73 24 43

MATH327: More Is Different

Statistical Mechanics, Thermodynamics, and All That

Tuesday, 27 January 2026

Something to consider

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

"Brownian motion" – Einstein 1905
Jean Perrin 1908
→ 1926 Nobel

What sort of arguments might this have involved?

[Could similar arguments apply to string theory?]

Today
- Big picture
- Logistics
- Prob. Foundations

Relativity + Quantum + Stat Mech.

LARGE number of objects

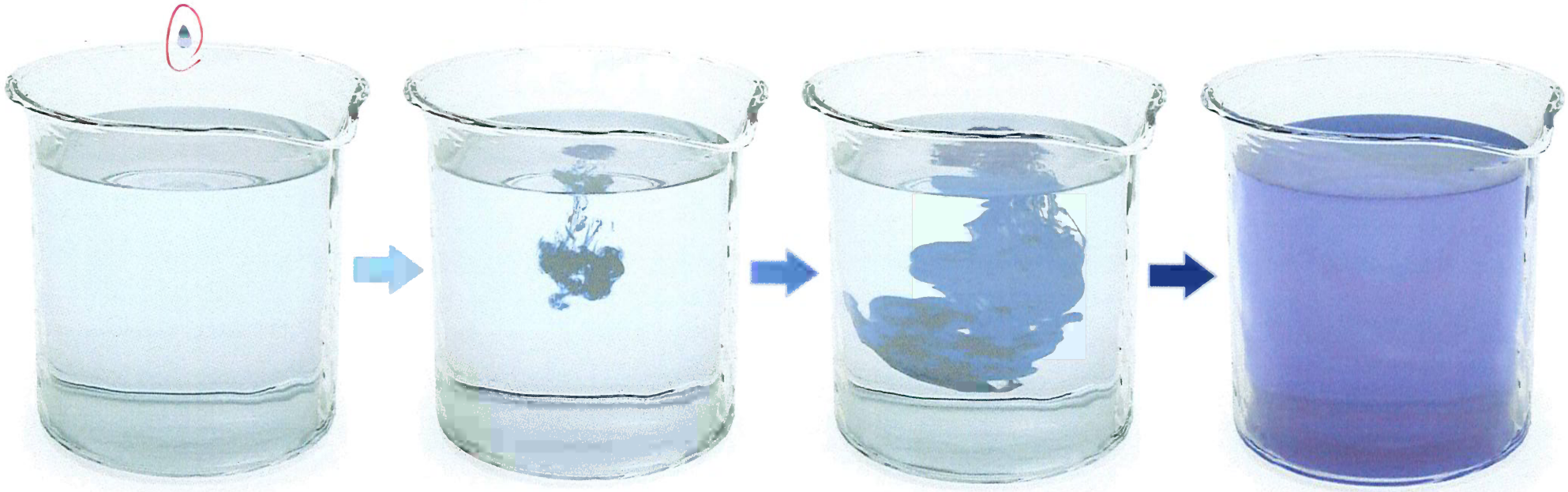
1 c.c. water ~ 10^{22} H_2O molecules

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

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

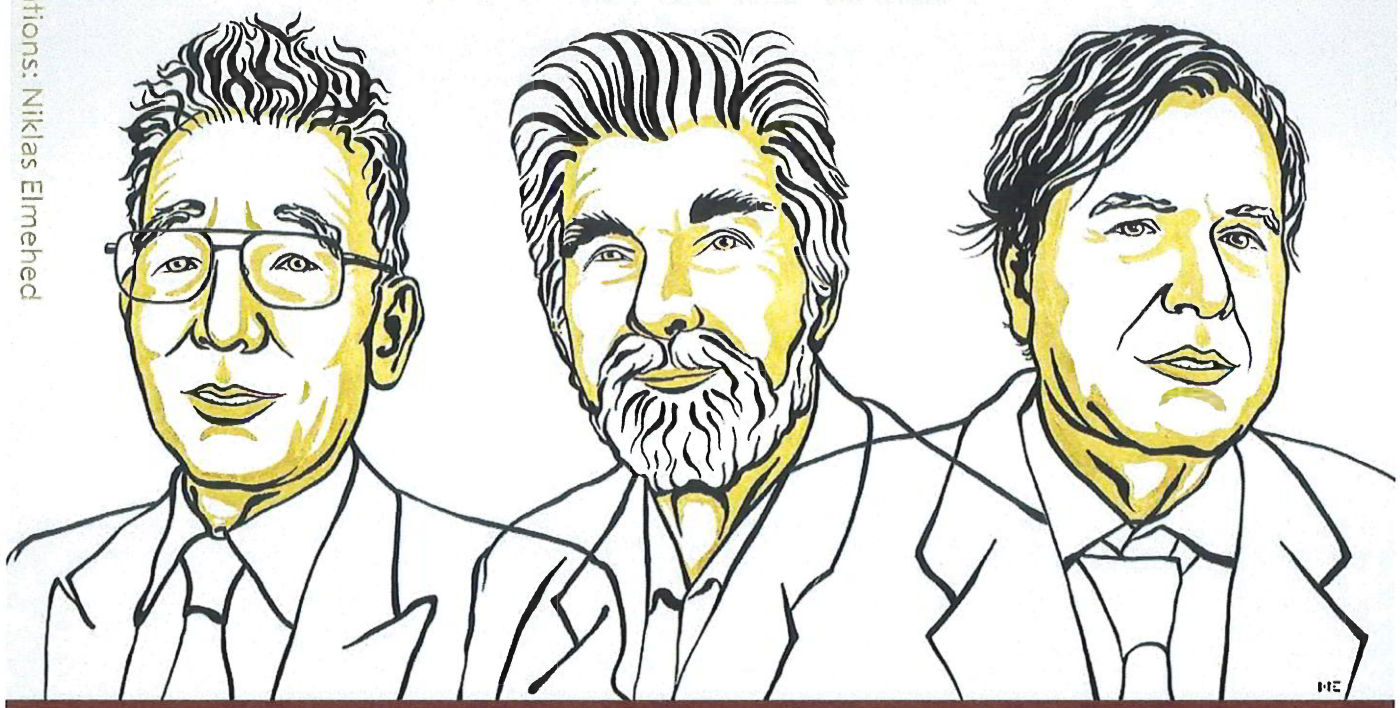
Consequence: Emergent phenomena

"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

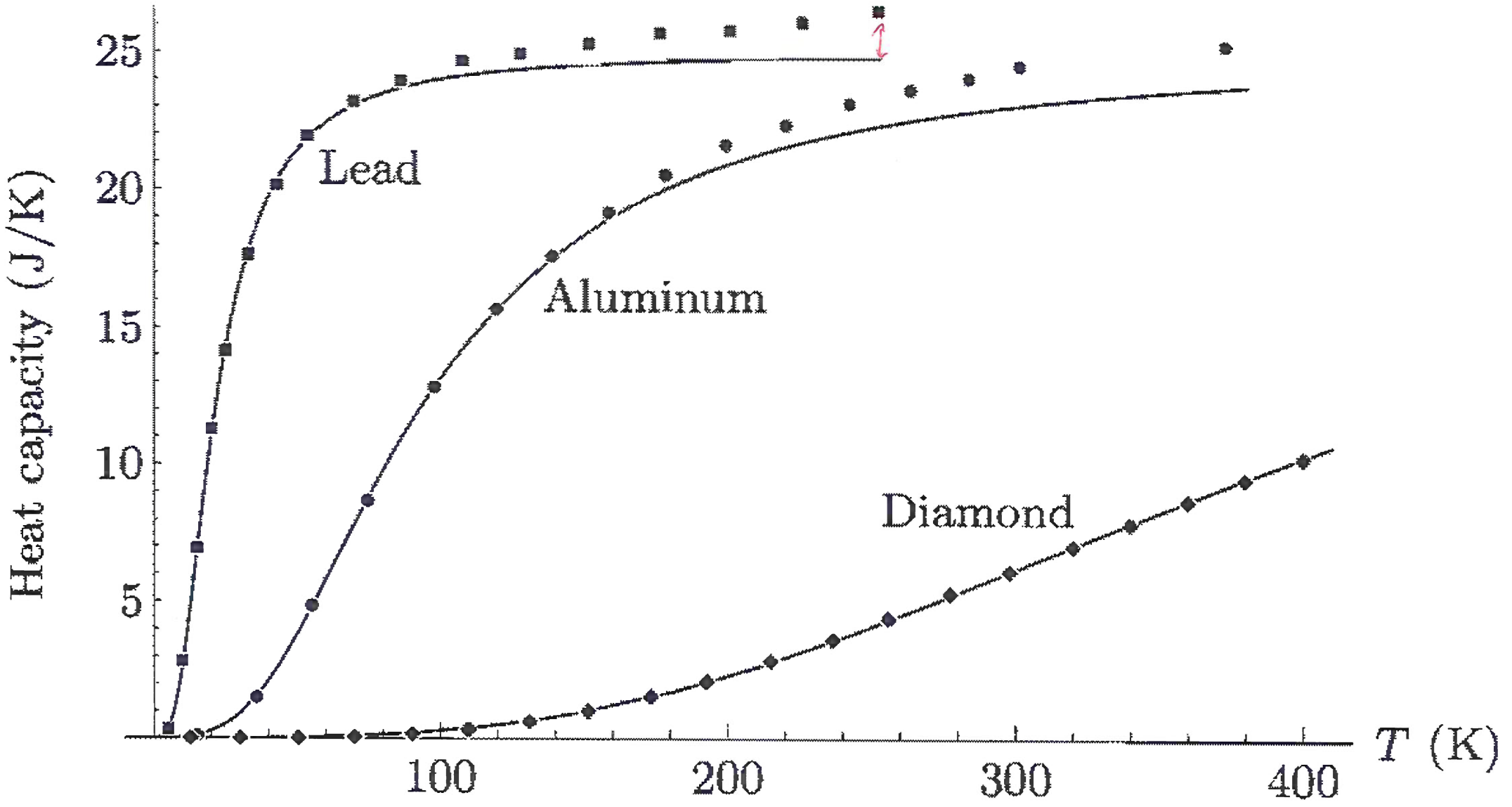
THE NOBEL PRIZE IN PHYSICS 2024

Illustrations: Niklas Elmehed

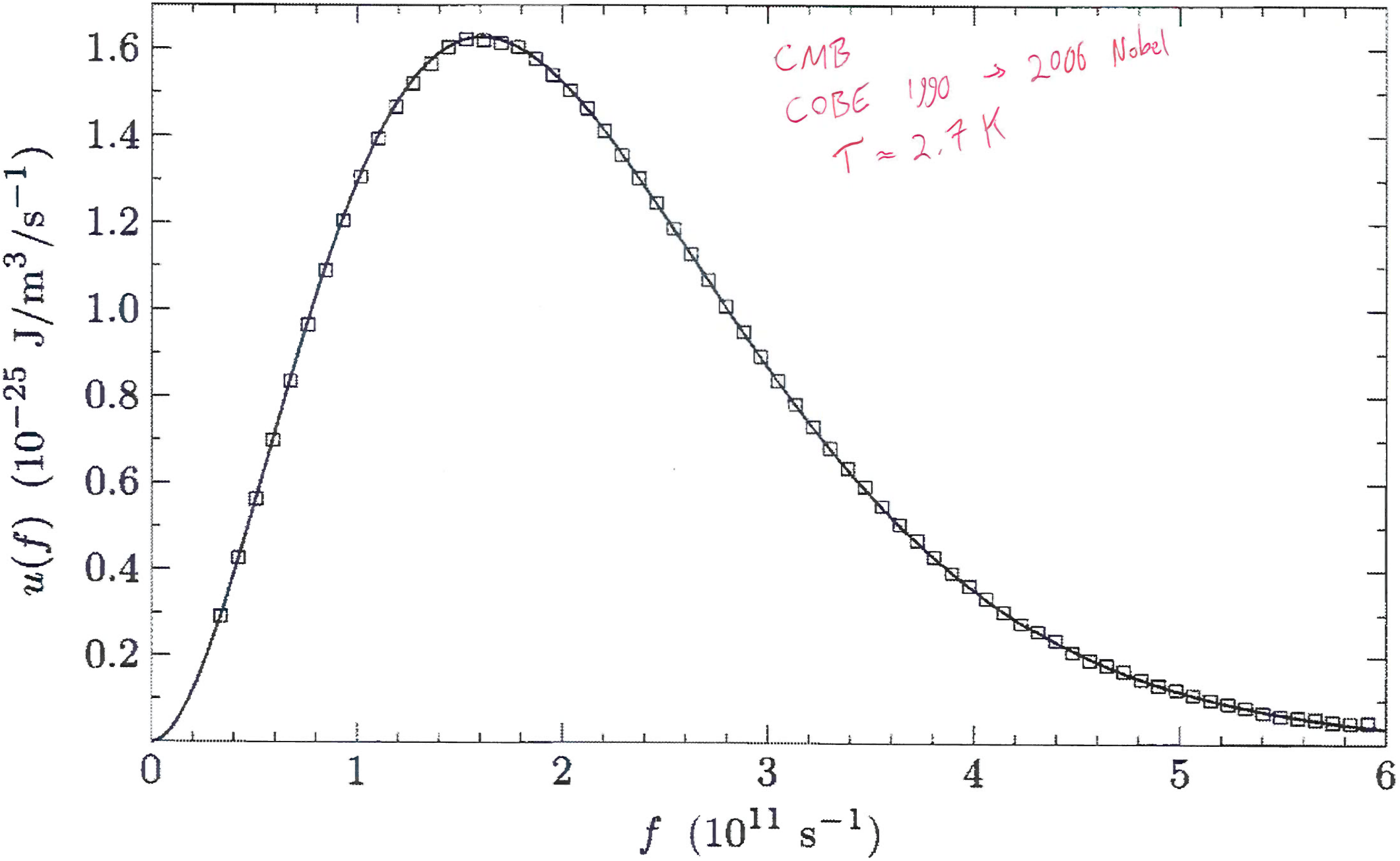
John J. Hopfield Geoffrey E. Hinton

"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
$C = aT + bT^3$


CMB
COBE 1990 → 2006 Nobel
T ≈ 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 theorem
→ emergence of smooth large-scale behaviour

Definitions:

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

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

Measurement ...