

Parcours International

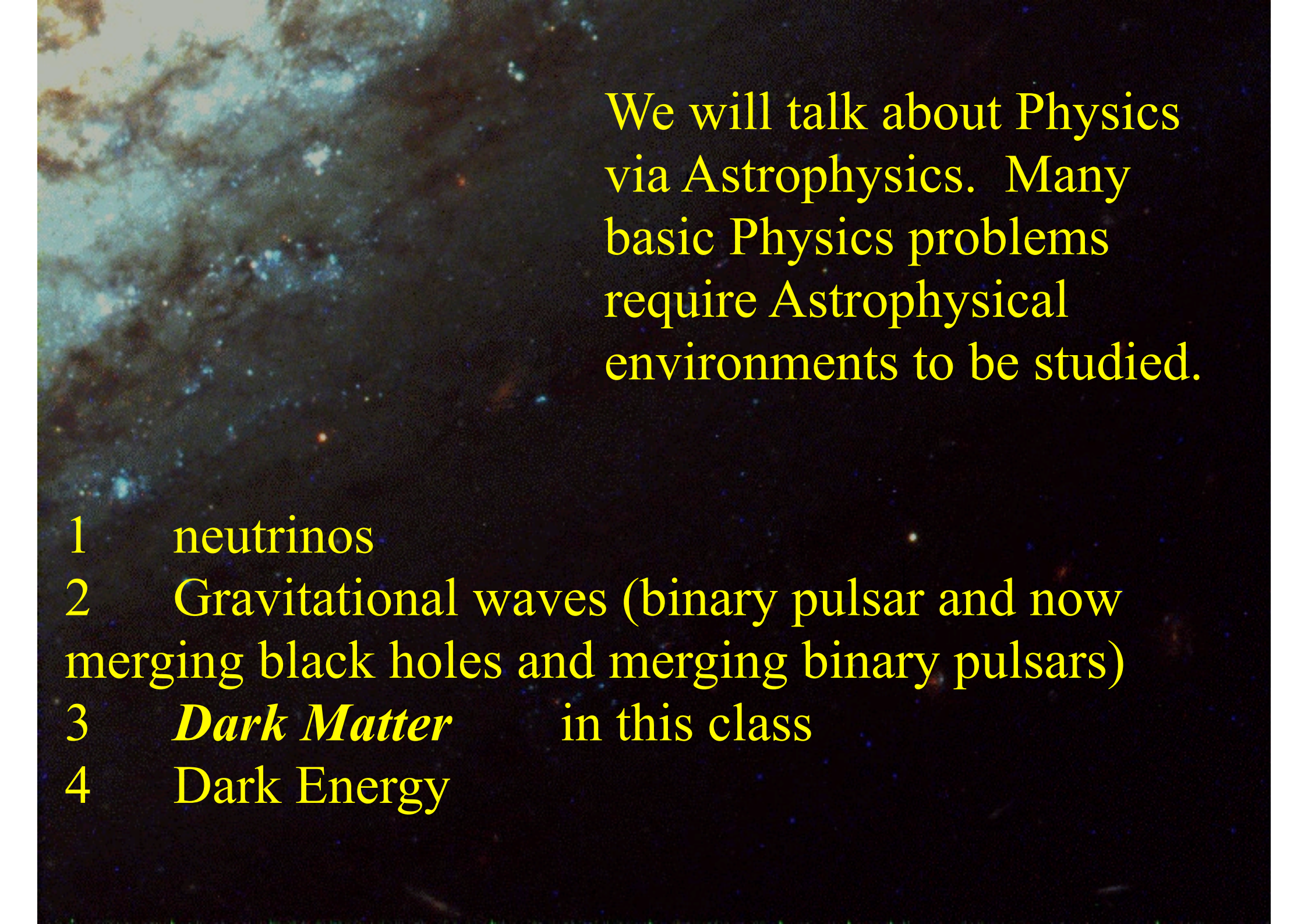
The Infinitely Large and Infinitely Small

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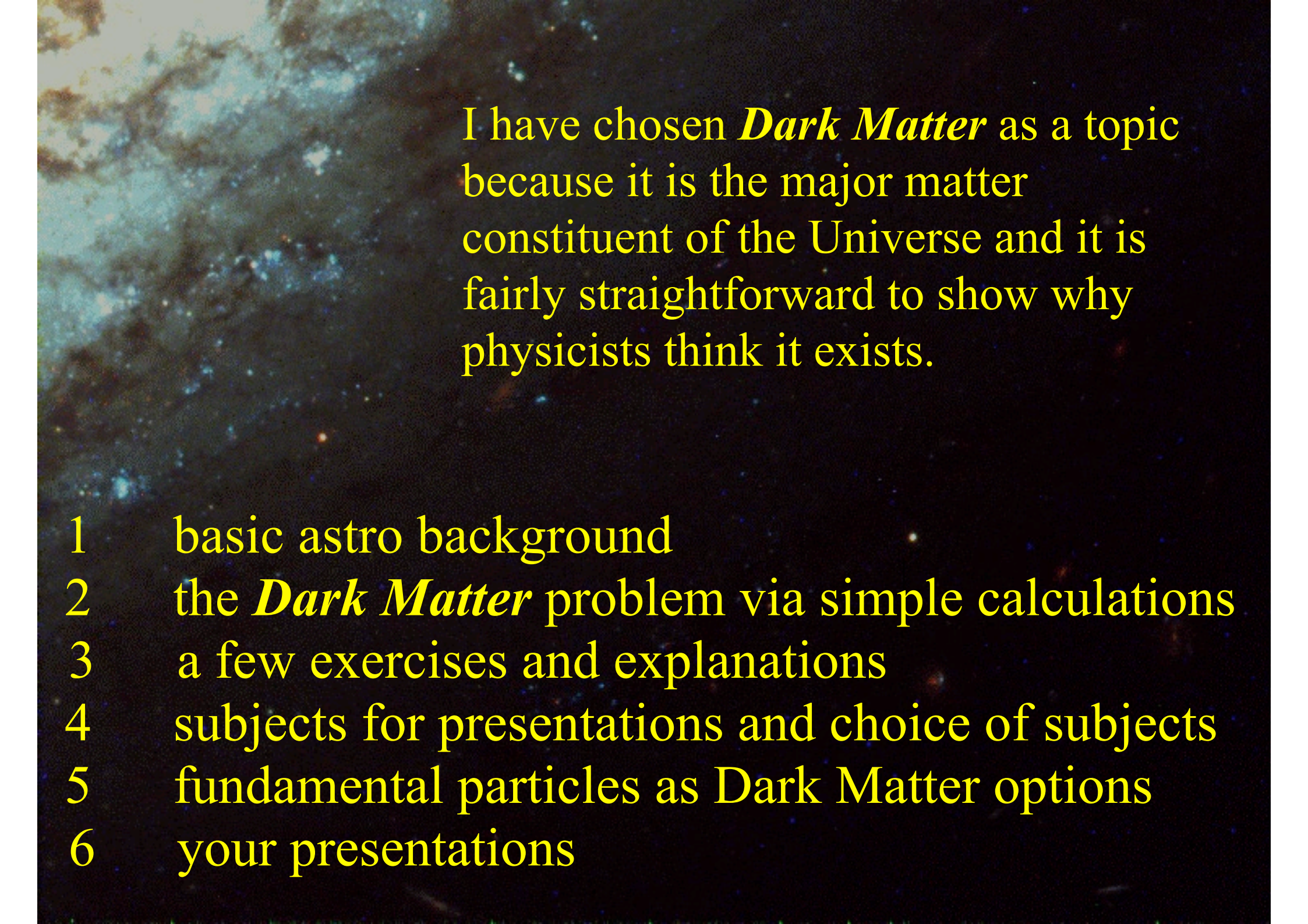
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We will talk about Physics
via Astrophysics. Many
basic Physics problems
require Astrophysical
environments to be studied.

- 1 neutrinos
- 2 Gravitational waves (binary pulsar and now
merging black holes and merging binary pulsars)
- 3 ***Dark Matter*** in this class
- 4 Dark Energy



I have chosen *Dark Matter* as a topic because it is the major matter constituent of the Universe and it is fairly straightforward to show why physicists think it exists.

- 1 basic astro background
- 2 the *Dark Matter* problem via simple calculations
- 3 a few exercises and explanations
- 4 subjects for presentations and choice of subjects
- 5 fundamental particles as Dark Matter options
- 6 your presentations

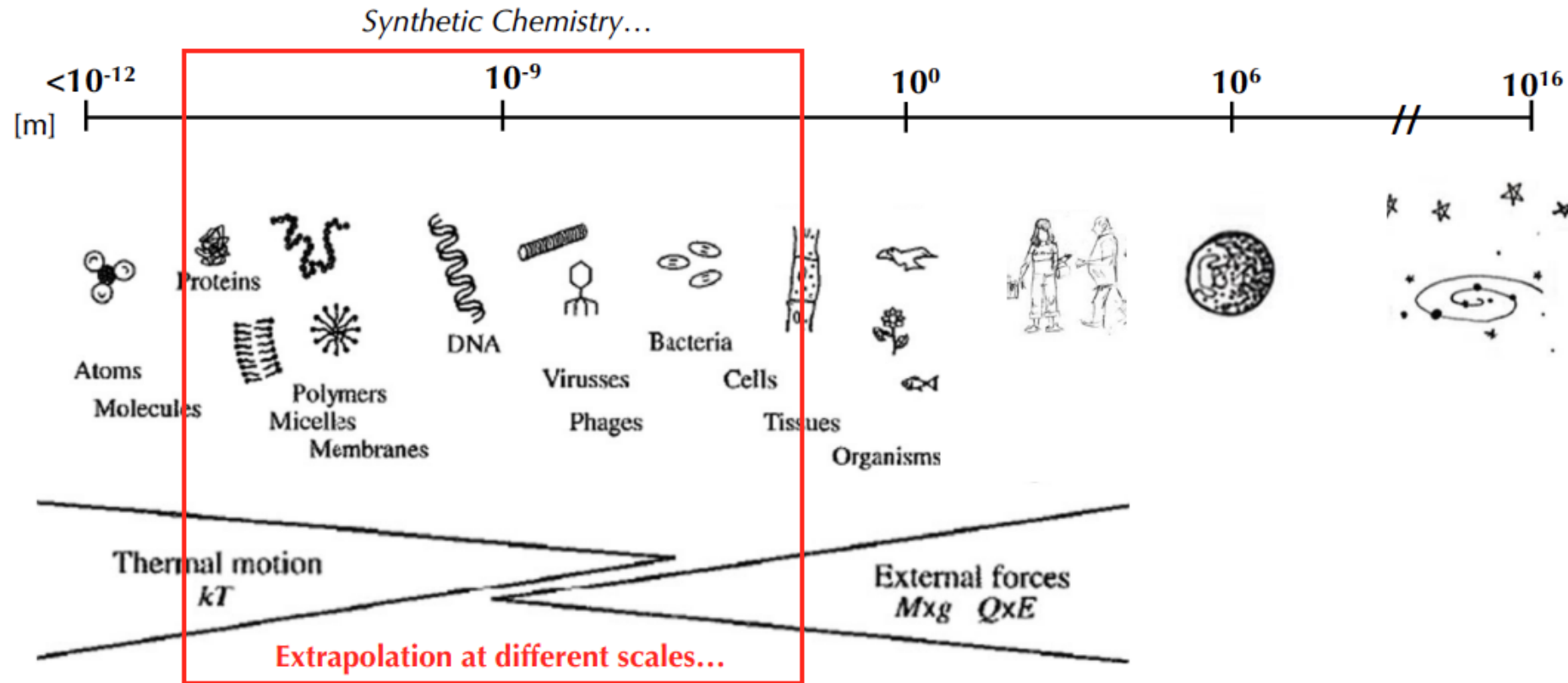
Brownian motion at the microscale
-The infinitely Large and Infinitely Small-

Laura Alvarez, UF Chemistry

January 17, 2025

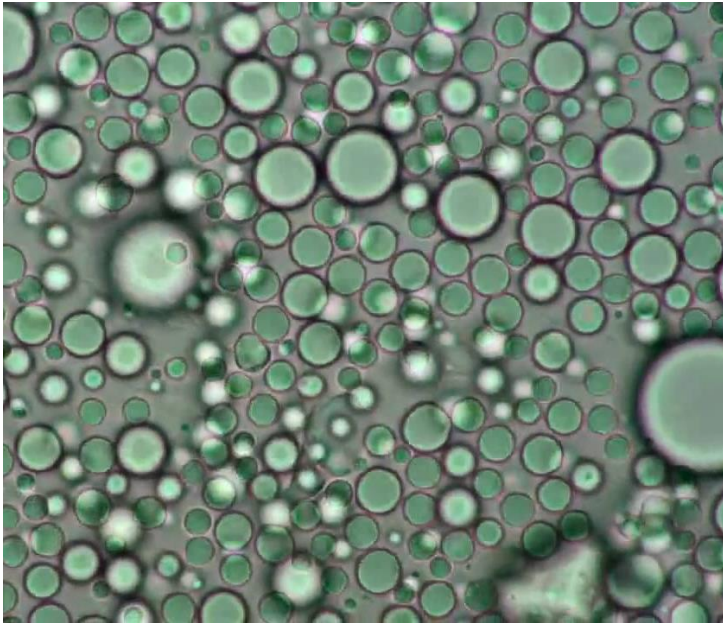
Brownian motion at the microscale

Microscale $\rightarrow$ Colloids $\rightarrow$ Brownian particles

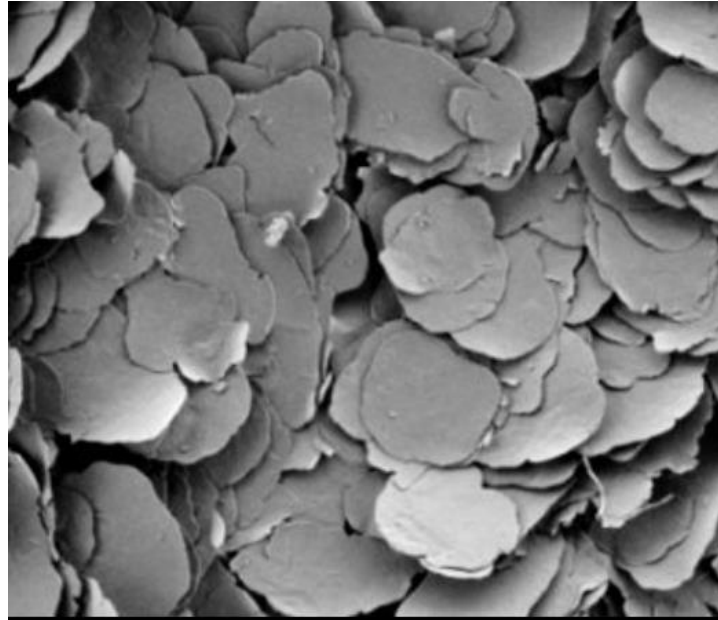


Brownian motion at the microscale

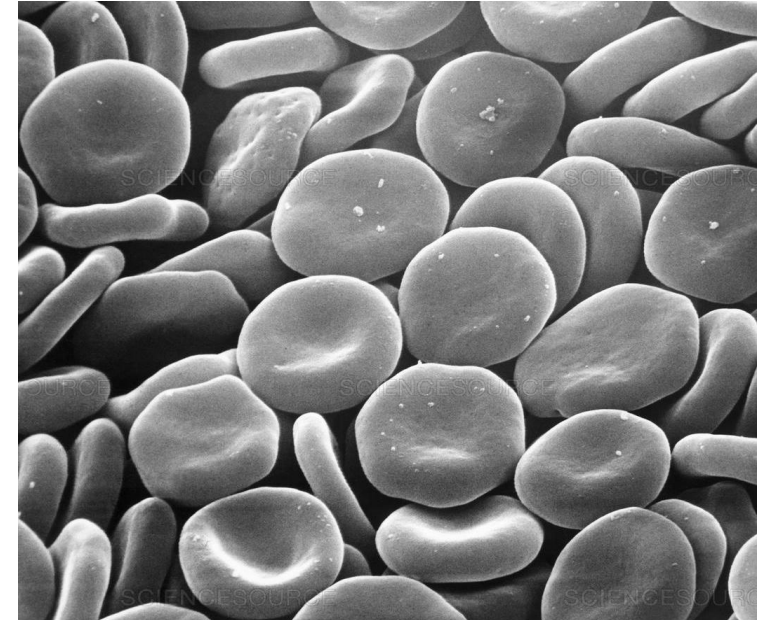
Microscale → Colloids → Brownian particles



Microparticles



Colloids



Random walk

What is Brownian motion → Molecular reality

Diffusion

Thermal motion

Kinetic energy

Infinitely small & large

Infinitely large and small “objects” in maths

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Sets and mathematical objects

If a “set” is a “thinkable collection of objects”, then quickly logical contradictions appear : what about the “set of all sets” ? Does it contain itself as element?

Part 1: infinitely large !

- What can we say about finite sets? Do they “exist” ?
- What can we say about infinite sets? Do we “allow” the natural numbers $\{1, 2, 3, \dots\}$ to exist as a “set” ?
- What consequences does this have? Are there “differently large” infinite sets? How many?

Part 2: infinitely small !

- Can we construct numbers with sets? What is a number anyhow and “how small” can numbers be?
- Can we reconcile 17th-century concept of “infinitesimally small quantities” with a modern approach? Does this help in doing maths?

Possible subjects.

- The Hilbert Hotel. When it's full, there is still plenty of space.
- Infinite series, paradoxa and the “Basel problem”
- (Un)computable functions.
- The “continuum hypothesis”. Is there something “between” natural and “real” numbers?
- The “axiom of choice” and the Banach-Tarski Paradox: one can decompose an orange into finitely many parts and make two oranges out of them. What does that now mean?
- “algebraic” numbers -vs- “transcendental” numbers. What and how many are there?
- Cantor set, Koch snowflakes and fractal dimension. Code your way and discover the fractal dimension of real data (coastlines, tree branches, blood vessels, or city layouts).
- Gödel enumeration: any text or book is “just” one natural number. Things that speak about themselves: “This phrase is wrong” – is it true or wrong?
- ETC.

About Causality in Datascience

Computer science's Lecture in
The infinitely Large and infinitely Small

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2026

ACM Turing prizes ($\simeq$ Nobel prizes in CS) in Artificial Intelligence:

1969 Marvin Minsky

1971 John McCarthy

1975 Allen Newell, Herbert A. Simon

1994 Edward Feigenbaum, Raj Reddy (*for ES ?*)

2011 Judea Pearl (*see below*)

2018 Yoshua Bengio, Geoffrey Hinton, Yann Le Cun (*for DL*)

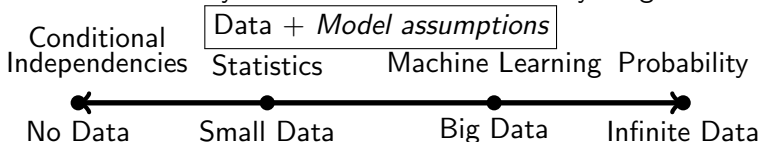
2024 Andrew Barto, Richard S. Sutton (*for RL*)

Rationale for Judea Pearl:

"For fundamental contributions to artificial intelligence through the development of a calculus for probabilistic and causal reasoning."

The aim of this lecture is to present a part of his theory and its relations with current progress.

From the infinitely Small DATA to the infinitely Large DATA



Felix, qui potuit rerum cognoscere causas. (Virgil, 29 BC)

Correlation is not causation. (see website spurious correlation)

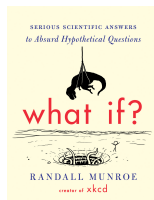
Judea Pearl said observation, like in ML, is limited to correlation.

His key point is to carefully add assumptions, a model, on the process generating data (usual in statistics).

Carefully means with an explicit language that later allows calculus.

It leads to three levels of queries:

- 1 **Observational:** I passively collect data ($P(X|Y)$), what do I see ?
- 2 **Experimental:** I may force some parameters ($P(X|do(Y = y))$), what do I do ?
- 3 **Counterfactual:** **What if** I combine some local laws ?



Example of application: In practice, some experiments are forbidden, for example for ethics in health studies. If my model contains sufficient assumptions for an experiment, then the result of a hypothetical experiment may be found on observational data without performing the experiment (do-calculus).