MATH327: More Is Different

Statistical Mechanics, Thermodynamics, and All That

Monday, 27 January 2025

28 56 28

Something to consider "Brownian motion" Einstein 1905 Perrin 1908 (1926 Nobel)

The existence of atoms was established long before technology could identify individual atoms.

What sort of arguments might this have involved?

[Could similar arguments apply to string theory?]

Today

Big picture

Logistics

Probability Foundations (?)

Relativity + Quantum + Stat Mech ↙

LARGE # of DoF ~ "particles"

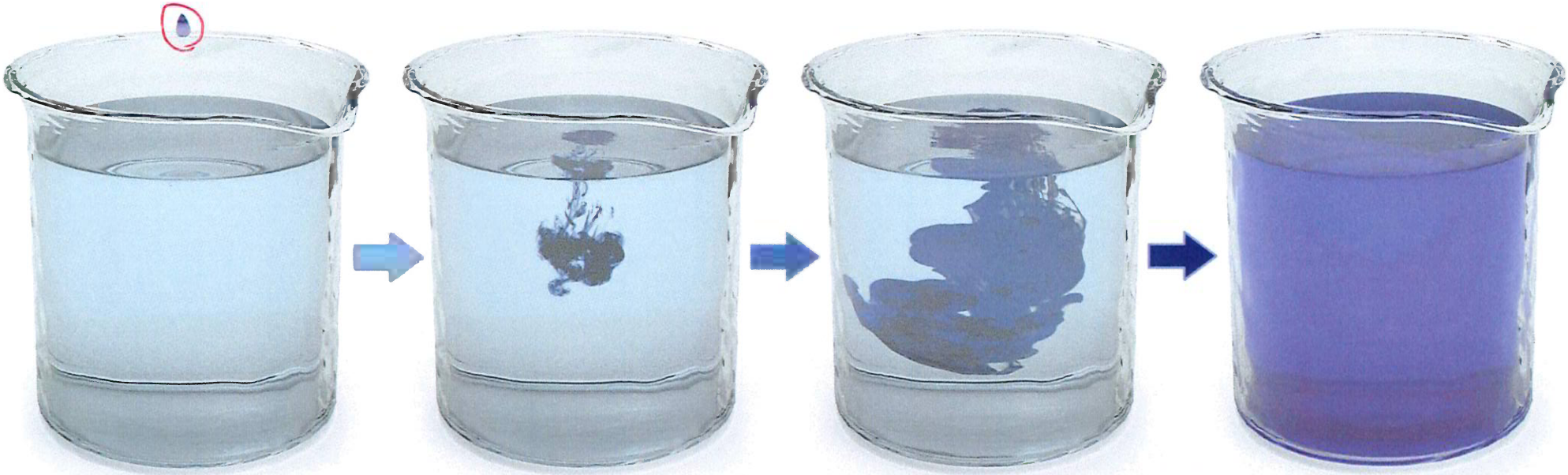
1 cc. water ~ 10^{22} H_2O molecules

Snapshot: ~ 10^{22} × (position + momentum) × 3 × 8B ~ 10^{24} bytes 10^{12} TB

Dynamics: ~ 10^{22} coupled diff eq.

Consequence: Emergent phenomena

"Arrow of time" →



commons.wikimedia.org/wiki/File:Blausen_0315_Diffusion.png

THE NOBEL PRIZE IN PHYSICS 2021

Illustrations: Niklas Elmehed

Syukuro Manabe

Klaus Hasselmann

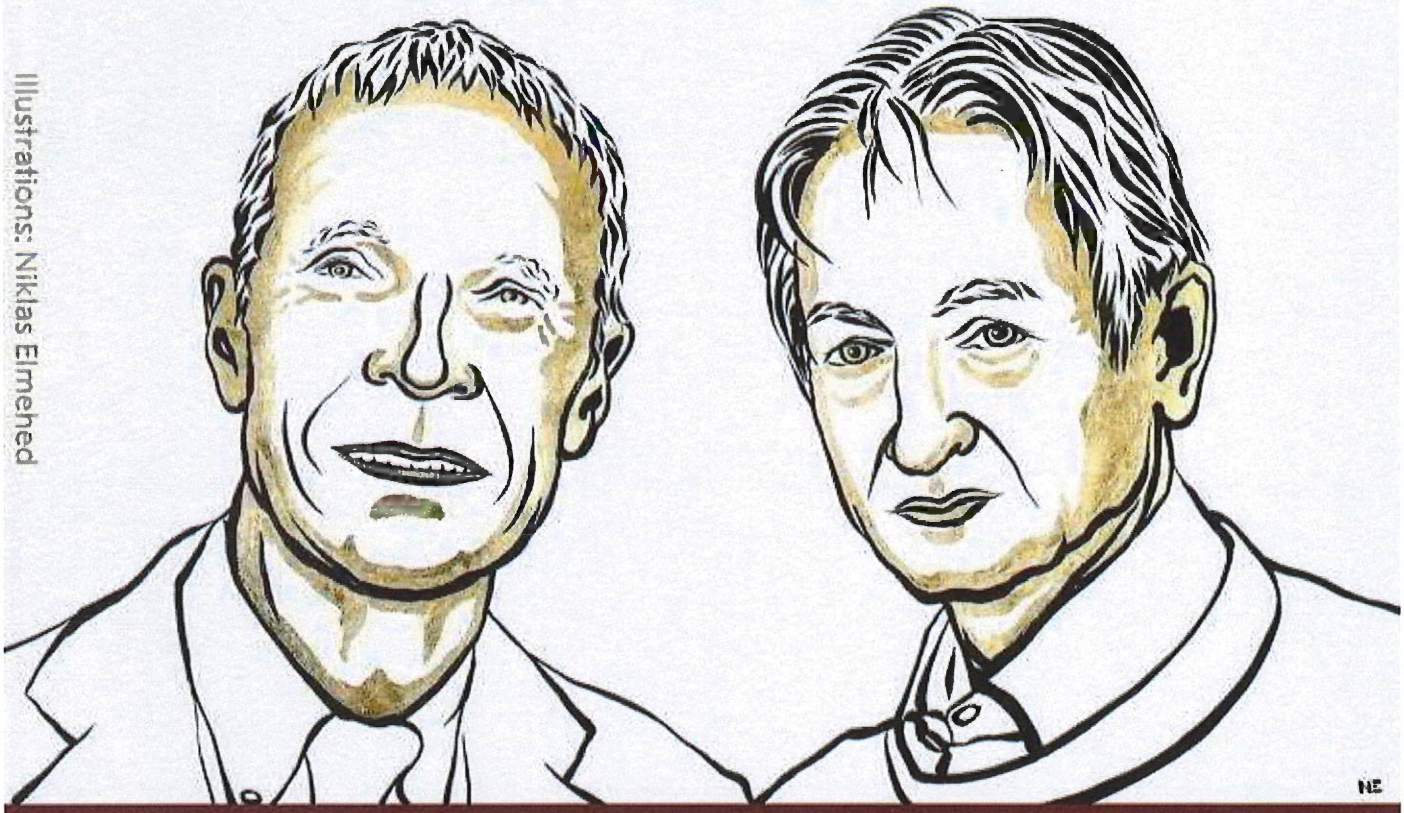
"for the physical modelling of Earth's climate, quantifying variability and reliably predicting global warming"

Giorgio Parisi

"for the discovery of the interplay of disorder and fluctuations in physical systems from atomic to planetary scales"

THE ROYAL SWEDISH ACADEMY OF SCIENCES

THE NOBEL PRIZE IN PHYSICS 2024

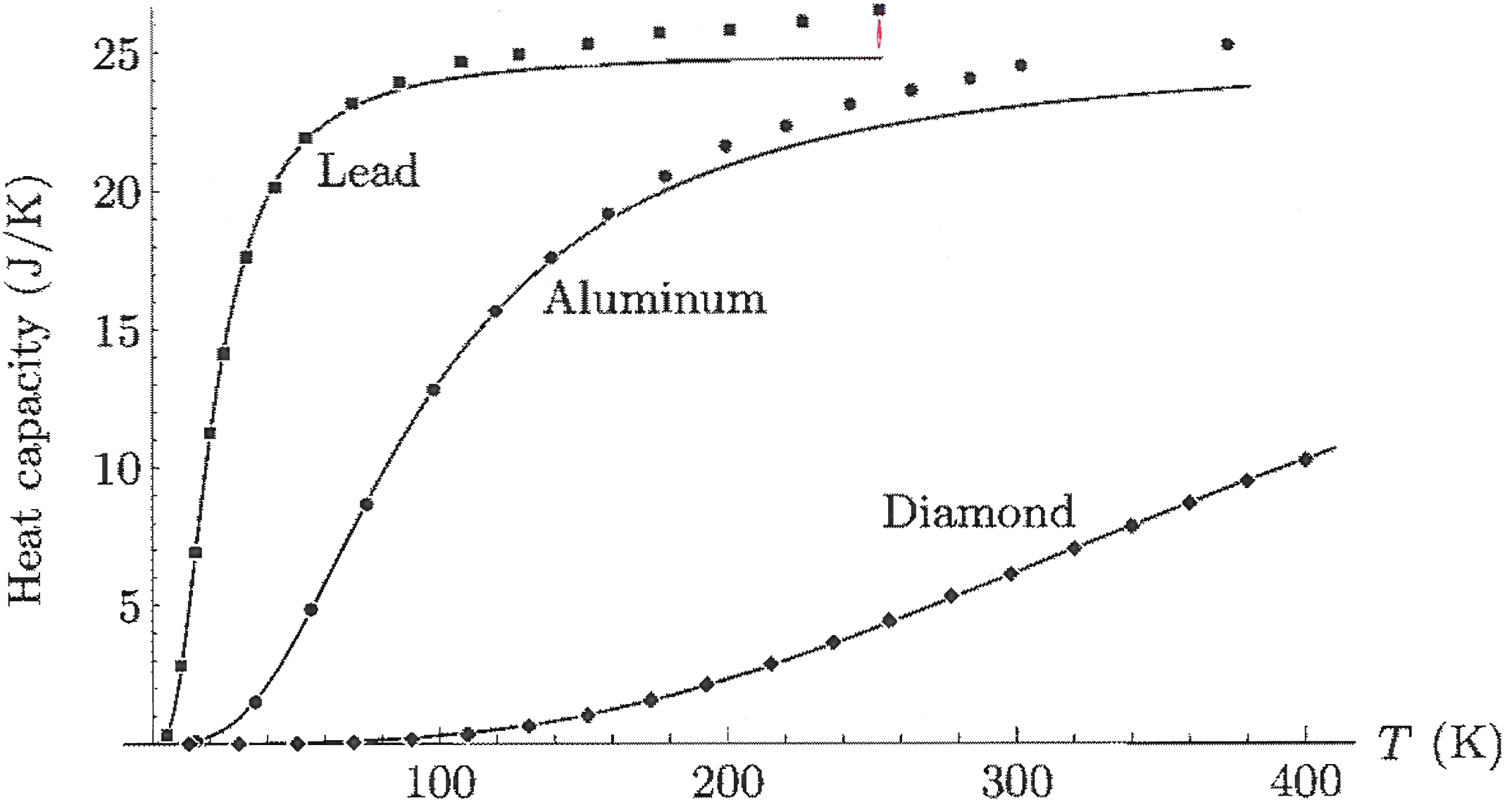


Illustrations: Niklas Elmehed

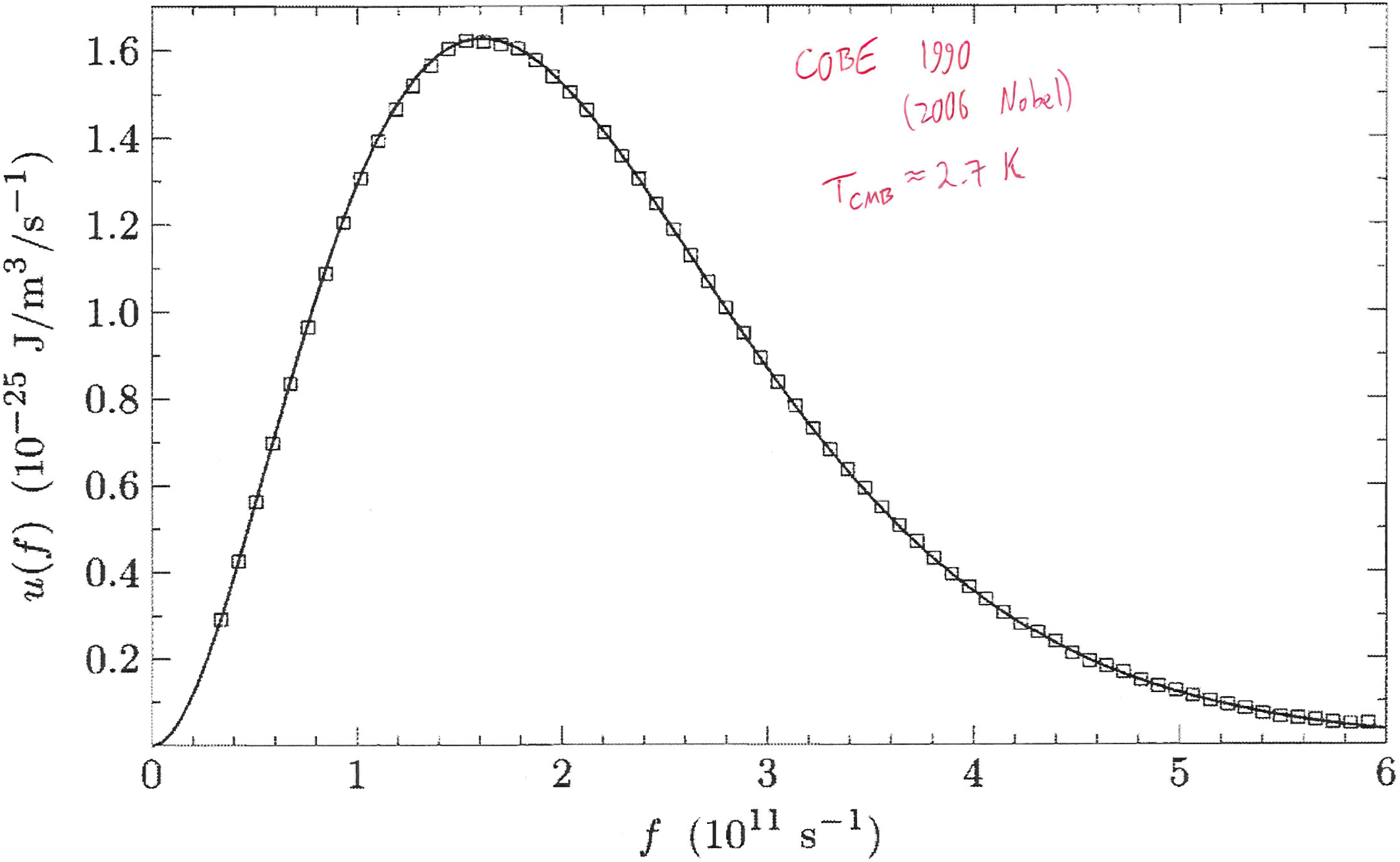
John J. Hopfield Geoffrey E. Hinton

"for foundational discoveries and inventions
that enable machine learning
with artificial neural networks"

THE ROYAL SWEDISH ACADEMY OF SCIENCES


Heat capacity (J/K)
25
20
15
10
5
Lead
Aluminum
Diamond
100
200
300
400
T (K)

C/T (mJ/K^2)
2
4
6
8
T^2 (K^2)
0
2
4
6
8
10
12
14
16
18
Gold
Silver
Copper
$C = aT + bT^3$


COBE 1990
(2006 Nobel)
$T_{CMB} \approx 2.7$ K
$u(f)$ $(10^{-25}$ J/m^3/s$^{-1})$
f $(10^{11}$ s$^{-1})$
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
0
1
2
3
4
5
6

Probability Foundations

Law of large numbers & central limit theorems
→ emergence of smooth large-scale behaviour

Definitions:

Random experiments $\mathcal{E}$ observes world
→ state w (omega)

$\Omega = \{w\}$ is set of all states for $\mathcal{E}$