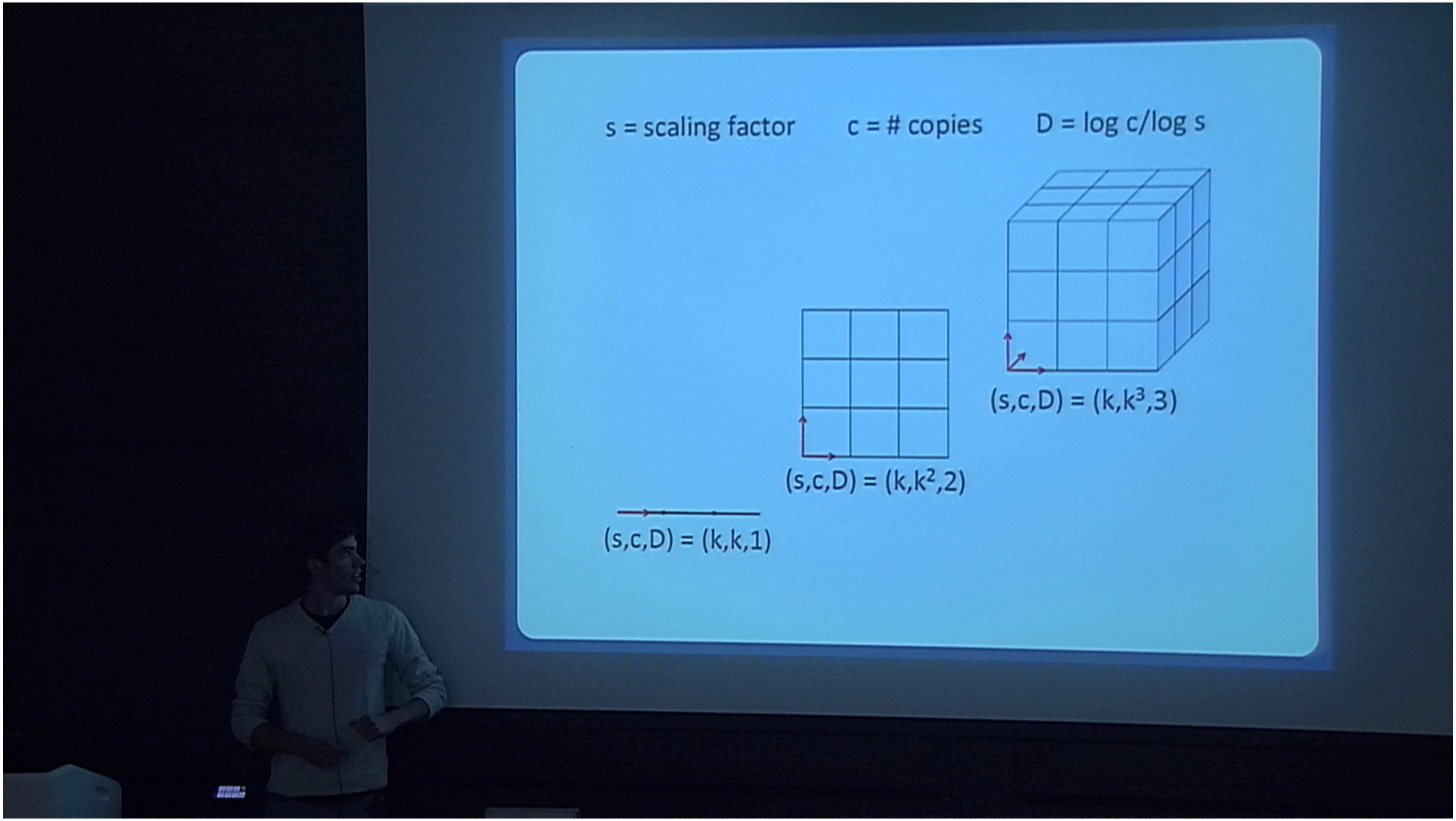
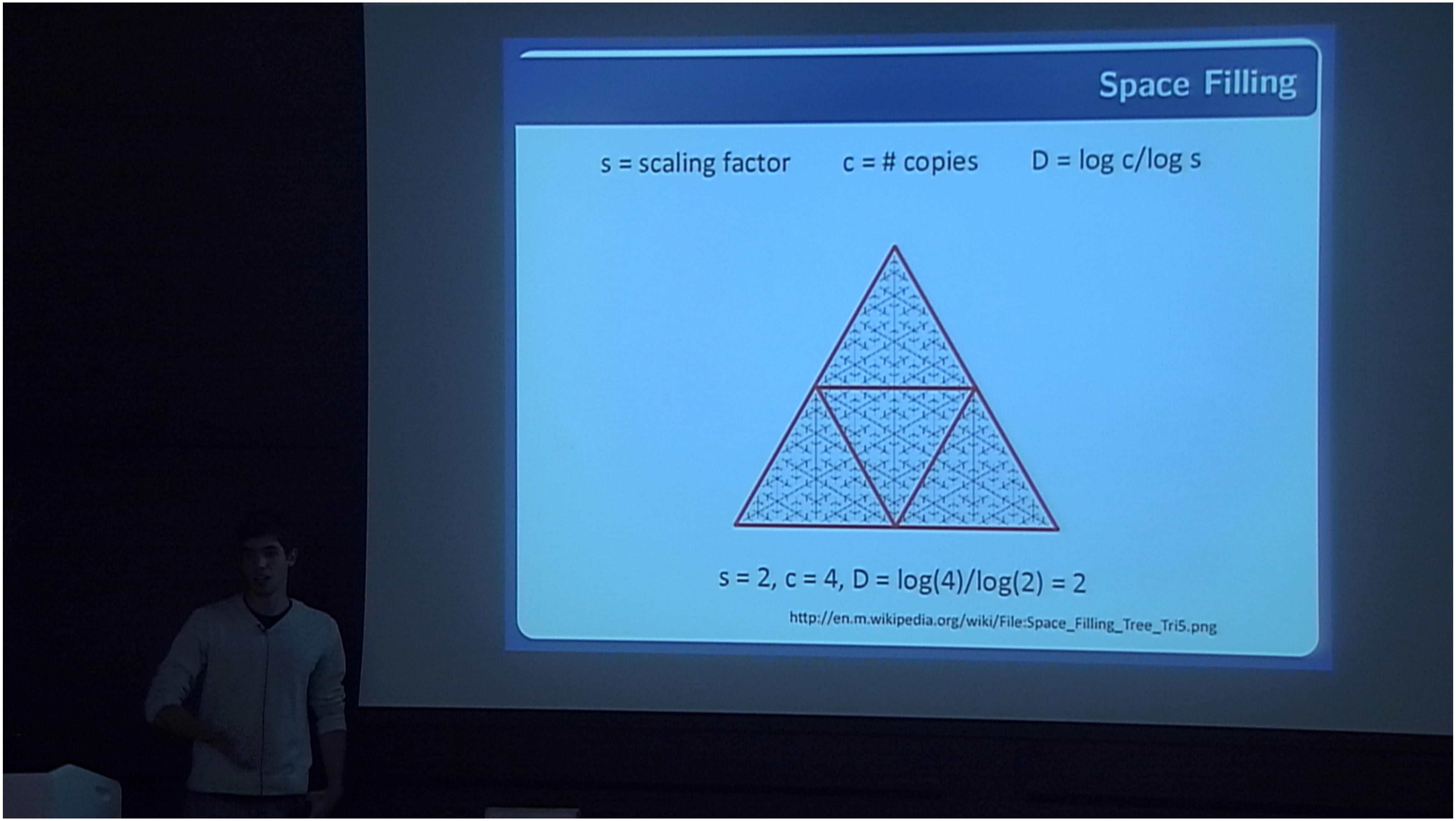
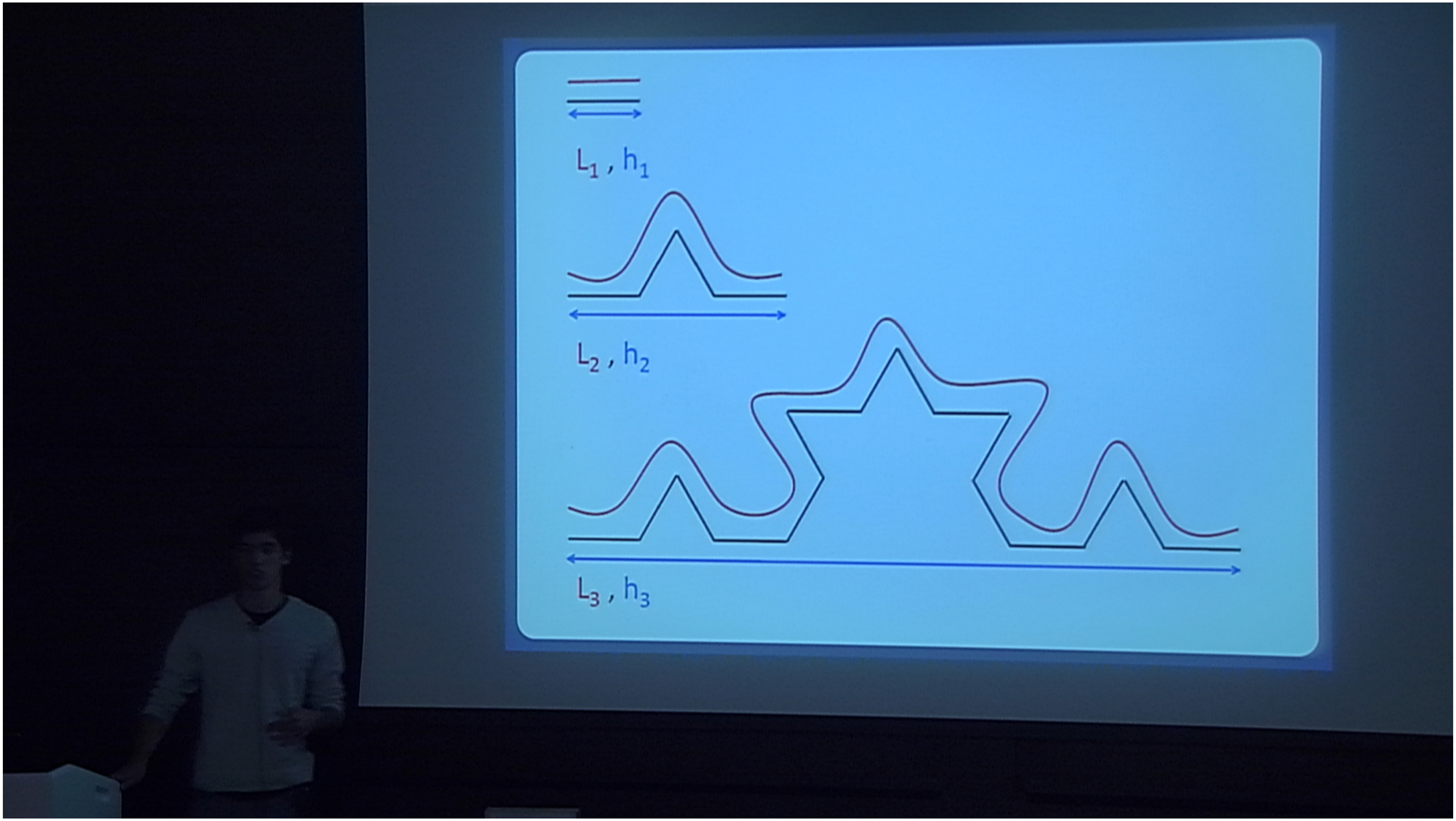
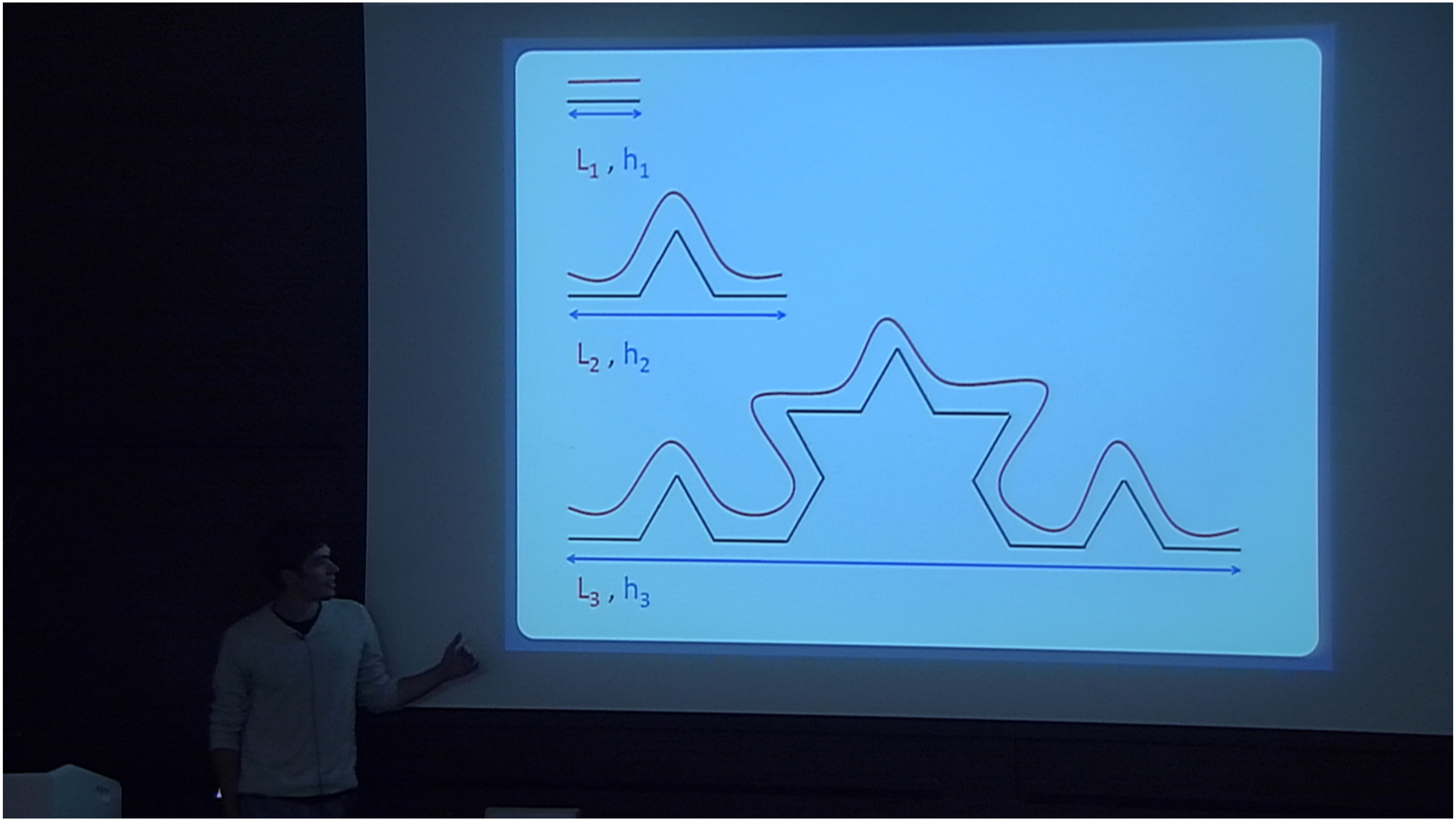

Fractal Dimension
s = scaling factor;   c = # copies;   (s,c) = (4,8)
R_0
R_1
R_2
$R_N = R_0/s^N$; $L_N = L_0 c^N/s^N$ ⟶ $L/L_0 = (R/R_0)^{1-D}$
Fractal Dimension D = log c/log s

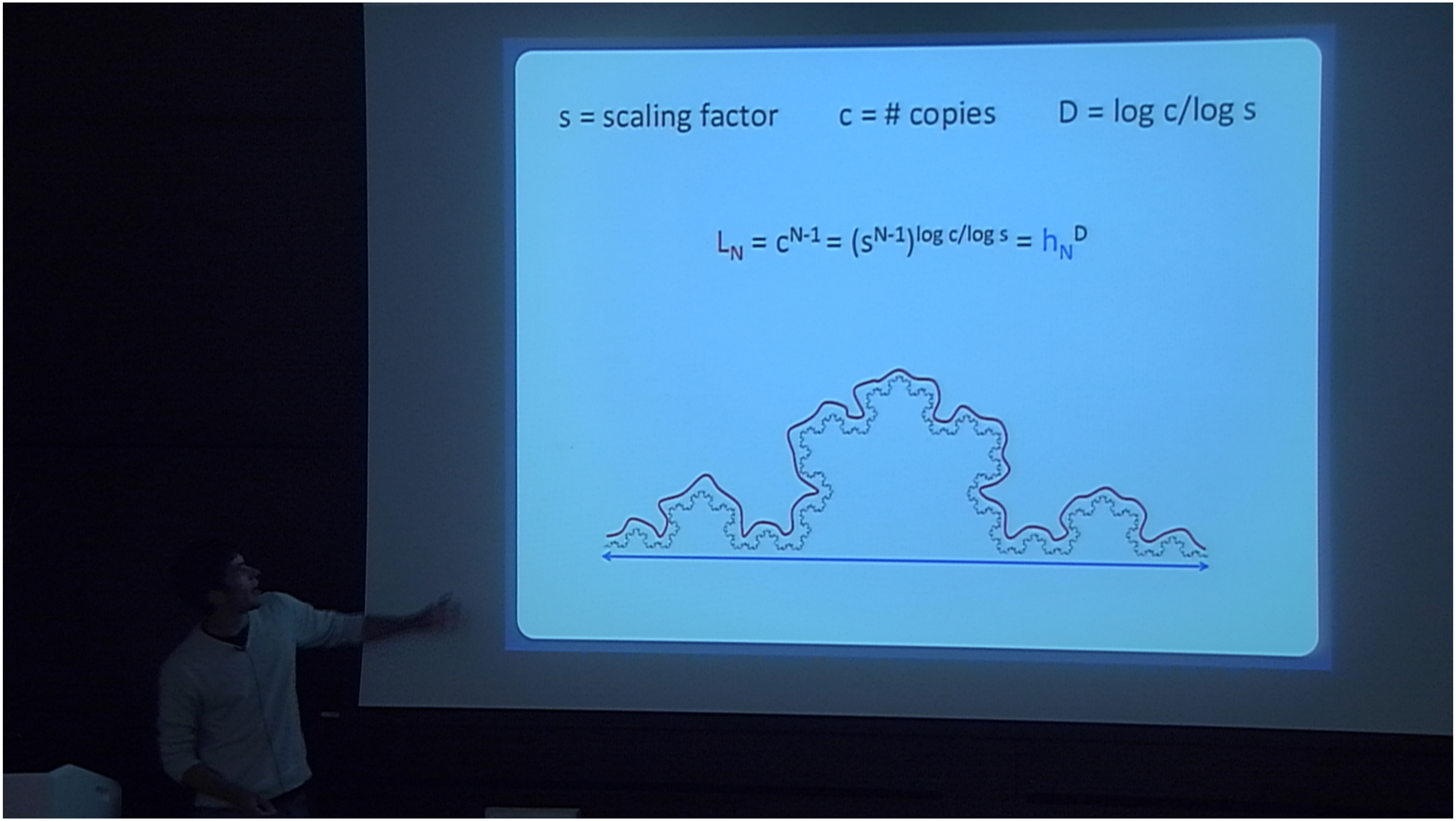

s = scaling factor
c = # copies
D = log c/log s
(s,c,D) = (k,k³,3)
(s,c,D) = (k,k²,2)
(s,c,D) = (k,k,1)

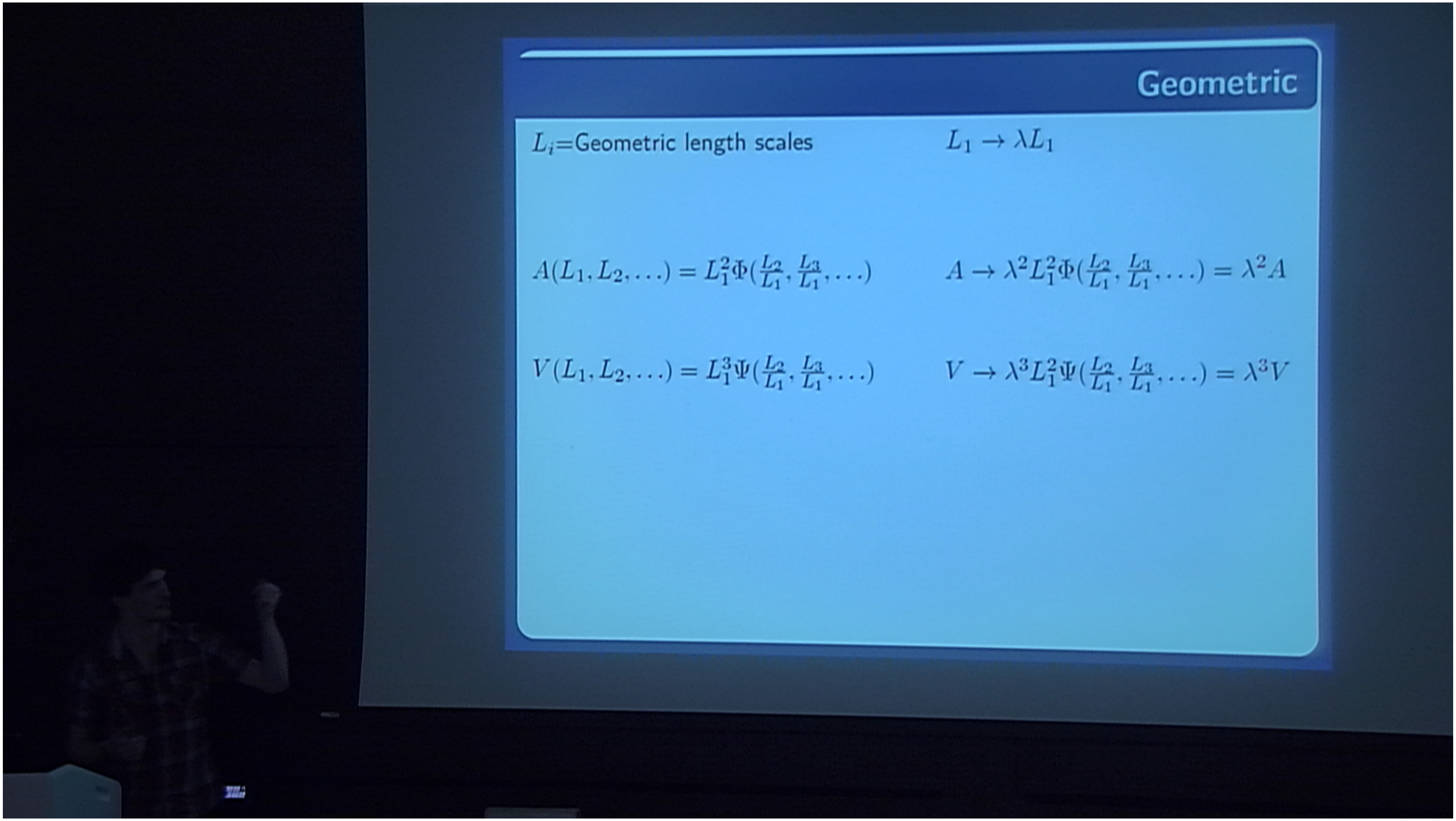


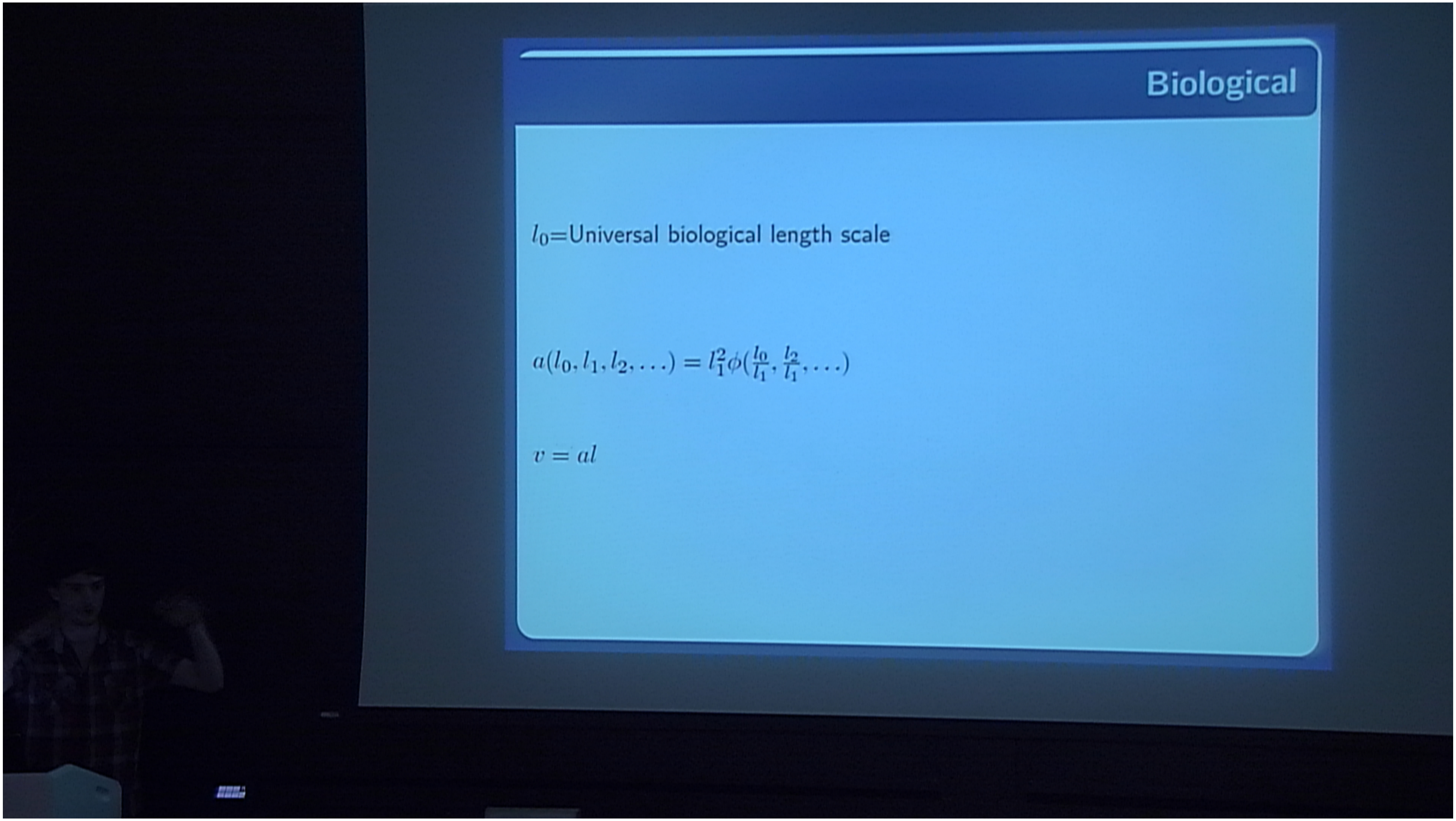
Space Filling
s = scaling factor
c = # copies
D = log c/log s
s = 2, c = 4, D = log(4)/log(2) = 2
http://en.m.wikipedia.org/wiki/File:Space_Filling_Tree_Tri5.png

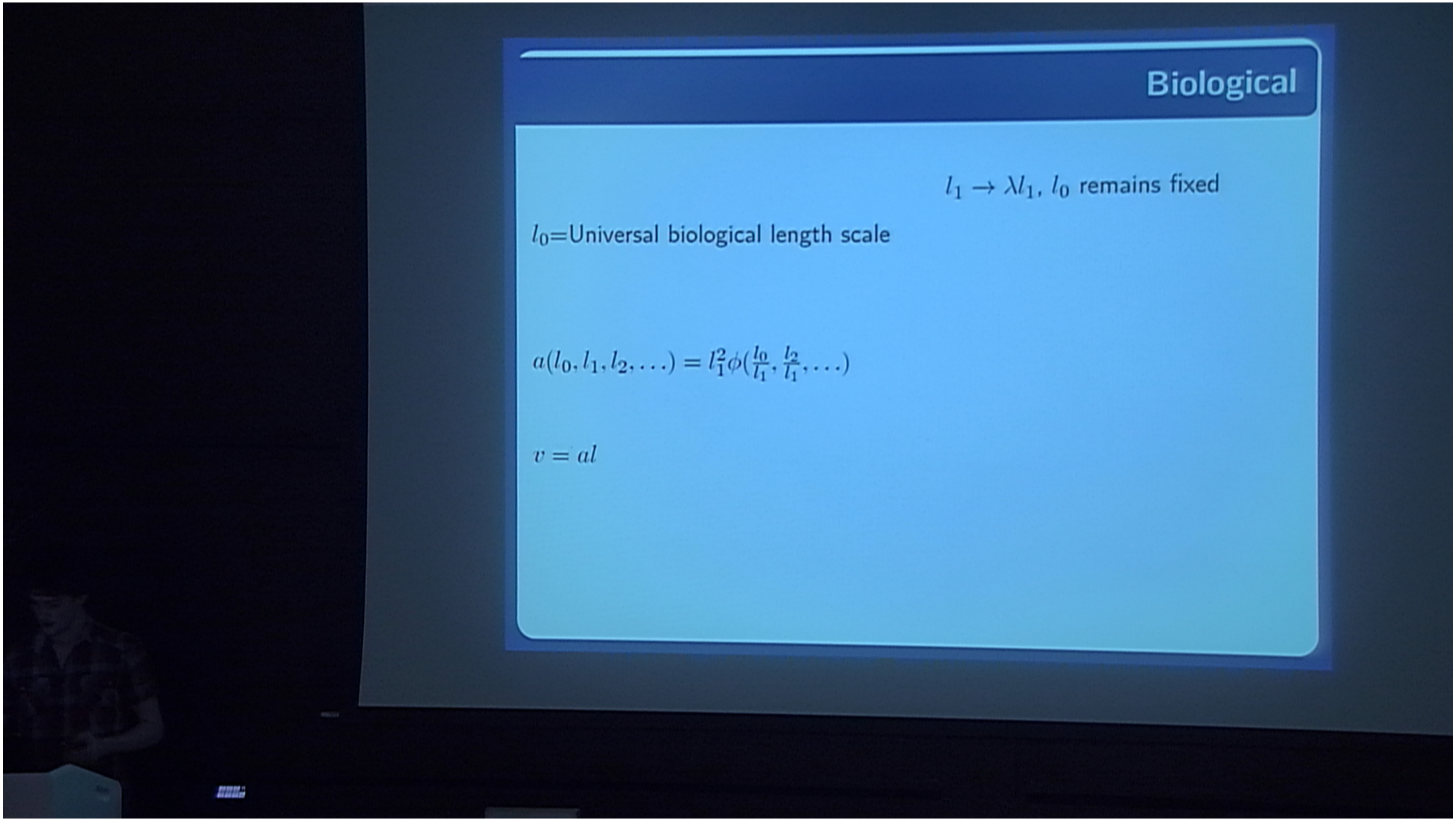

L_1 , h_1
L_2 , h_2
L_3 , h_3

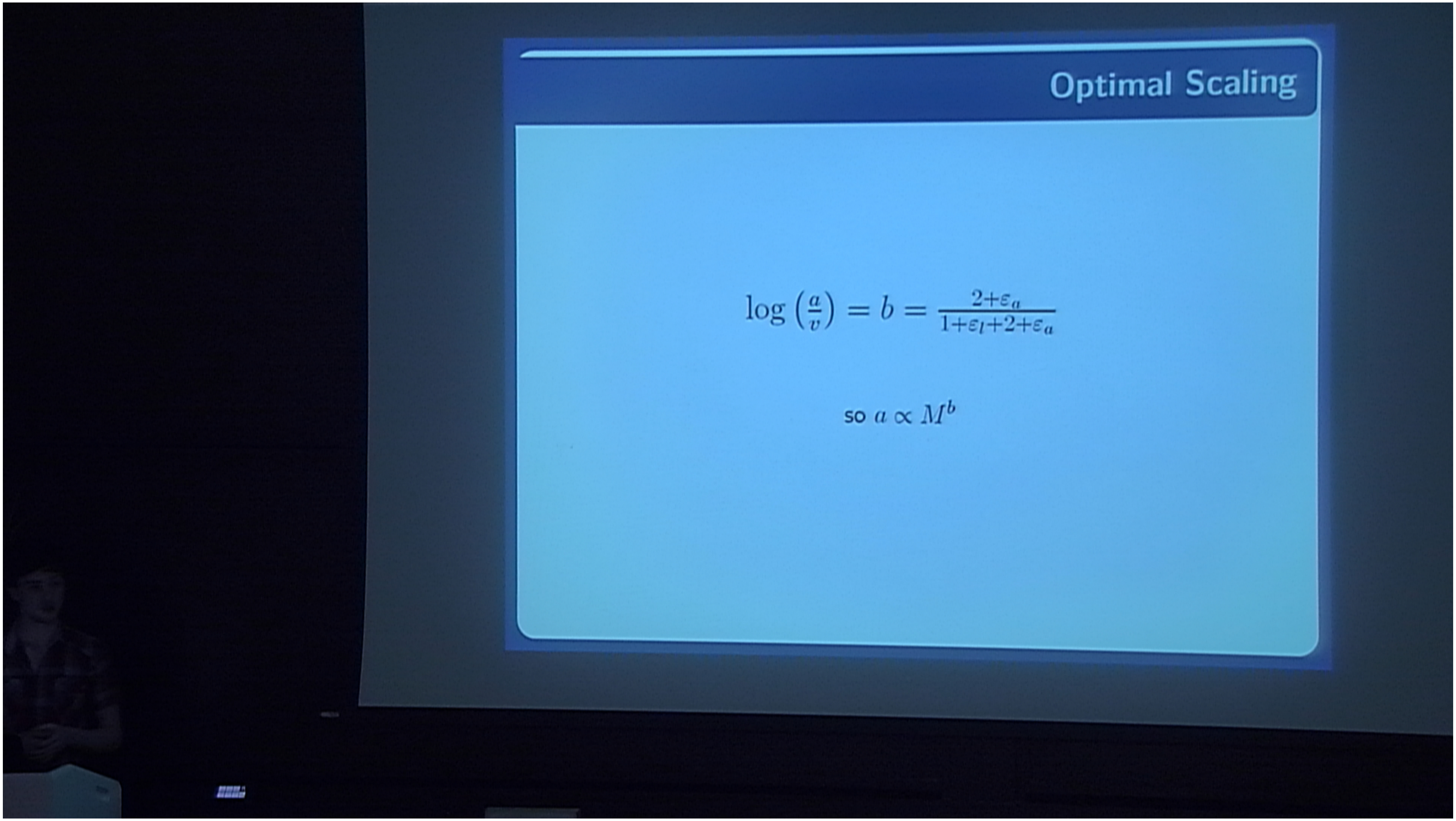

L_1 , h_1
L_2 , h_2
L_3 , h_3

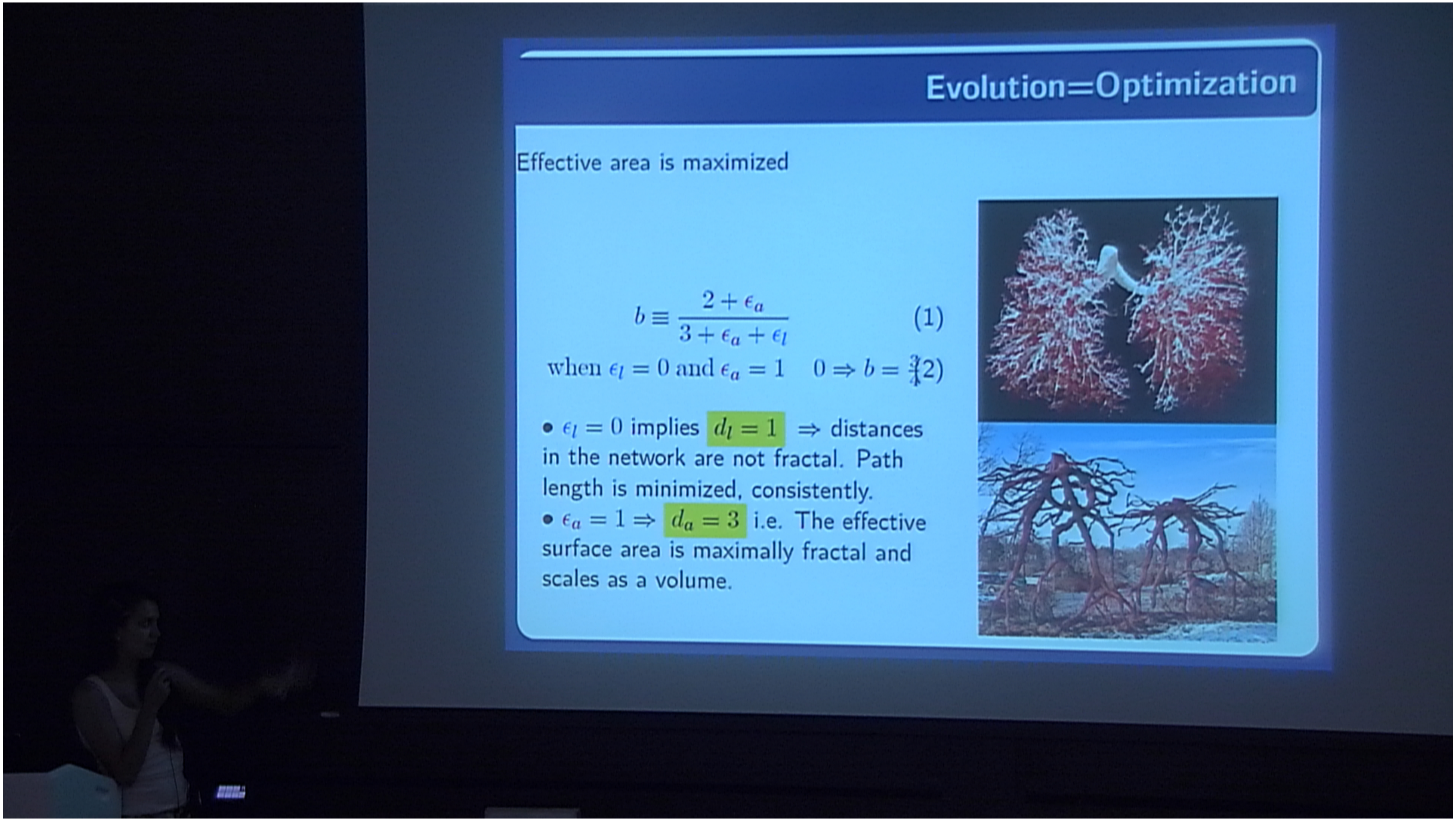

s = scaling factor
c = # copies
D = log c/log s
$L_N = c^{N-1} = (s^{N-1})^{\log c/\log s} = h_N^D$

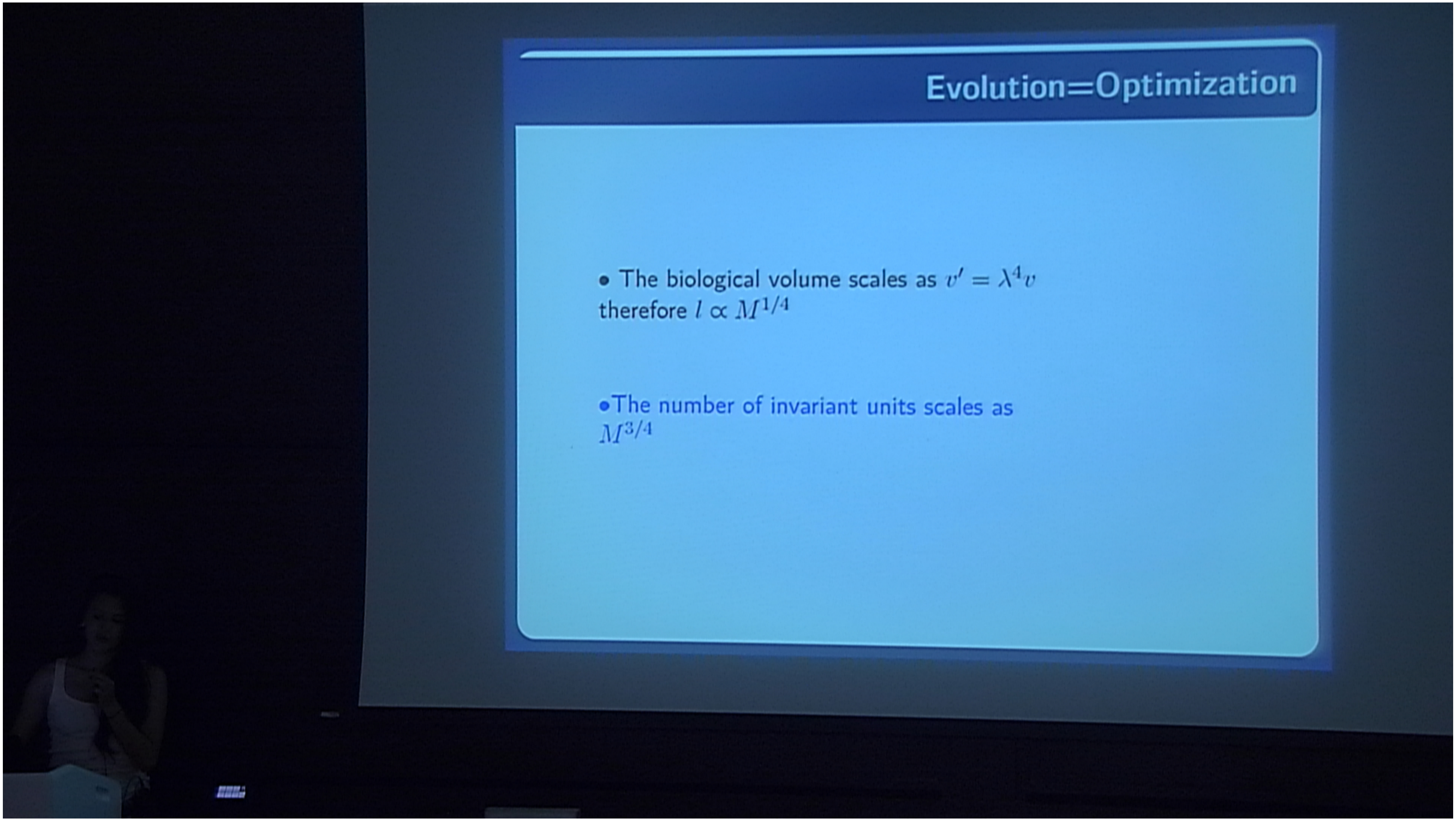

Geometric
L_i=Geometric length scales
$L_1 \to \lambda L_1$
$A(L_1, L_2, \ldots) = L_1^2 \Phi(\frac{L_2}{L_1}, \frac{L_3}{L_1}, \ldots)$
$A \to \lambda^2 L_1^2 \Phi(\frac{L_2}{L_1}, \frac{L_3}{L_1}, \ldots) = \lambda^2 A$
$V(L_1, L_2, \ldots) = L_1^3 \Psi(\frac{L_2}{L_1}, \frac{L_3}{L_1}, \ldots)$
$V \to \lambda^3 L_1^2 \Psi(\frac{L_2}{L_1}, \frac{L_3}{L_1}, \ldots) = \lambda^3 V$

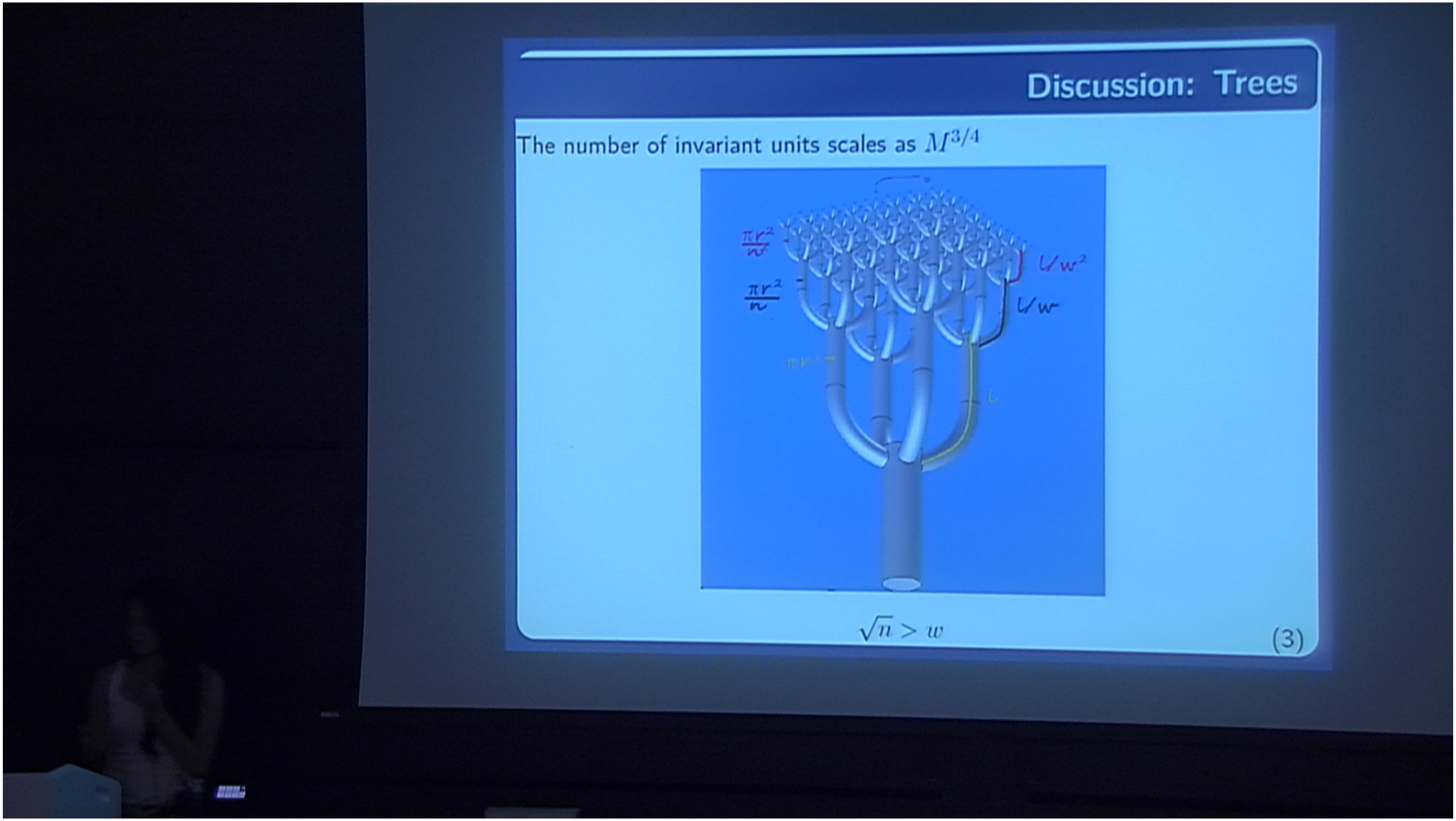

Biological
l_0=Universal biological length scale
$a(l_0, l_1, l_2, \ldots) = l_1^2 \phi(\frac{l_0}{l_1}, \frac{l_2}{l_1}, \ldots)$
$v = al$

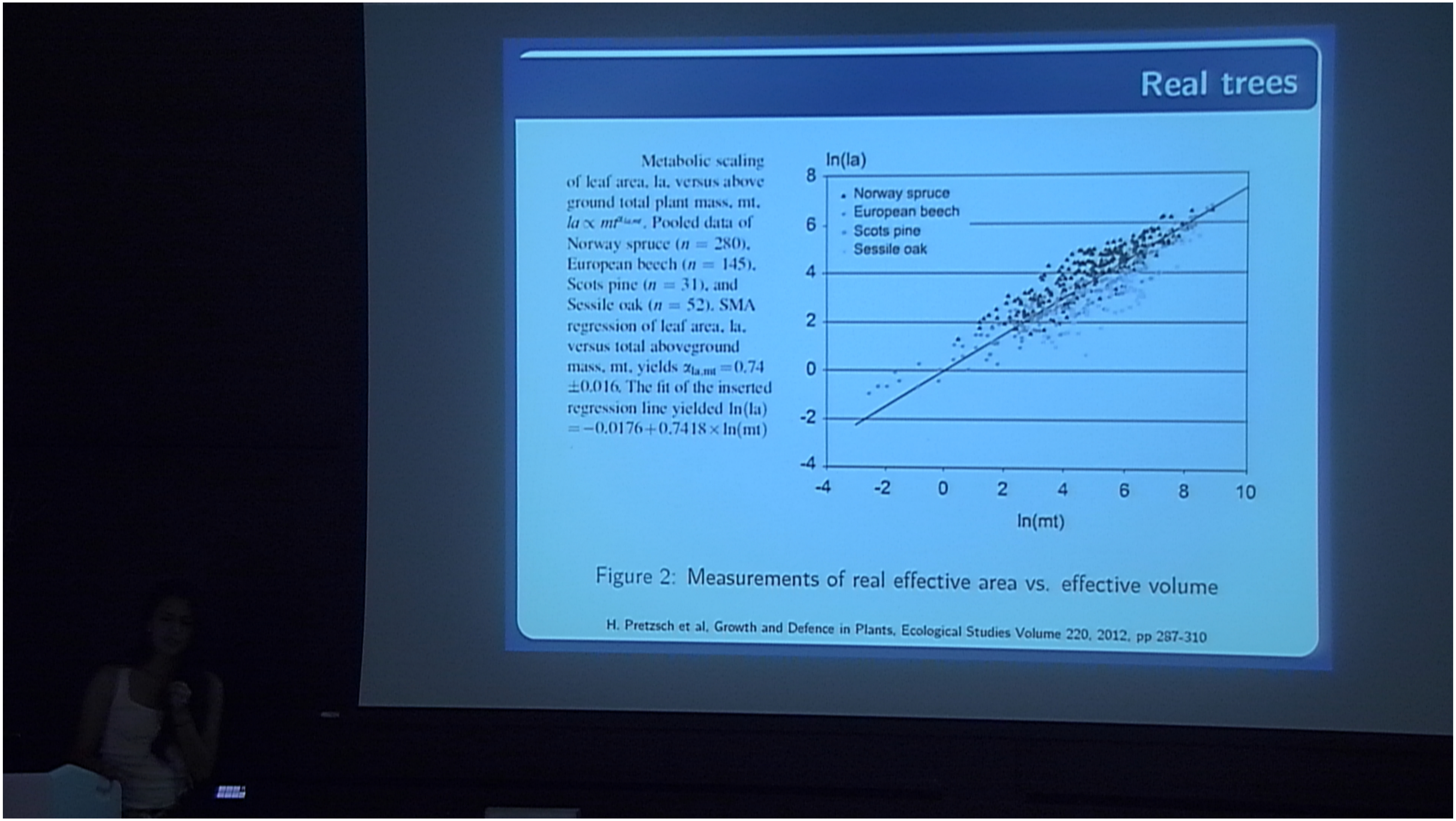

Biological
$l_1 \to \lambda l_1$, l_0 remains fixed
l_0=Universal biological length scale
$a(l_0, l_1, l_2, \ldots) = l_1^2 \phi(\frac{l_0}{l_1}, \frac{l_2}{l_1}, \ldots)$
$v = al$

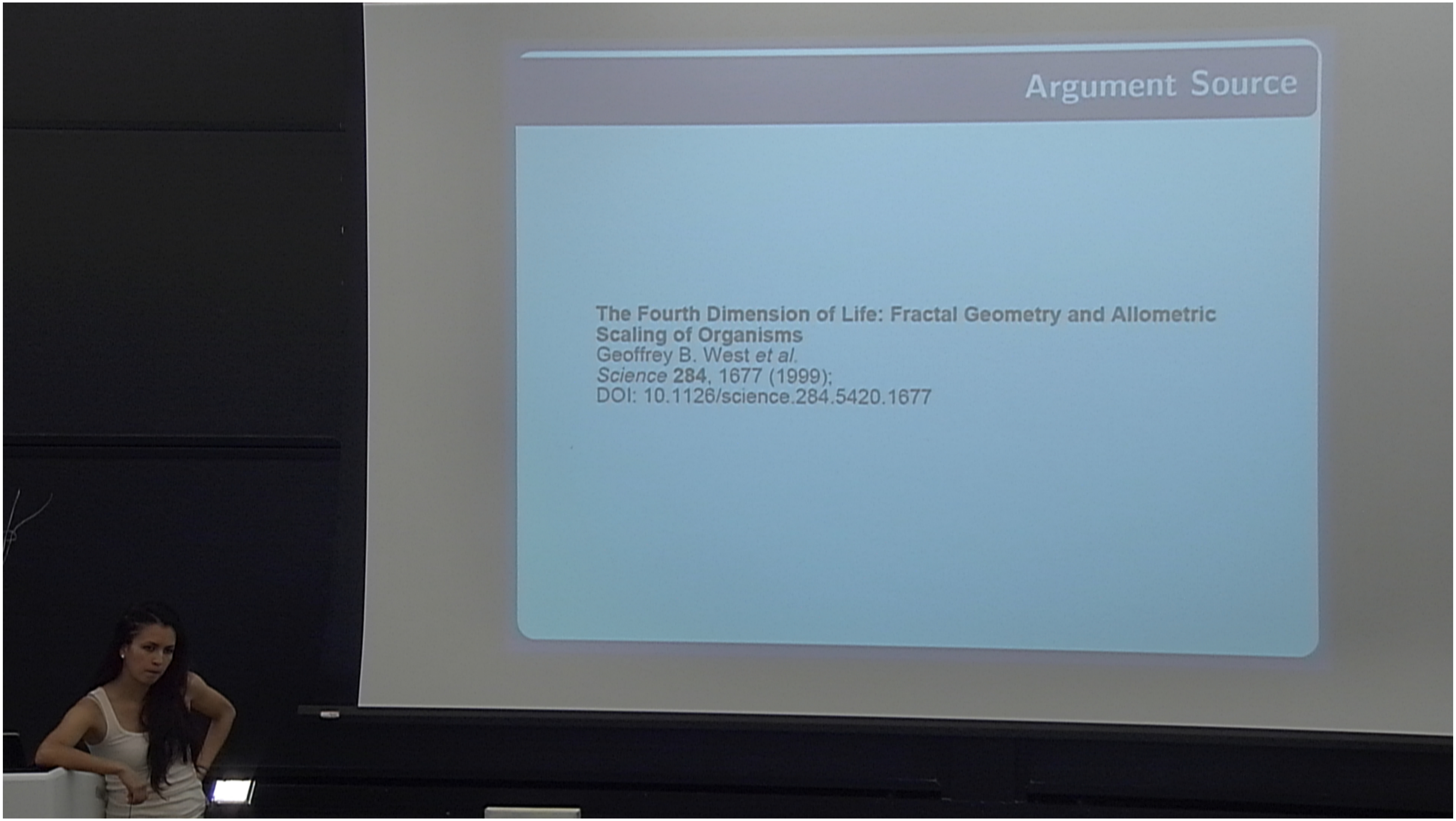

Optimal Scaling
$\log\left(\frac{a}{v}\right) = b = \frac{2+\varepsilon_a}{1+\varepsilon_l+2+\varepsilon_a}$
so $a \propto M^b$


Evolution=Optimization
Effective area is maximized
$b \equiv \frac{2+\epsilon_a}{3+\epsilon_a+\epsilon_l}$ (1)
when $\epsilon_l = 0$ and $\epsilon_a = 1$ $0 \Rightarrow b = \frac{3}{4}$ (2)
• $\epsilon_l = 0$ implies $d_l = 1$ ⇒ distances in the network are not fractal. Path length is minimized, consistently.
• $\epsilon_a = 1 \Rightarrow$ $d_a = 3$ i.e. The effective surface area is maximally fractal and scales as a volume.


Evolution=Optimization
• The biological volume scales as $v' = \lambda^4 v$ therefore $l \propto M^{1/4}$
•The number of invariant units scales as $M^{3/4}$


Discussion: Trees
The number of invariant units scales as $M^{3/4}$
$\frac{\pi r^2}{n}$
L/w^2
L/w
$\sqrt{n} > w$
(3)


Real trees
Metabolic scaling of leaf area, la, versus above ground total plant mass, mt, la ∝ mt^αla,mt. Pooled data of Norway spruce (n = 280), European beech (n = 145), Scots pine (n = 31), and Sessile oak (n = 52). SMA regression of leaf area, la, versus total aboveground mass, mt, yields αla,mt = 0.74 ±0.016. The fit of the inserted regression line yielded ln(la) = −0.0176 + 0.7418 × ln(mt)
ln(la)
Norway spruce
European beech
Scots pine
Sessile oak
ln(mt)
Figure 2: Measurements of real effective area vs. effective volume
H. Pretzsch et al, Growth and Defence in Plants, Ecological Studies Volume 220, 2012, pp 287-310


Argument Source
The Fourth Dimension of Life: Fractal Geometry and Allometric Scaling of Organisms
Geoffrey B. West et al.
Science 284, 1677 (1999);
DOI: 10.1126/science.284.5420.1677