NUCLEAR PHYSICS (SPRING 2023)

→ Begin online (later on we will change to in-person)

→ Slides & lecture notes:

http://139.180.195.74

→ COURSE : (theoretical)

1) General introduction
(nature of nuclear forces, QCD,
renormalization, etc.)

2) Two-nucleon system (nuclear forces
+ general two-body stuff)

3) Nuclear structure

Theoretical course

→ if you are a theoretician,
it should be okay

→ if you are an experimentalist,
concentrate on the qualitative
aspects of the course
≡

Evaluation

→ if possible, it will be only exercises

→ if there is an exam,
it will be about theory

(e.g. "explain in simple terms this
or that nuclear model", etc.)

→ 3 classes per day (15:50 - 18:20)

Problem: human attention span is about 20 minutes

Recommendation:

-> imagine we are in a classroom

-> take notes

Breaks every 40-45 minutes

We go to the physics now ...

LESSON 1: SCALES IN PHYSICS

→ What are "scales" in physics

→ How we can use them to understand (nuclear) physics

=

SCALE → DIMENSIONFUL QUANTITY

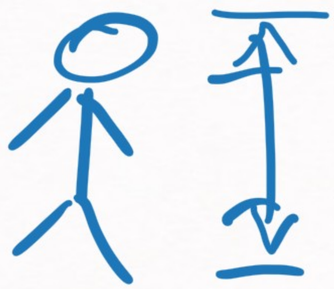
* LENGTH SCALE
(3m or 3fm)

* MOMENTUM SCALE
(3 MeV or 3 TeV)

} Choice of units

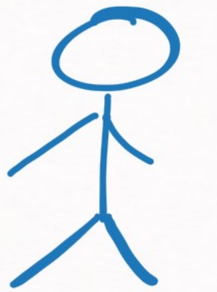
PHYSICS LOOKS DIFFERENT DEPENDING ON THE SCALE YOU ARE USED TO

Imagine you are using a scale of 1 m (human scale)

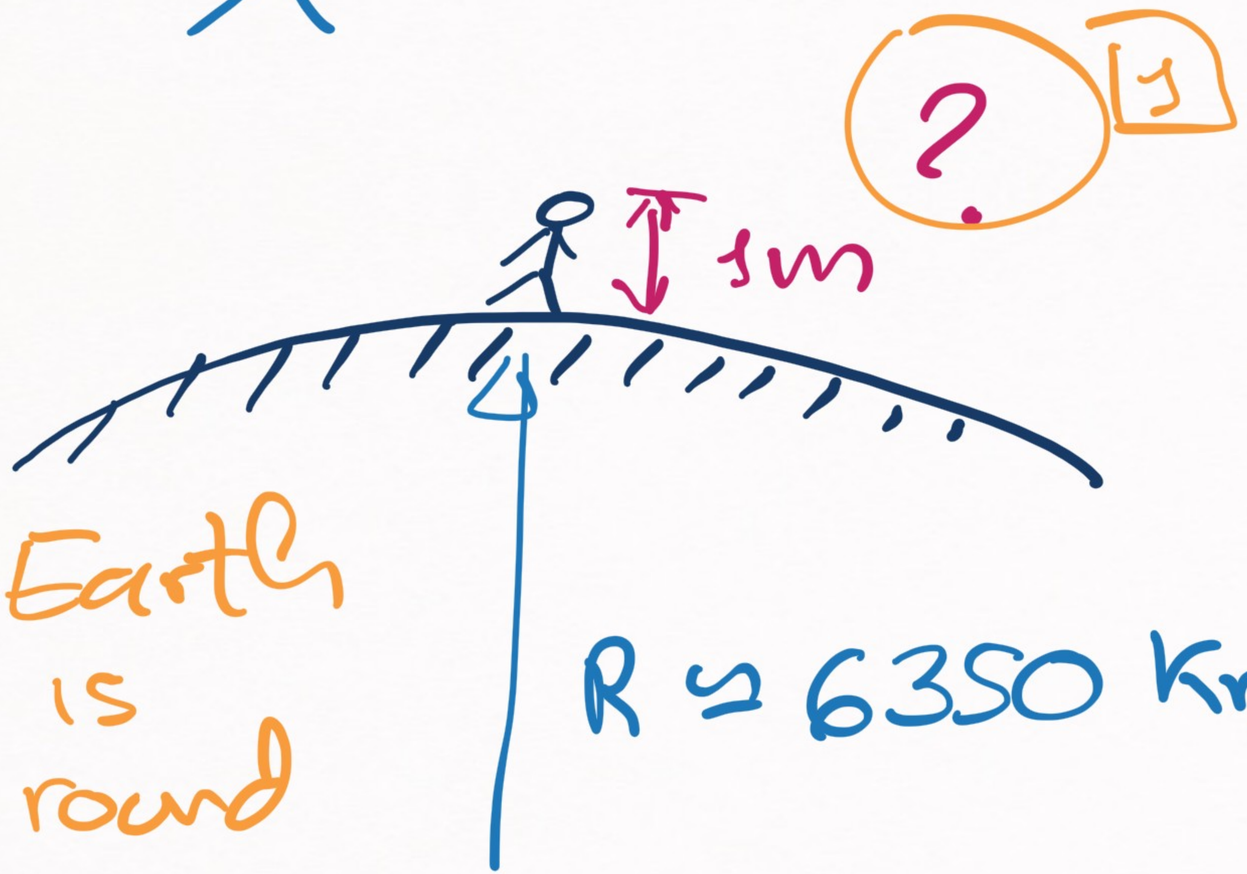


1.5 - 2.0 m

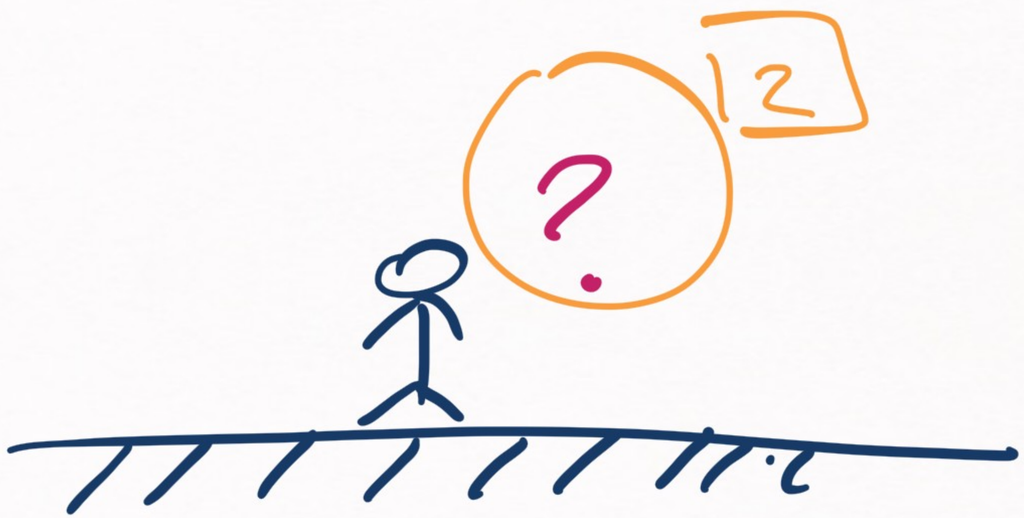
↳ scale at which we experience the world



→ natural scale about 1m



Earth is round



Earth is flat

$R \simeq 6350$ Km (Radius of earth)

At first sight you can't easily distinguish 1 & 2

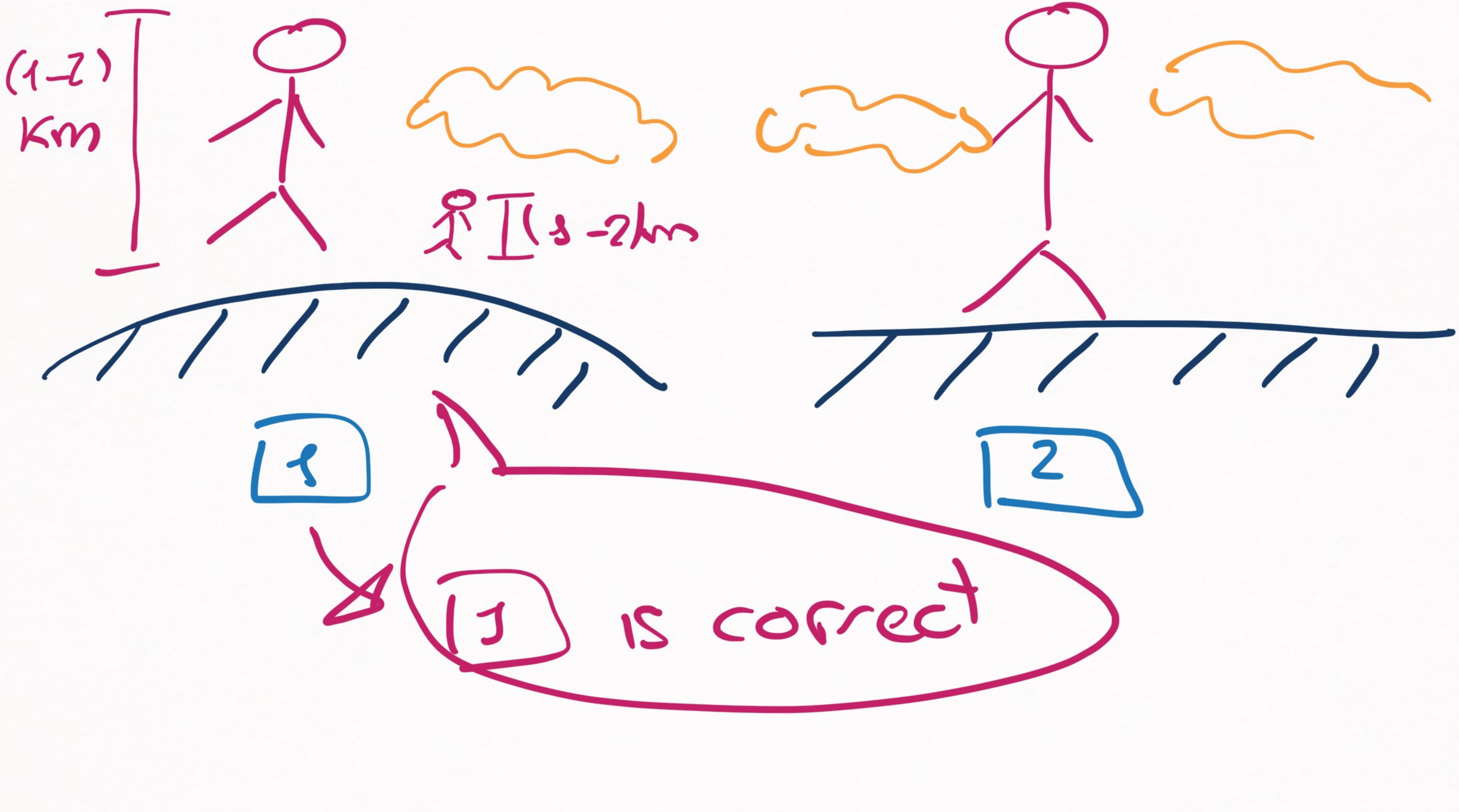
1 → round earth
2 → flat earth

} difference (from a human viewpoint) is about this:

$$\frac{\text{size of human}}{\text{size of earth}} \sim 10^{-7}$$

THE DIFFERENCE BETWEEN TWO EXPLANATIONS IN PHYSICS DEPENDS ON THE SCALE YOU ARE USING

If you are small, not much of a differe


(1-2) km
1 - 2km
1
2
3
is correct

OTHER EXAMPLES

1) IF YOU MOVE AT 5 KM/hour

→ no difference between newtonian mechanics & relativistic mechanics

$$\text{difference} \rightarrow \frac{v}{c} \sim \frac{5\,m/s}{3 \cdot 10^8\,m/s} \sim 10^{-(9-8)}$$

2) EARTH ORBITING THE SON) → (a)

VS ELECTRON ORBITING A PROTON

(b)

a) → Acton of earth orbiting the son is really large

$$\int \tfrac{1}{2} m \dot{\underline{x}}^2 \, dt \rightarrow \underline{\text{large}}$$

b) Action of the electron orbiting a proton is very small

a) $\frac{I}{\hbar} \gg 3$ → impossible to notice quantum effects

b) $\frac{I}{\hbar} \sim 3$ → possible to notice quantum effects

a) Earth-sun system → classical mechanics

b) Electron-proton system

→ quantum mechanics

a) vs b) → difference is the scale of both systems (when compare w/ th)

→ We will have all kinds of examples
of how physics change w/scales

→ TOUR AROUND SCALES &

HOW WE UNDERSTAND

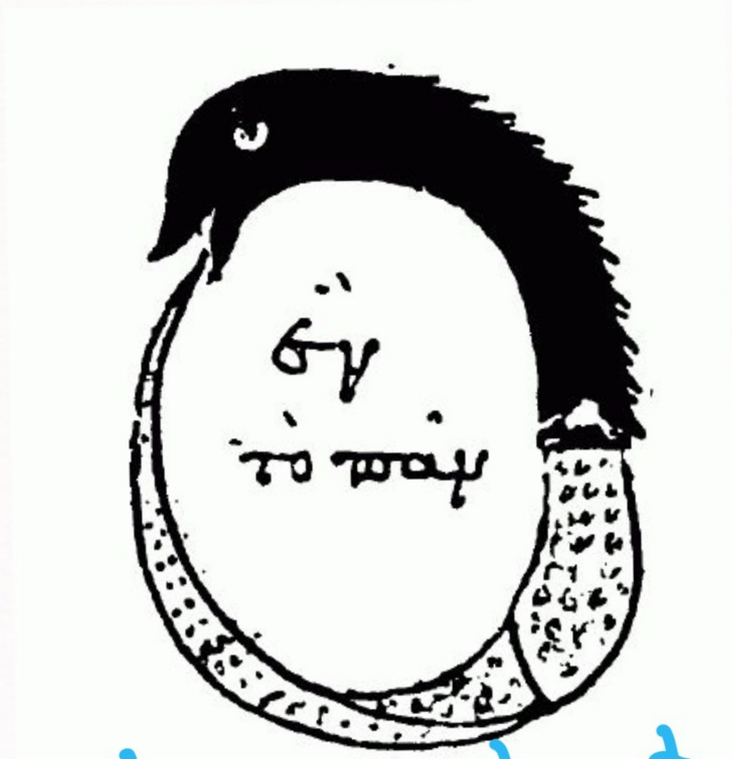
THE WORLD AT

DIFFERENT SCALES

Different length scales → from $L \to \infty$ to $L \to 0$

We will see how our understanding of the world changes at each scale

$L \to \infty$ (L is a length scale)



→ we are not doing physics anymore, but metaphysics

→ everything will be speculation

→ ouroboros

ἓν τὸ πᾶν (all is one)

[not very interesting for physicists]

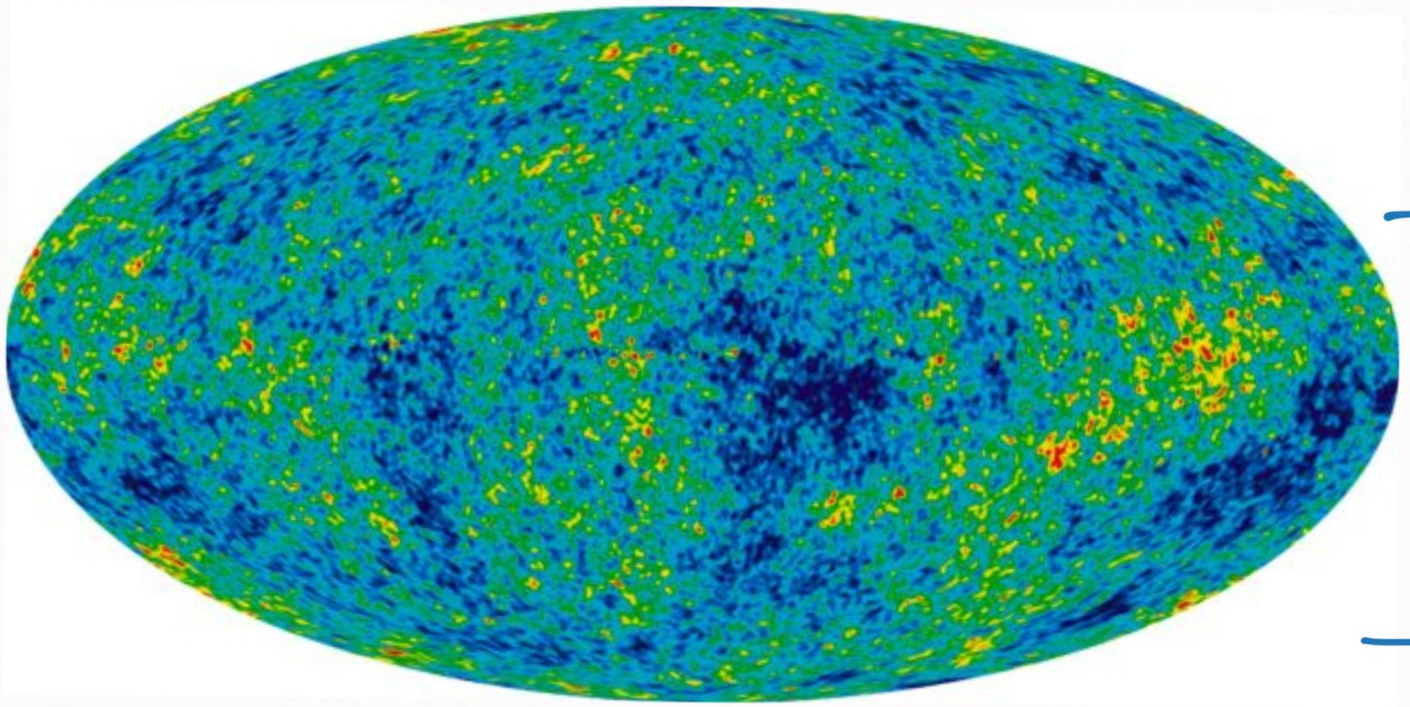
$L = 10^9$ light years

↳ general relativity

COSMOLOGY

→ what is the geometry of the universe?

→ how did the universe begin?



(microwave background)

$L = 10^3 - 10^5$ light years

general relativity

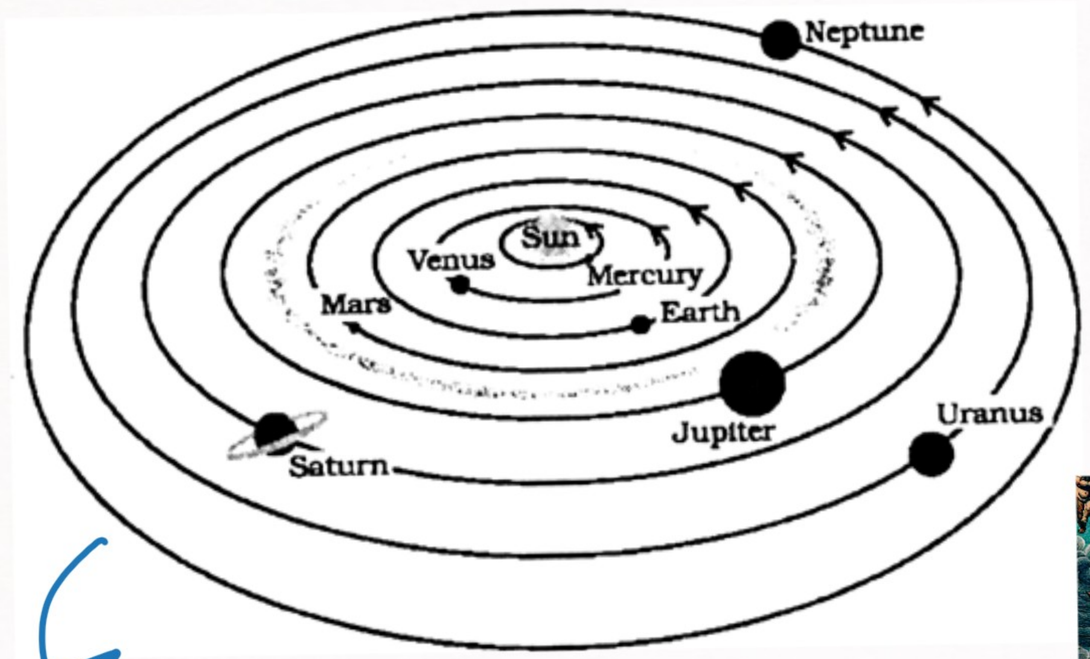
ASTROPHYSICS

→ How do I explain galaxy formation & rotation?

etc.

$L = 100$ a.u.

(a.u. = astronomical unit or $150 \cdot 10^6$ km)

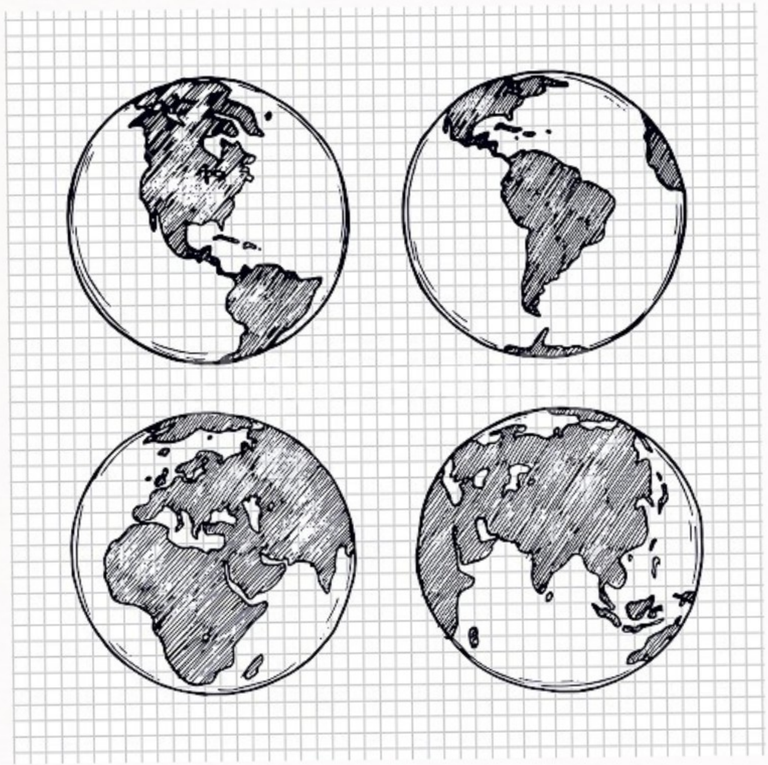


SOLAR SYSTEM

CLASSICAL MECHANICS

(1) → precession of Mercury will be the only weird thing

$L = 10^4 km$ ⟶ size of the earth



GEOGRAPHY

ECOLOGY

CLIMATE

$$L = 10^3 \text{ km}$$

COUNTRIES

ECONOMY

SOCIOLOGY

3

ECOSYSTEMS

$L = 1\,km$

(size of Berkeley campus)

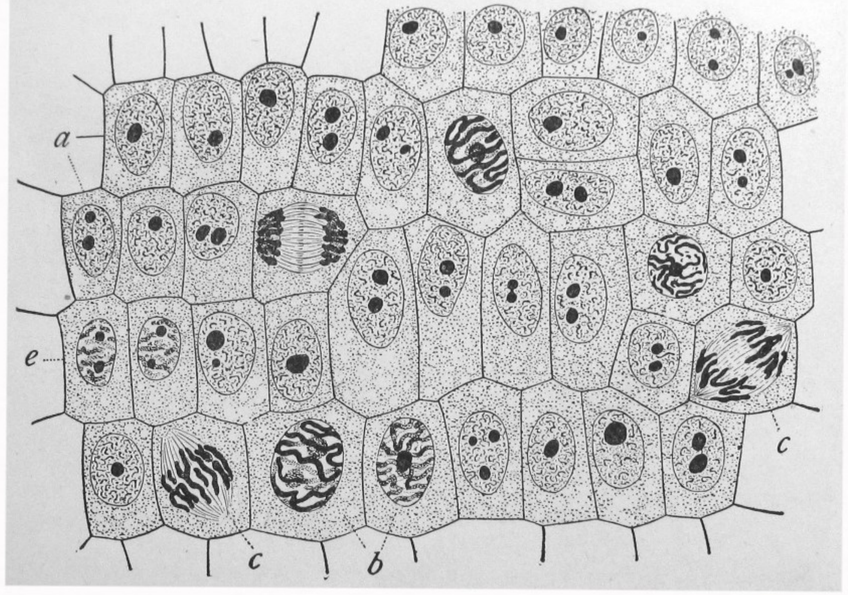
SOCIAL LIFE & INTERACTIONS

WALKING, DRIVING

$L = 1\,m$ → EVERYDAY LIFE

→ CLASSICAL MECHANICS

$L = 10^{-5}\,m$



→ BIOLOGY

(MICROBIOLOGY ACTUALLY)

⇒

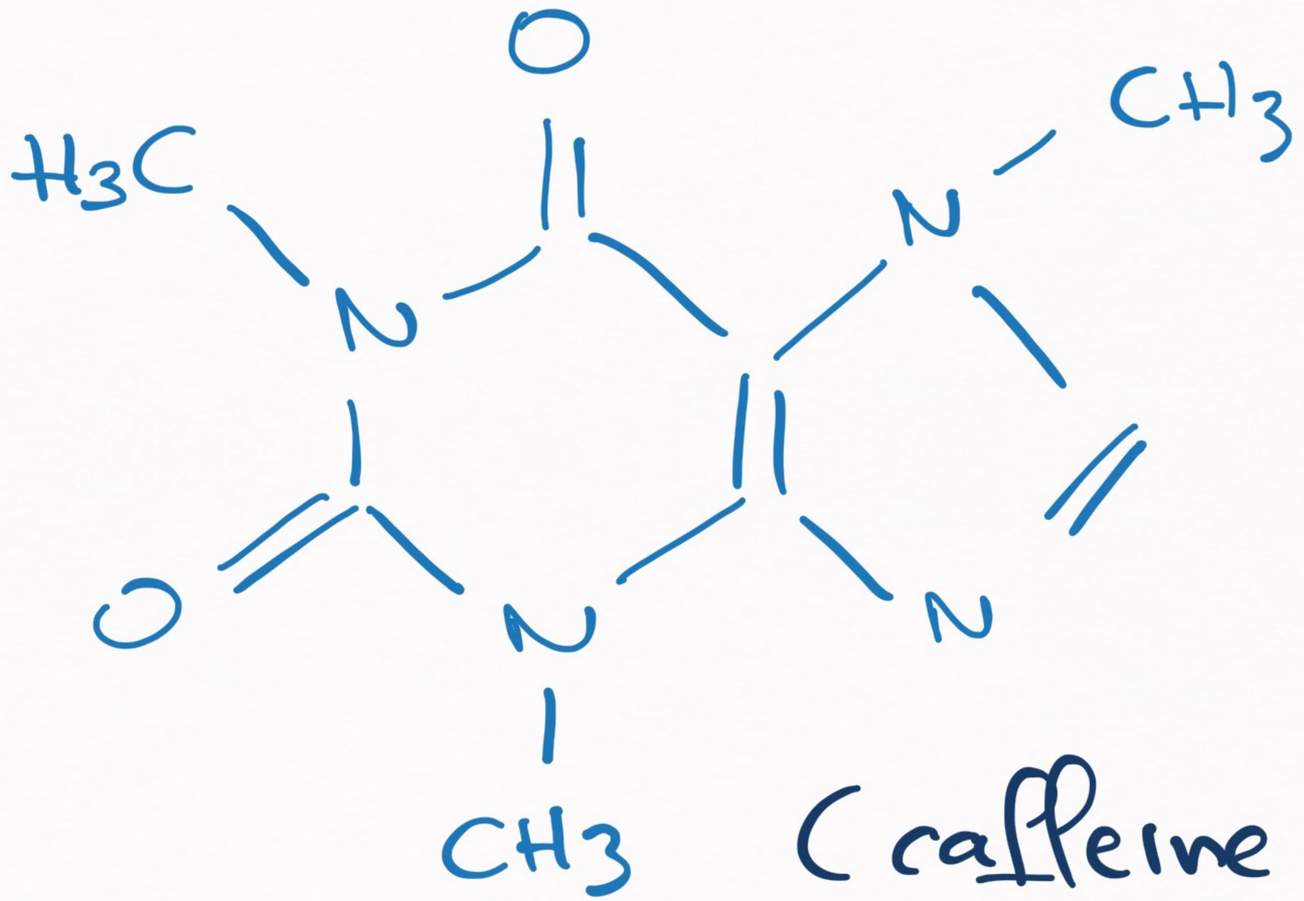
$L = 10^{-9}\,m$

(1 Å)

=

↓

CHEMISTRY

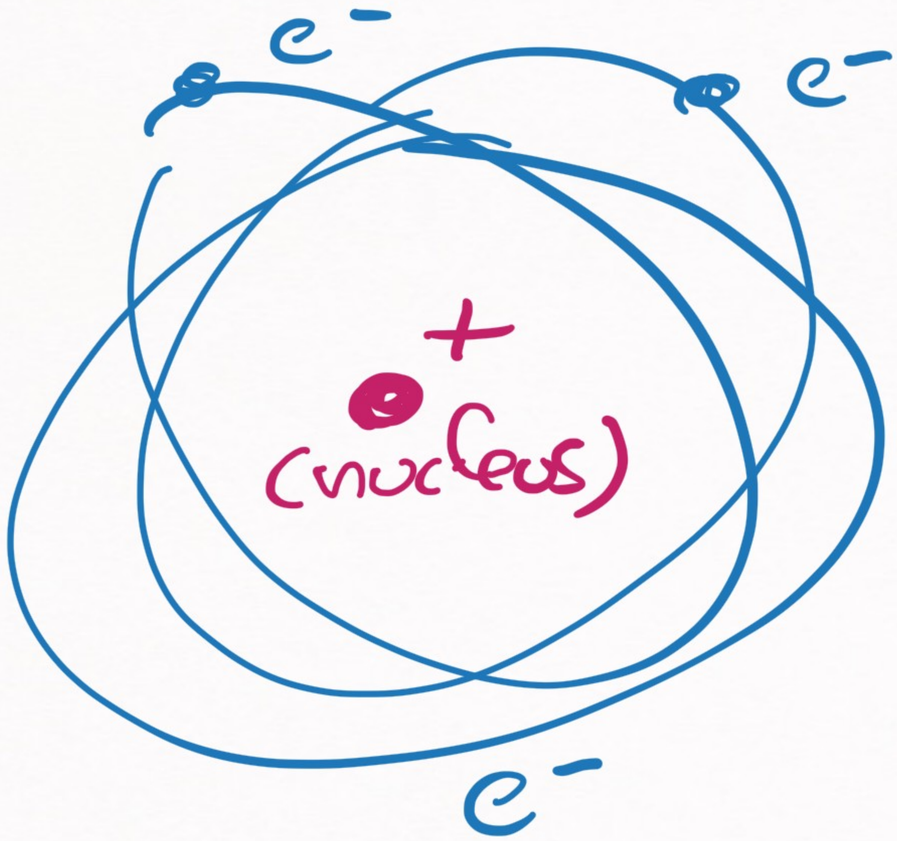


(caffeine)

=

$L = 10^{-10}\,m$

→ ATOMIC PHYSICS

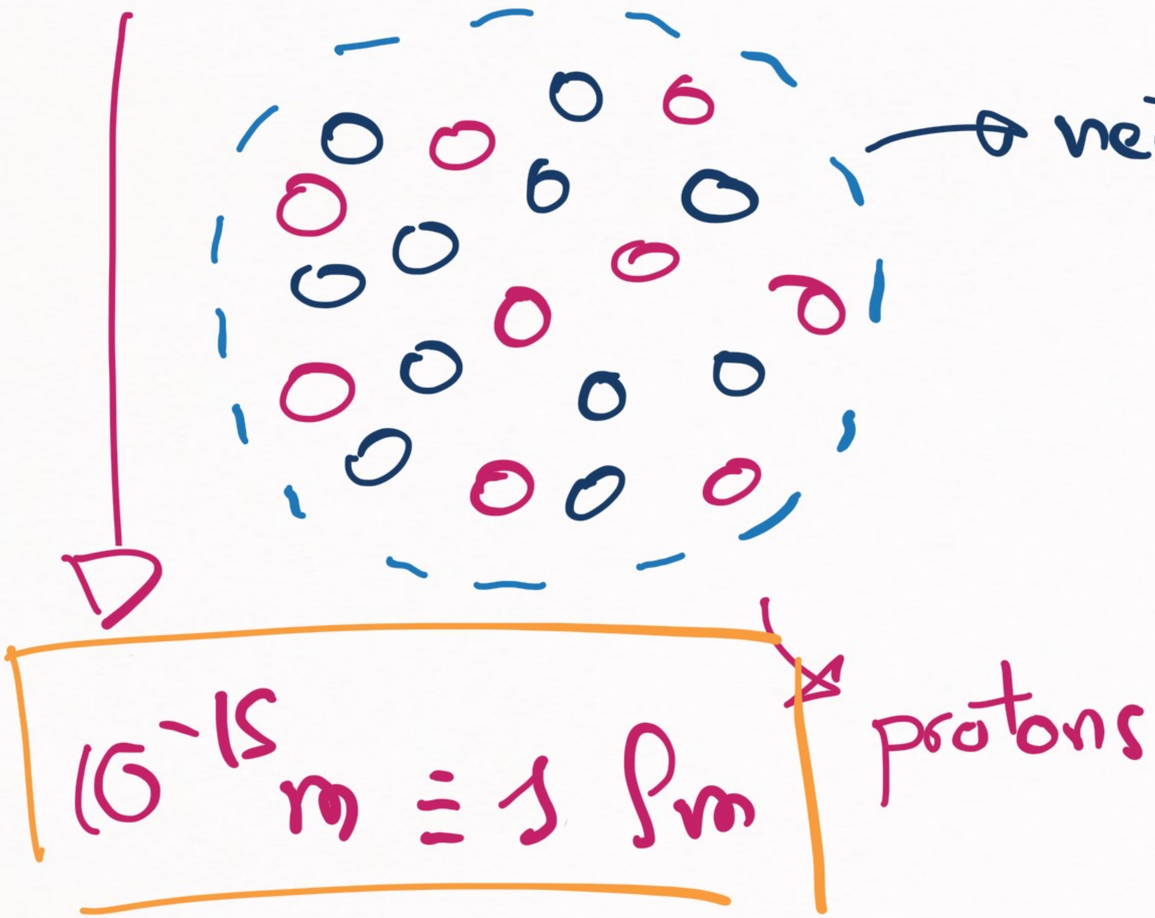


→ atoms

→ explain their energy levels

→ quantum mechanics

$L = 10^{-15}\,m$ → NUCLEAR PHYSICS



our course this year

→ quantum mechanics

→ a bit of quantum field theory

$L = 10^{-16}\ m$

proton

1 fm or 10^{-15} m

quarks

gluons

0.1 fm or 10^{-16} m

$L = 10^{-16}\,m$ → QUANTUM CHROMODYNAMICS

theory of quarks & gluons

(QUANTUM FIELD THEORY)

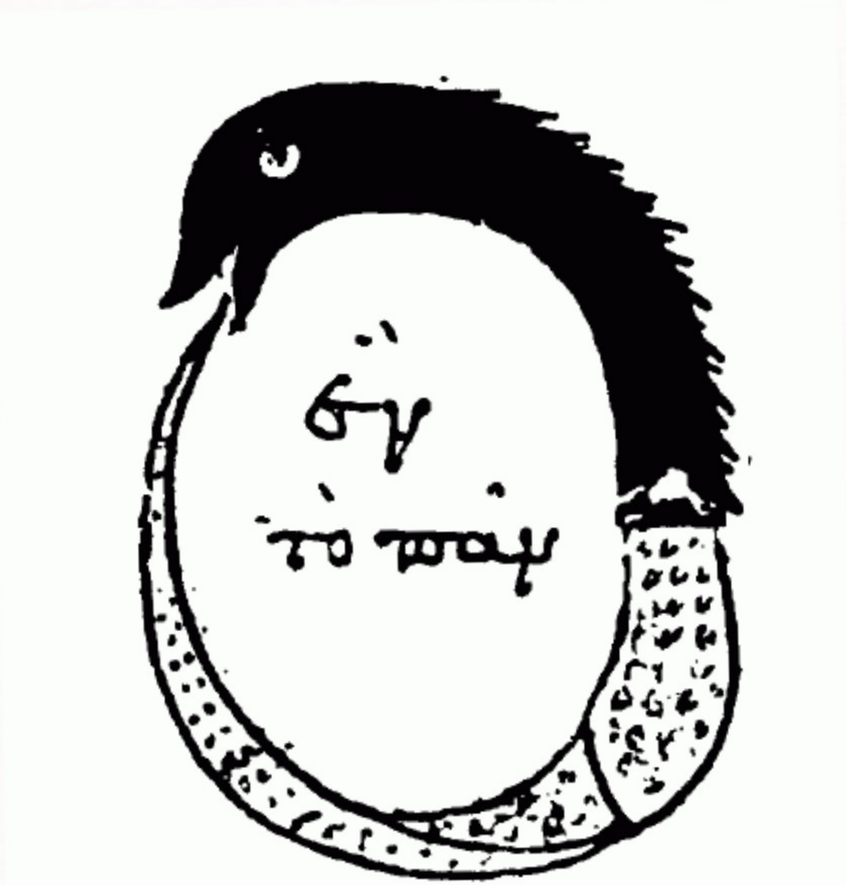
$L = 10^{-35}\,m$ (PLANCK SCALE)

↳ QUANTUM GRAVITY

(We don't know too much about it!)

⇒

$L = 0$ → back again to METAPHYSICS



→ no physics anymore

→ only speculation

(exactly as happened for $L = \infty$)

OBSERVATION

0/∞ ARE DIMENSIONLESS

→ any number in physics has to have units

→ only exception: 0 & ∞

(they don't change if you change the units)

→ [WE CAN EXPLOIT SCALES
TO UNDERSTAND PHYSICS BETTER]

WHY? → BECAUSE, AS WE HAVE SEEN,

OUR UNDERSTANDING
OF NATURE DEPENDS
ON OUR CHOICE
OF SCALE

NEXT LESSON

→ ATOMIC PHYSICS :

HYDROGEN ATOM

Instead of the usual approach
(solving Schrödinger Eq.),
we will try a different
understanding

→ FRIDAY IS: SO

(NEXT LESSON)