

# Parcours International

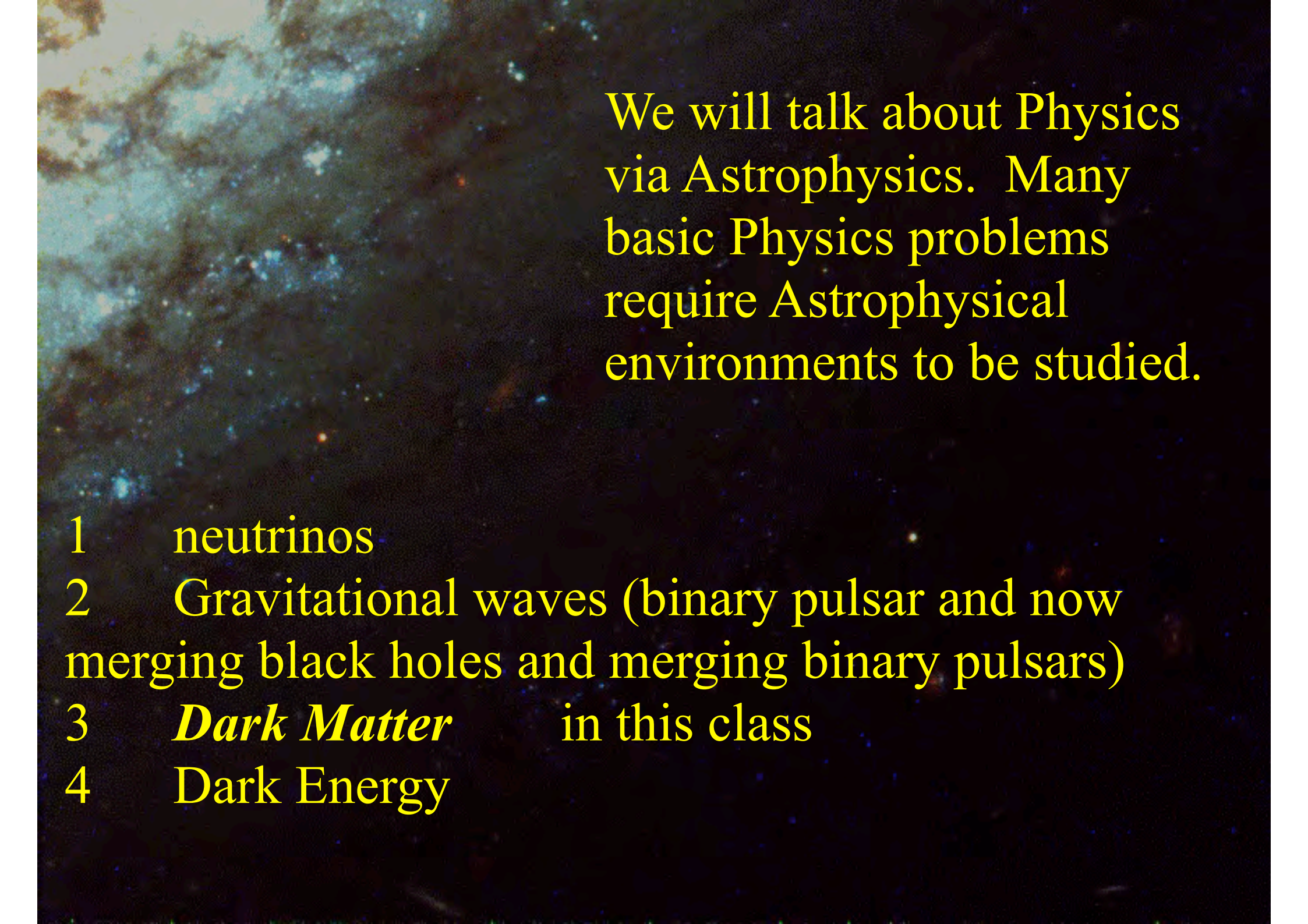
## *The Infinitely Large and Infinitely Small*

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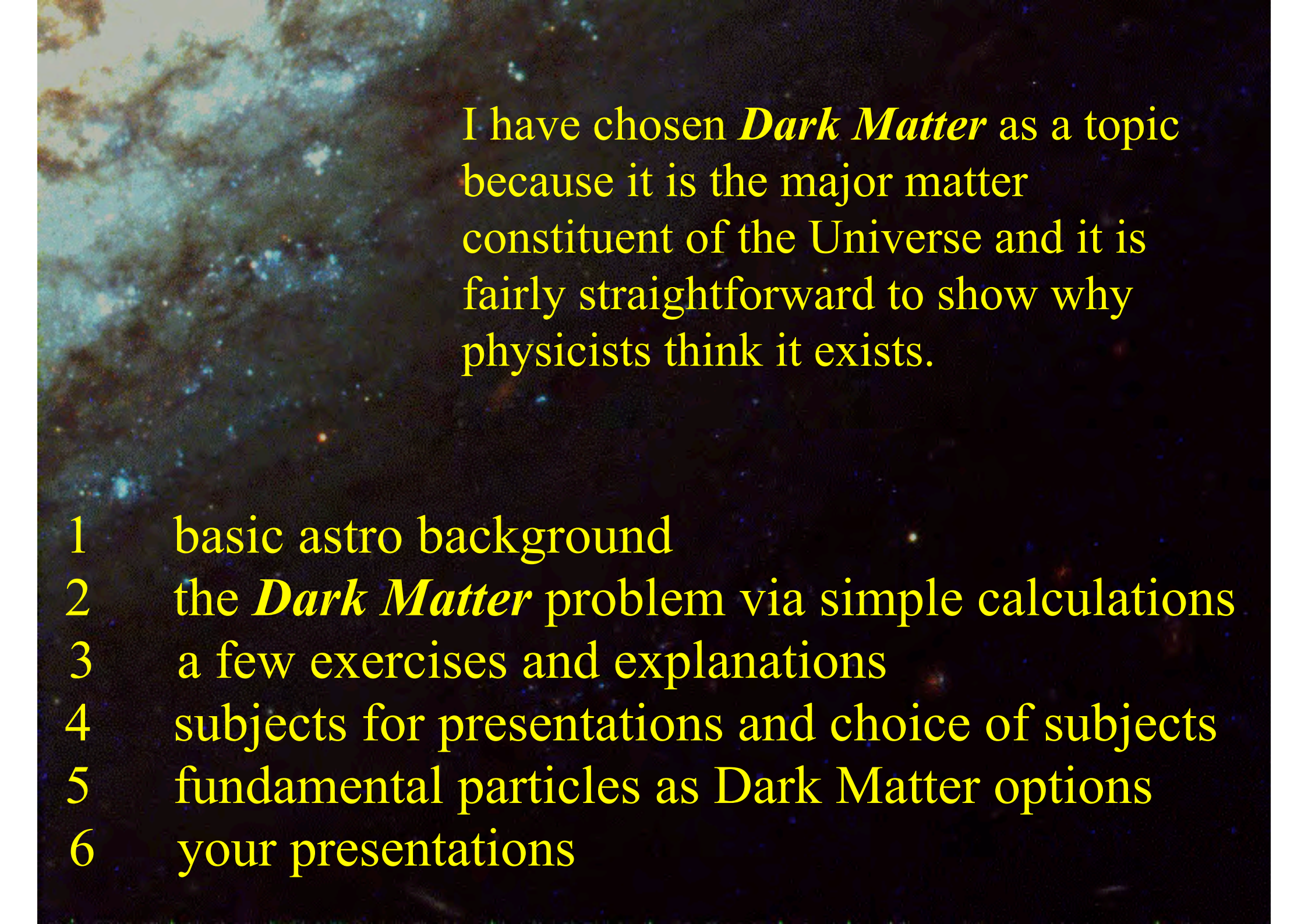
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We will talk about Physics  
via Astrophysics. Many  
basic Physics problems  
require Astrophysical  
environments to be studied.

- 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

A microscopic image showing numerous small, bright green fluorescent particles scattered across a dark background. The particles vary in size and brightness, with some appearing as distinct, larger spots and others as smaller, fainter dots. The overall distribution is somewhat random, typical of a colloidal suspension or a microfluidic system.

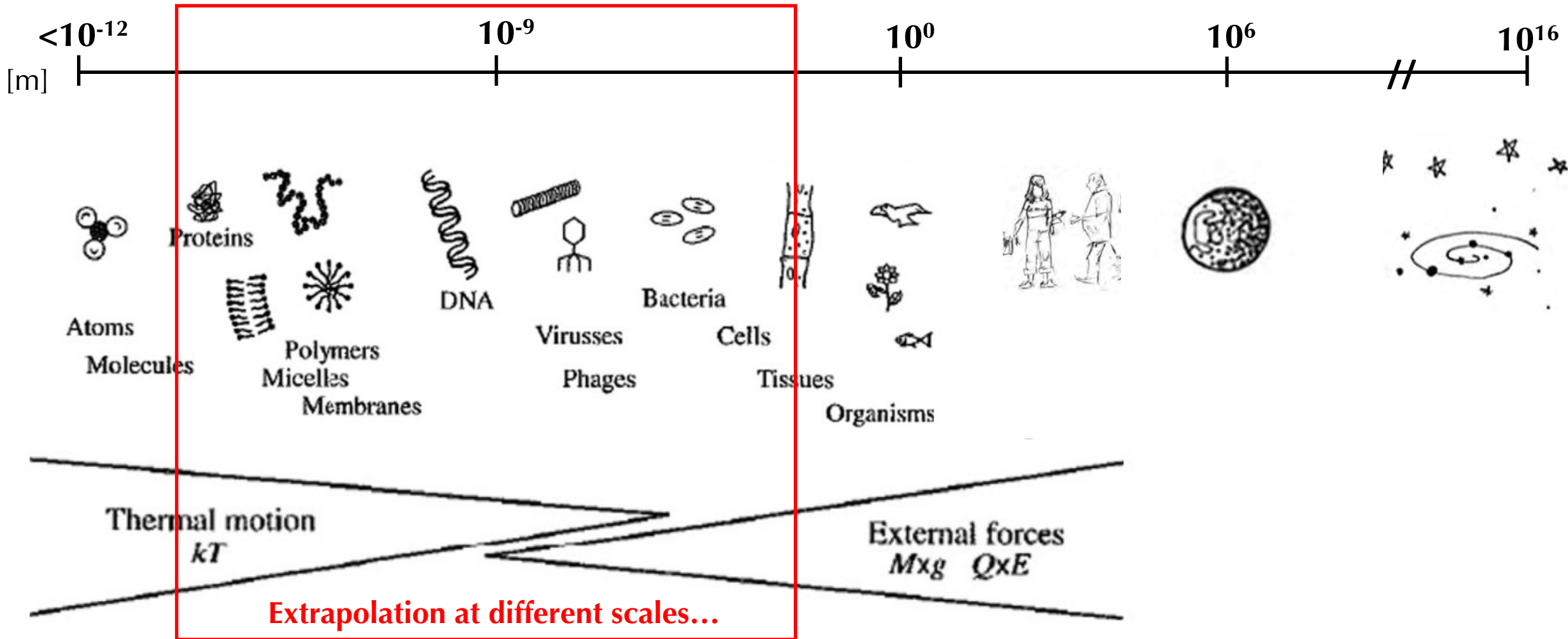
**Brownian motion at the microscale**  
**-The infinitely Large and Infinitely Small-**

**Laura Alvarez, UF Chemistry**

**2023**

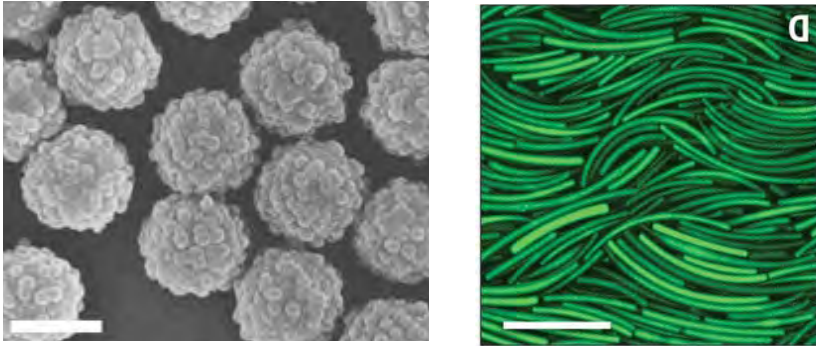
# Brownian motion at the microscale

*Synthetic Chemistry...*

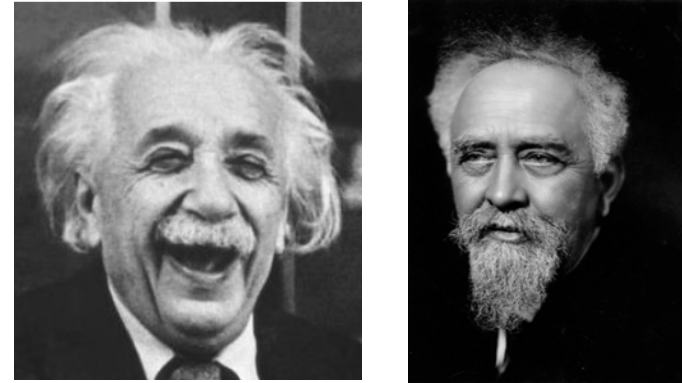


# Brownian motion at the microscale

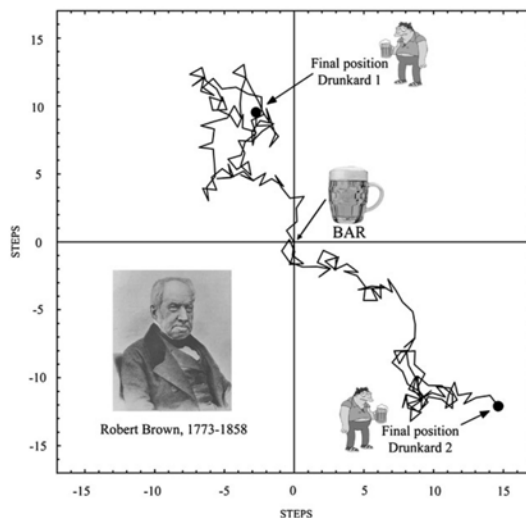
1. Microscale (colloidal) systems and their physical-chemical properties.



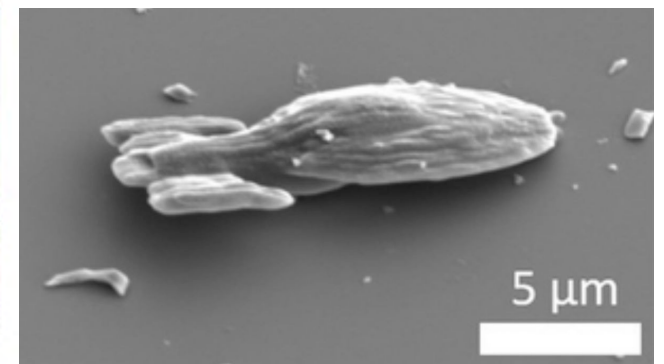
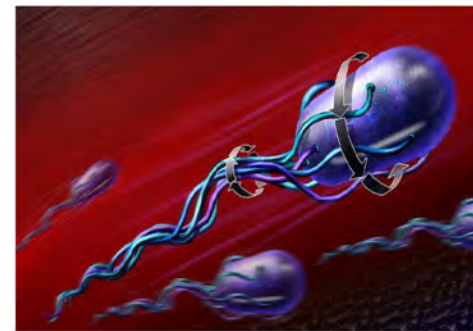
3. Brownian motion and molecular reality



2. From an experimental observation to its physical and mathematical implications at different scales



4. Passive vs. Active Brownian motion: designing artificial motion at the microscale



Micro(nano)scale

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# Brownian motion at the microscale

## **Evaluation**

1. Presentation: the possible projects will be given the first day. (You are also free to choose!).
  2. Small assignments (they will be taken into account as a plus to the final grade).
  3. Daily participation: small group exercises in some of the lectures
- !!! Possibility of doing experiments and/or use python code for better grades

# Infinitely small & large

## Matter sizes — Size matters

Bernhard Haak

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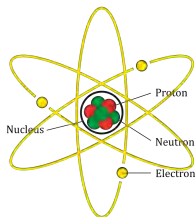
January 17, 2022



# Matter sizes — Size matters

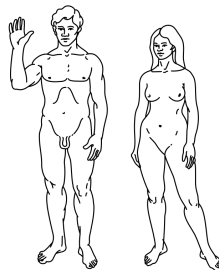
**Physics** is about inventing mathematical models that fit observations / measurements and allow predictions.

**Schrödinger's Question:** Is random behaviour at atomic scale consistent with deterministic mechanics?



scale 1

Schrödinger's suggestion:  $10^{23}$  "random things" average out to determinism. We will study how and why this happens.



scale 100.000.000.000.000.000.000

# Subject list

- Probability in a nutshell: basic concepts.
- Integrals and probabilities having “densities”
- Gaussians: the “normal” distribution.
- Explicit convergence rates of averages of “random variables” towards a normal distribution.

The emphasis is on **intuition** and **easy proofs**.

# Project list (propositions)

- $k\pi \bmod 1$  for  $k \in \mathbb{Z}$ : Weyl's equidistribution theorem.
- Stirling's formula (needed for next two subjects).
- Random walk on a "grid": Why does a 1D or 2D random walk "come back" to origin?
- Random walk on a grid in dimension  $d \geq 3$ :  
"a drunken bird never finds home".
- Random walk on a graph: the Google page-rank algorithm.
- Random or not random? Program a random walk orbit in 2D - once with a RNG - and once using digits of  $\pi$  as "random" source.
- Random in cryptography (contact me: to be further specified)
- ...
- (tell me what inspires you - I'll find a subject for you!)

IMPORTANT: I might be obliged to "fill gaps" and do unchosen projects myself in the lecture - so please tell me quickly if you are interested.

# An introduction to Quantum Computing

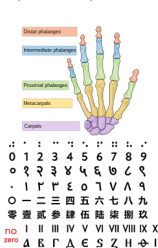
Yvan Le Borgne, LaBRI (Computer science Lab)

January 17, 2022

- ▶ 5 Lectures ( $5 \times 1h20$ )
- ▶ No screen (today is the exception !)
- ▶ Evaluation:
  - ▶ possibility to make a presentation on an article.
  - ▶ Exercices: implement quantum circuits in python via <https://qiskit.org/>

# Toward a (second !) quantum computer ?

(Some) physical supports of calculus

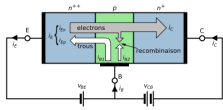
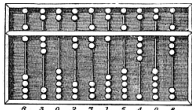


Transistor (1947)

Elementary step of computation  $T(B, E) = C$ :  
 $T(1, 1) = 0$  et sinon  $T(B, E) = 1$

(Classical) Gate:

$\text{NAND}(x, y) := \text{NOT} \circ \text{AND}(x, y)$



**Theorem:** NAND (and COPY) are enough to express in circuits any boolean function:

$$f : \{0, 1\}^k \longrightarrow \{0, 1\}^n$$

$\Rightarrow$  Classical computer (science)



## Potential applications

$$35 \rightarrow 5 \times 7$$

Shor's quantum algorithm for prime's factorization of integers.

- A threat for cryptography: many protocols, like RSA, relies on the assumption that this is not feasible for large numbers.

<https://csrc.nist.gov/projects/post-quantum-cryptography>

- An opportunity for cryptography (No-cloning theorem for Quantum States, BB84 protocol).
- Efficient simulations of quantum phenomenon in chemistry.
- Quantum supremacy: a classical computer with additional 50 universal quantum bits will outperform any classical computer.

# Lecture's syllabus and evaluation

## Lectures:

- ▶ Just a quantum register in a classical computer is enough.
- ▶ Formal definition of quantum bits, logical gates.
- ▶ Description of Mach-Zehnder interferometer via qbits and quantum logical gates.
- ▶ No-cloning theorem and BB84 protocol in cryptography.
- ▶ (If times permit) EPR paradox, Bell'inequalities and Aspect's experiment.

## Evaluation (if selected among the four lectures):

Presentation of a problem in the context of quantum computing.

- ▶ A problem more efficiently solved by quantum algorithms, see <http://quantumalgorithmzoo.org>
- ▶ A discussion on the various announcement of Google, D-Wave, IBM, ... or Gil Kalai on quantum computers
- ▶ Implement (in python) some quantum circuits  
<https://qiskit.org/...>