# Introduction to Particle Physics

## (for non physics students)

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# How Old is the Universe?

20.00 Creation Big Bang

world cup 1st half;2nd half; sleep

05.00 SUN → EARTH 06.00

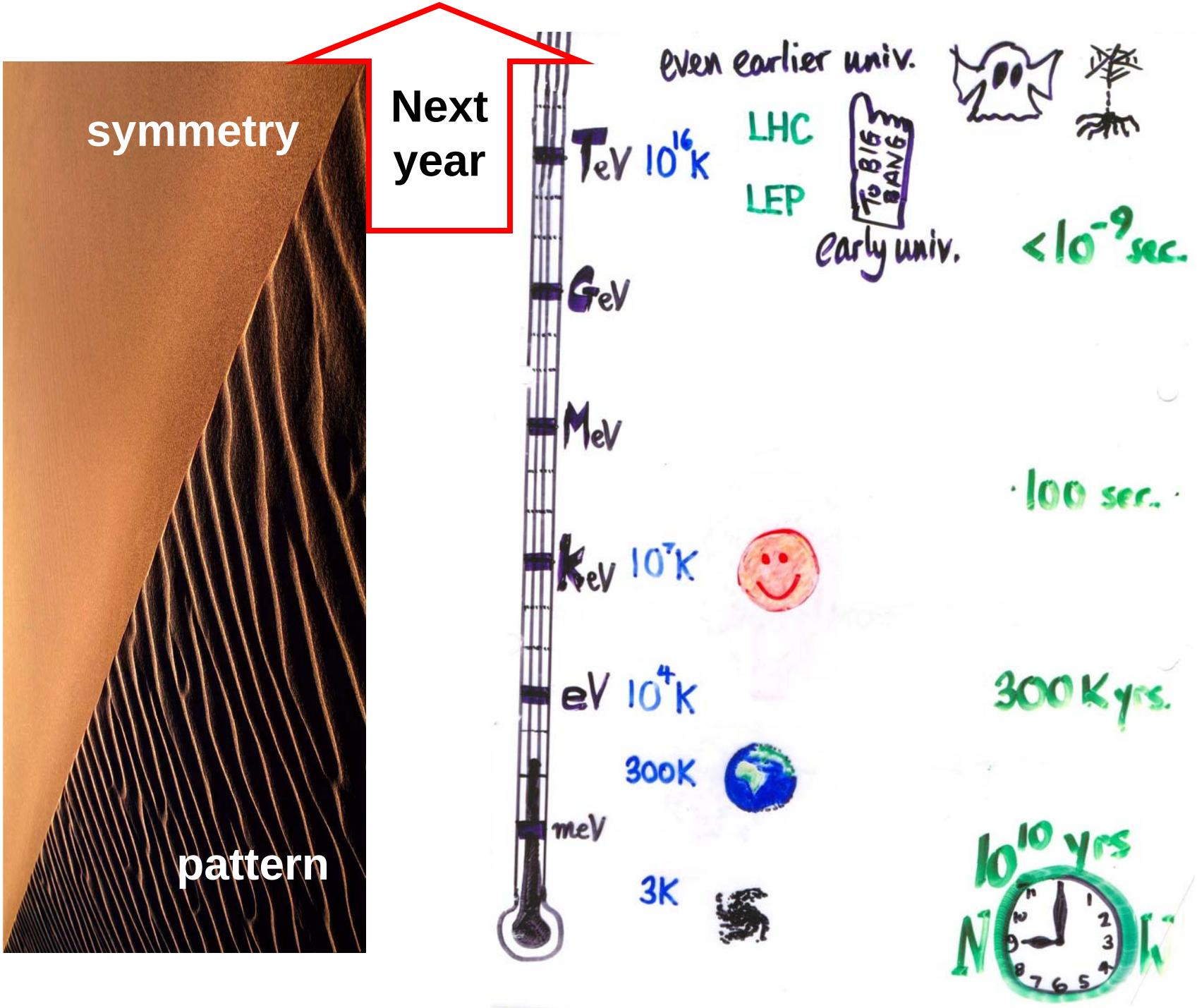
breakfast; come to lectures

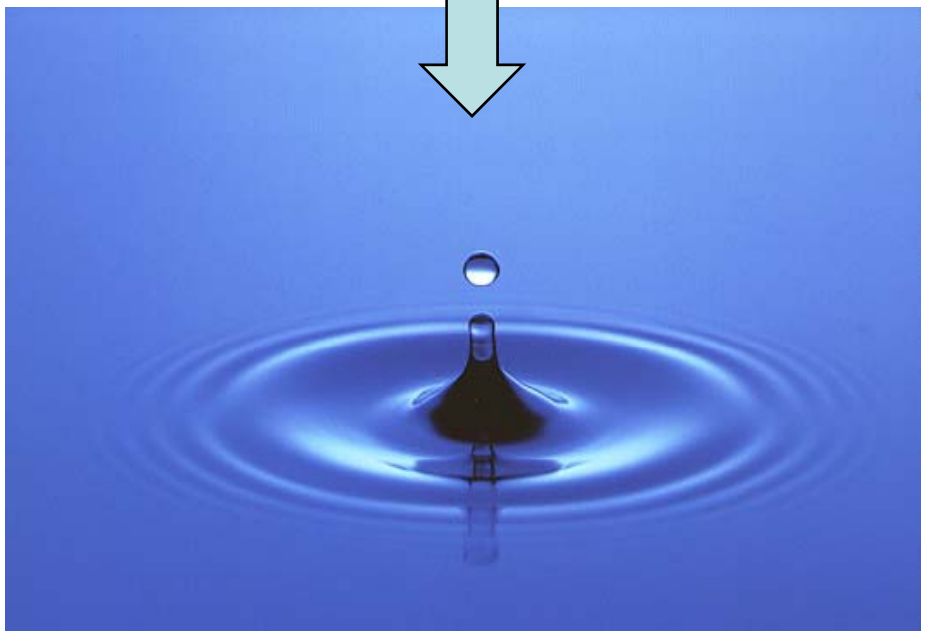
09.30 Oldest Fossils

09.59;30" rst Humanoids

09.59 - The Millenium

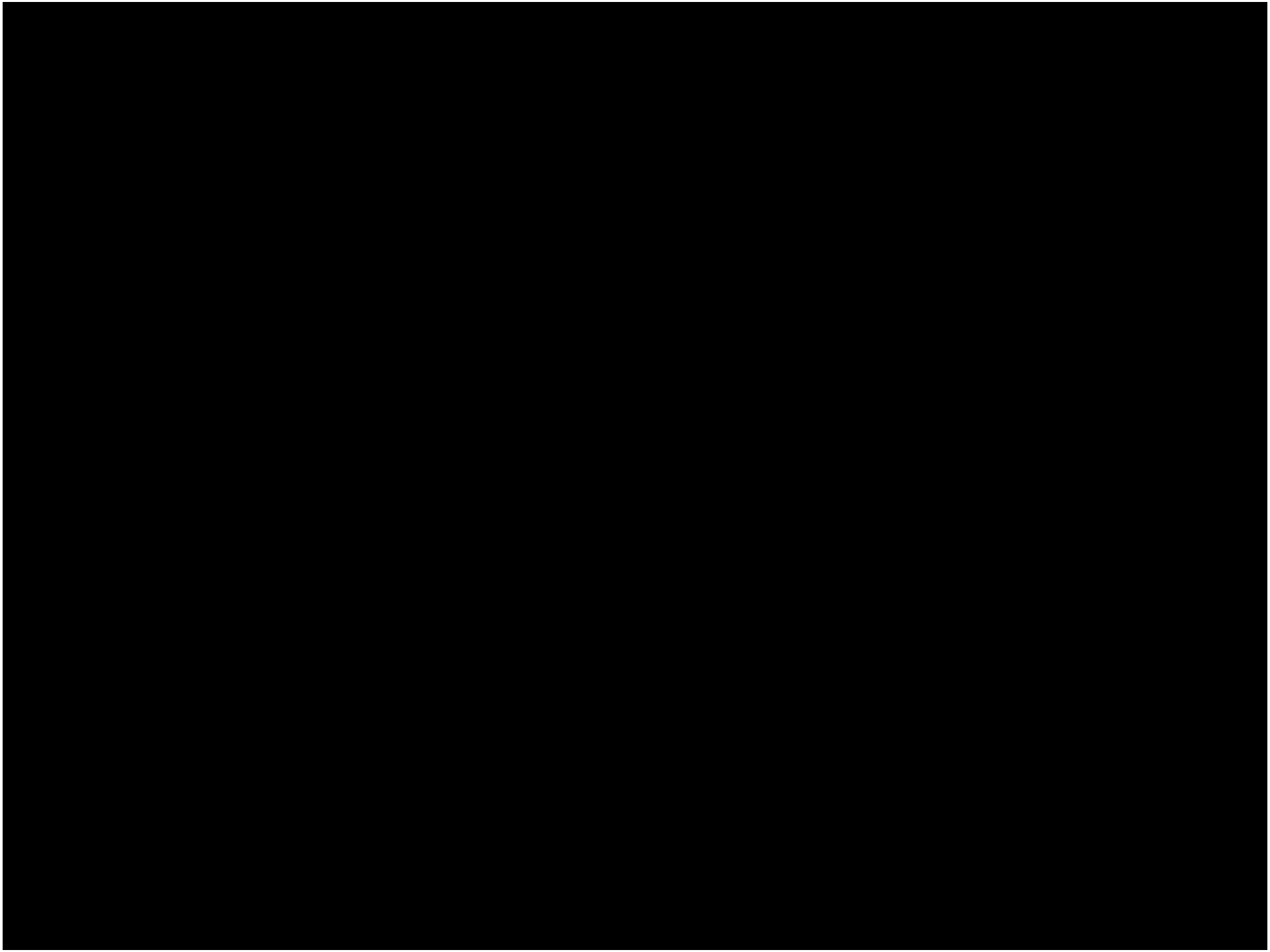
10.00 NOW


symmetry
pattern
Next year
even earlier univ.
LHC
LEP
To BIG BANG
early univ.
$<10^{-9}$ sec.
TeV $10^{16}$K
GeV
MeV
100 sec.
KeV $10^{7}$K
eV $10^{4}$K
300 K yrs.
300K
meV
3K
$10^{10}$ yrs



**patterns and structures when cold (low energy)**

**Symmetry when warm (high energy)**

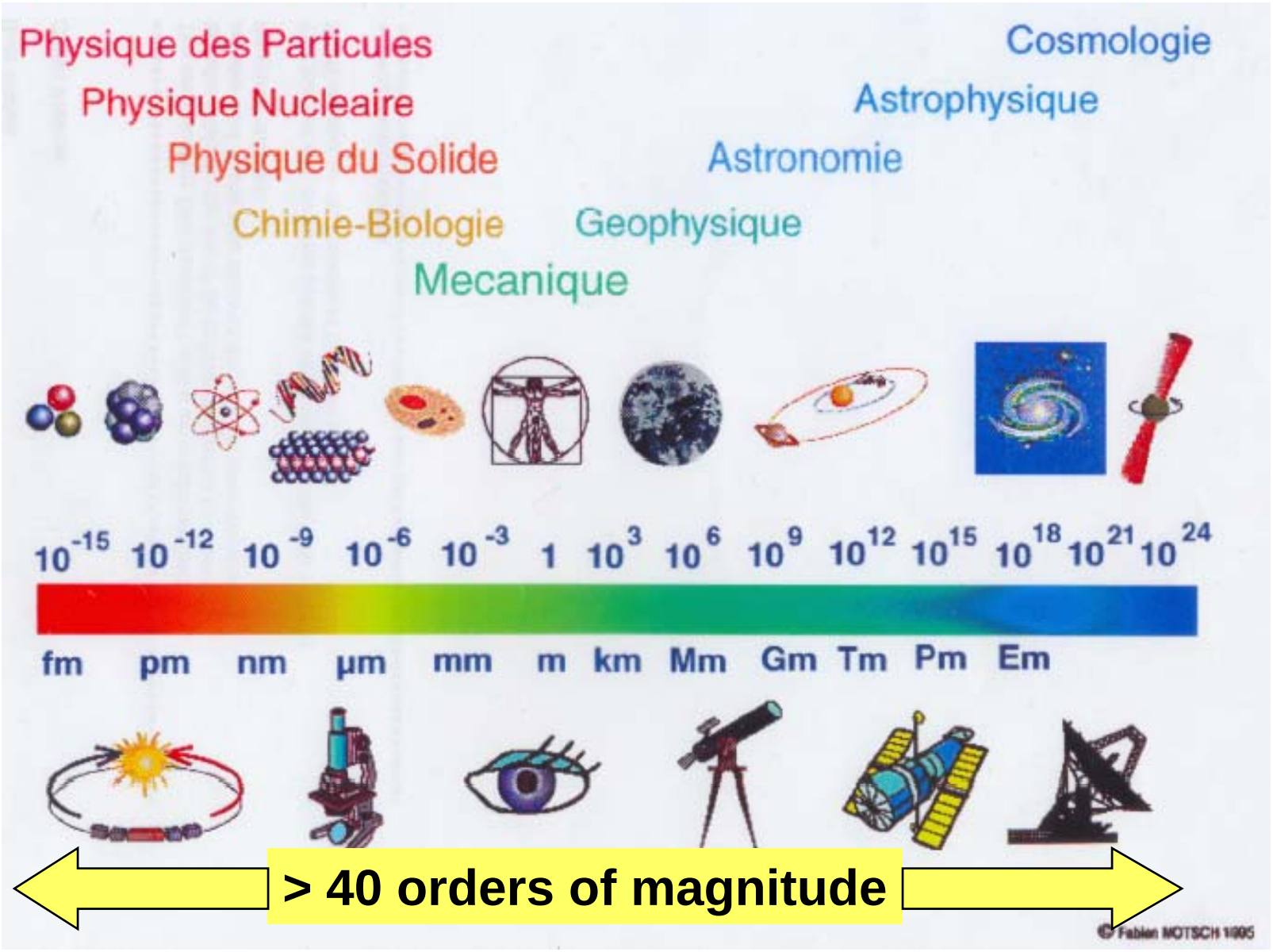


MATTER

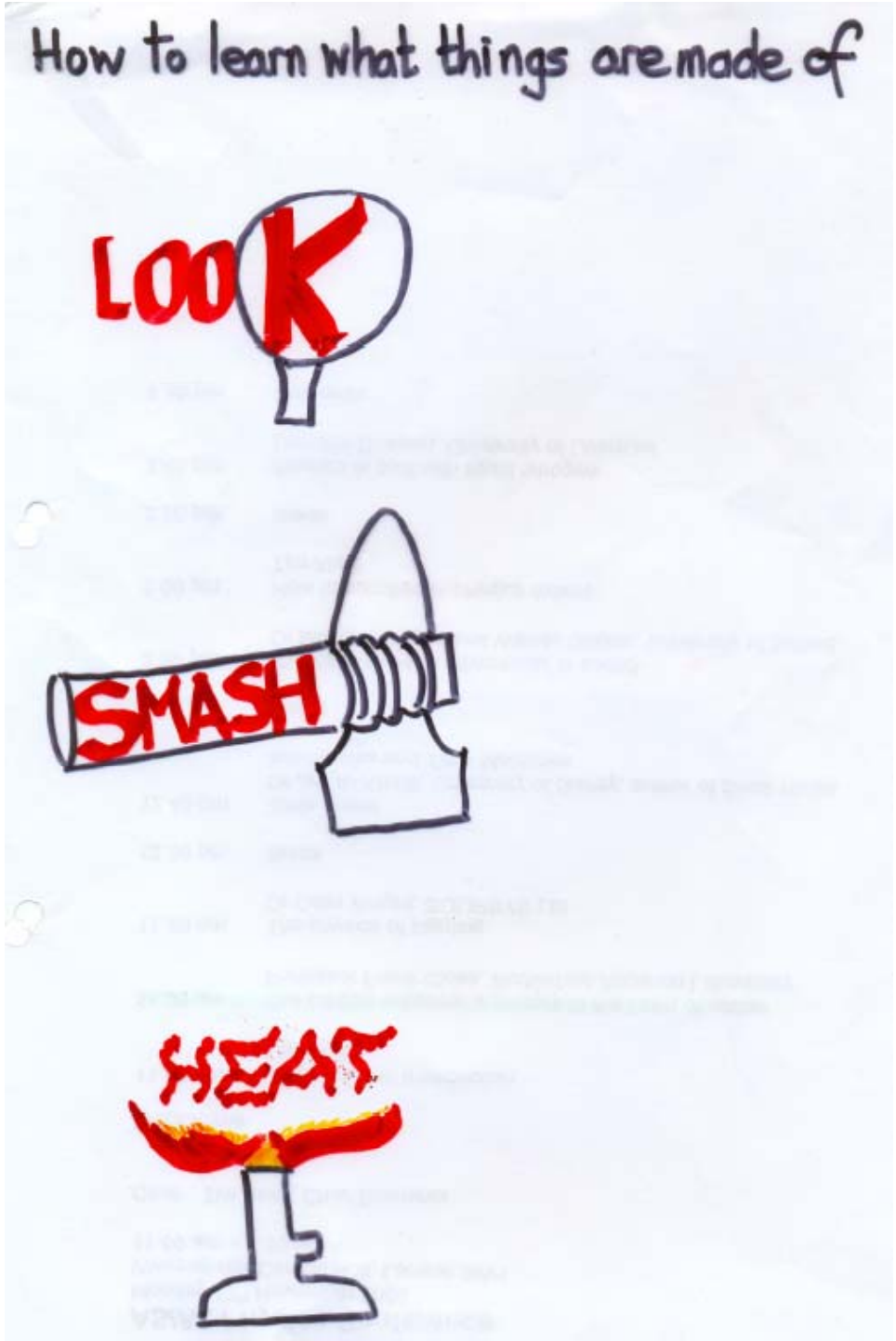
ANTIMATTER

**…why didn’t it mutually destruct?**
**…why is there anything left?**

# Matter and the Universe



**What is matter made of ?**

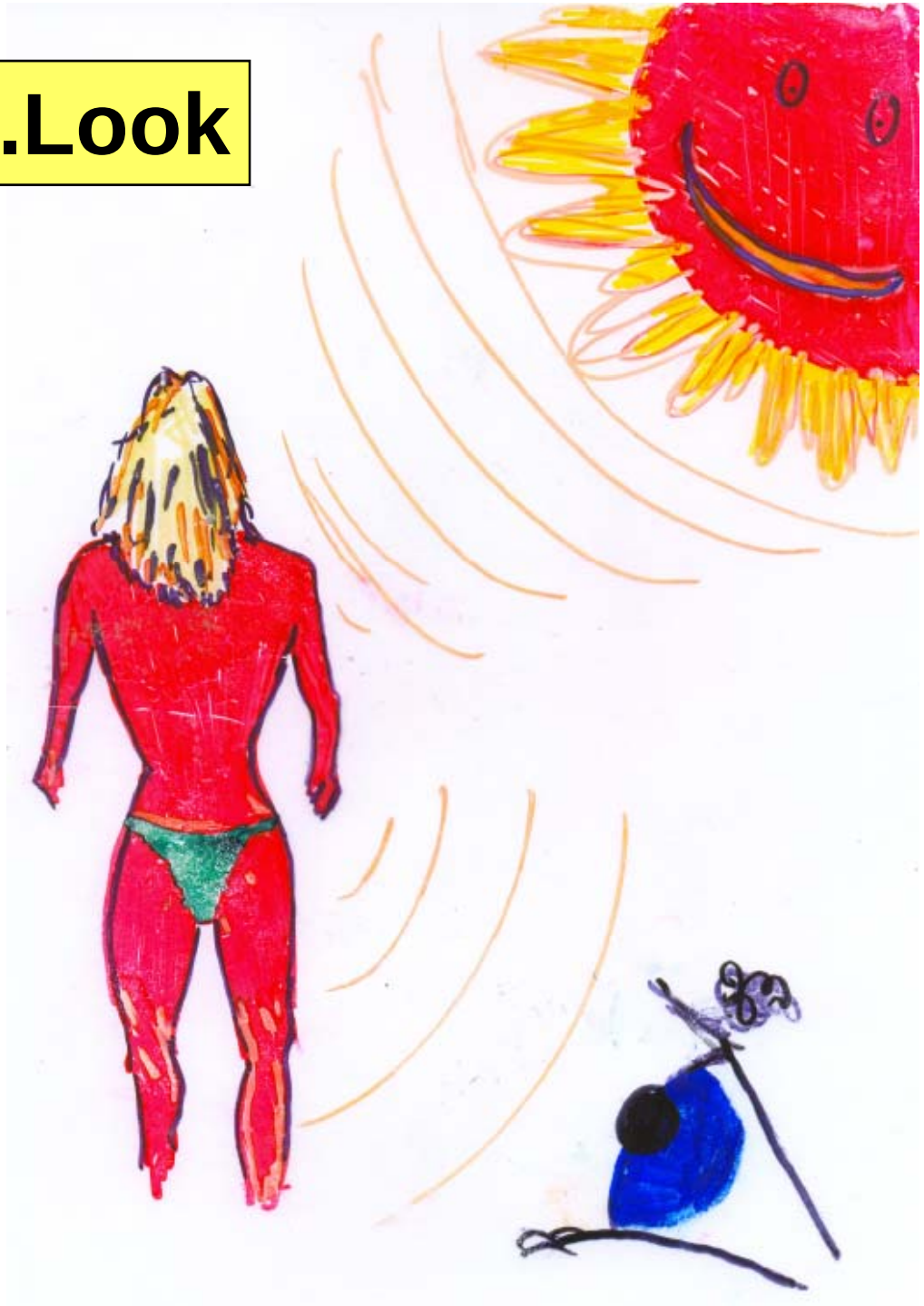


# 1.Look

**Light source**

**Object**

**Eye**



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**Light source**

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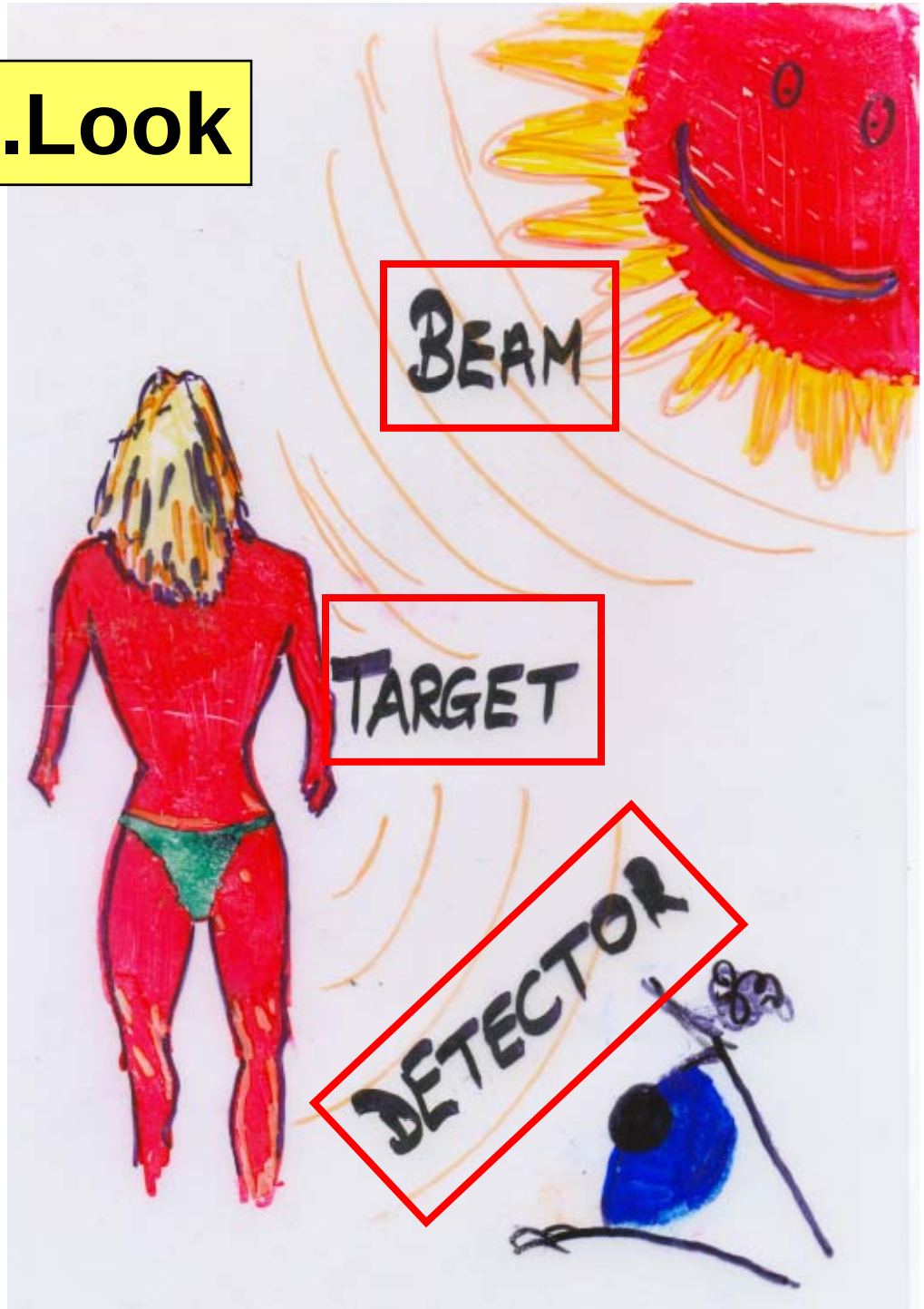
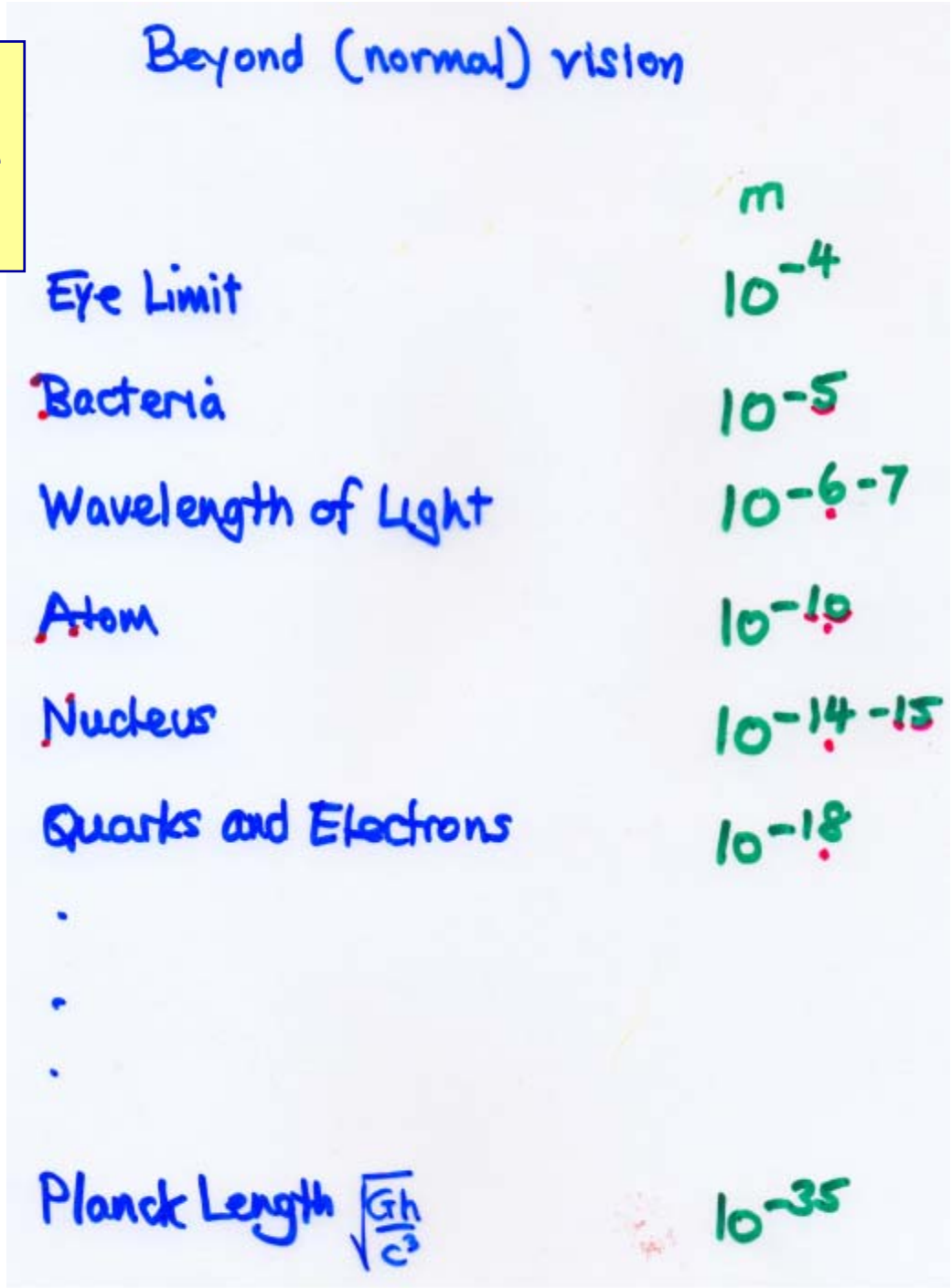
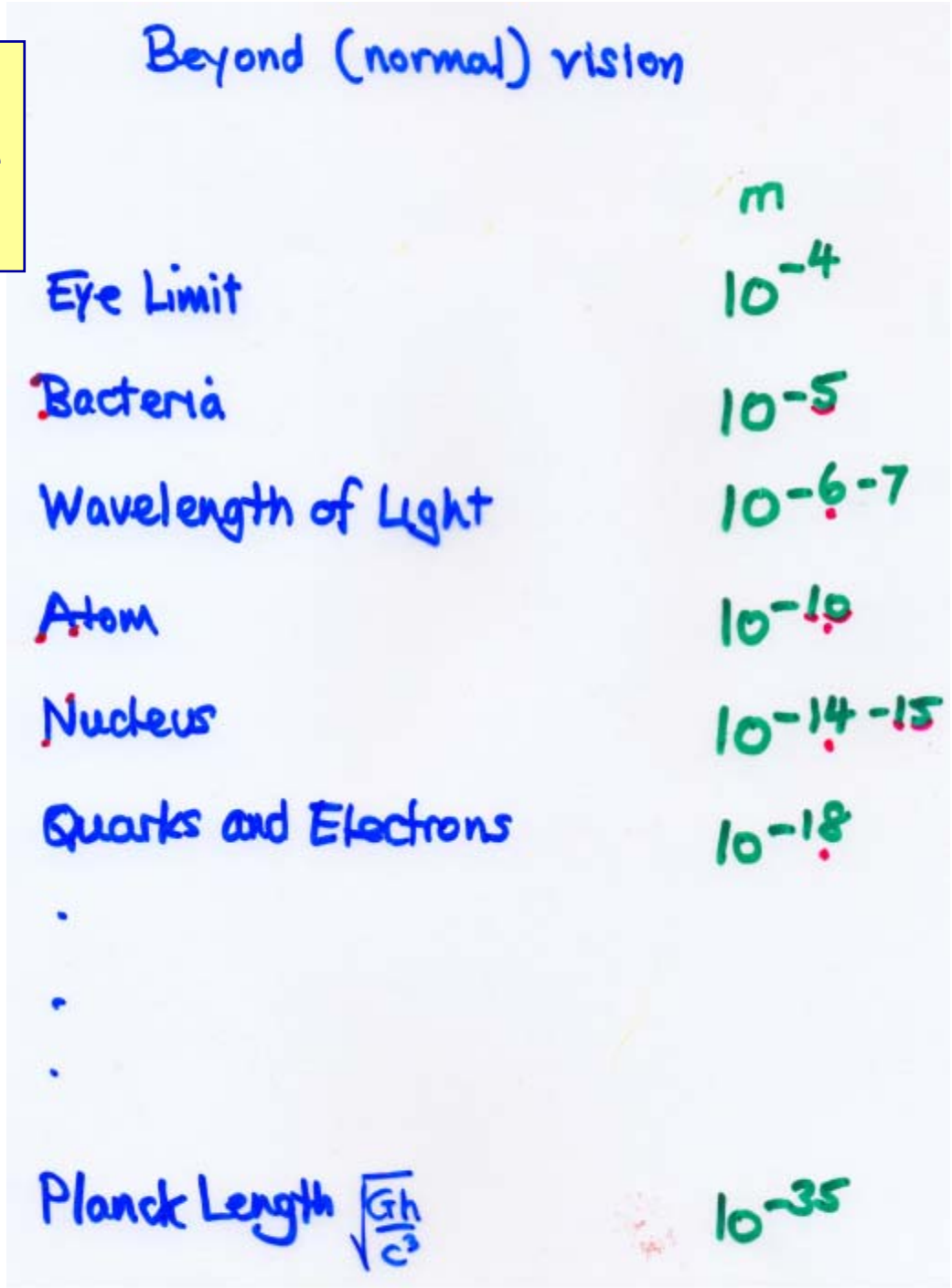


**Catch 22:**
**There's a limit to what we can see with our eye**



**Catch 22:**
**There's a limit to what we can see with our eye**

**To look at smaller things we need to use instruments that can "extend" our vision**



How to learn what things are made of


**The problem is the wavelength of light compared with the size of what you're trying to look at**



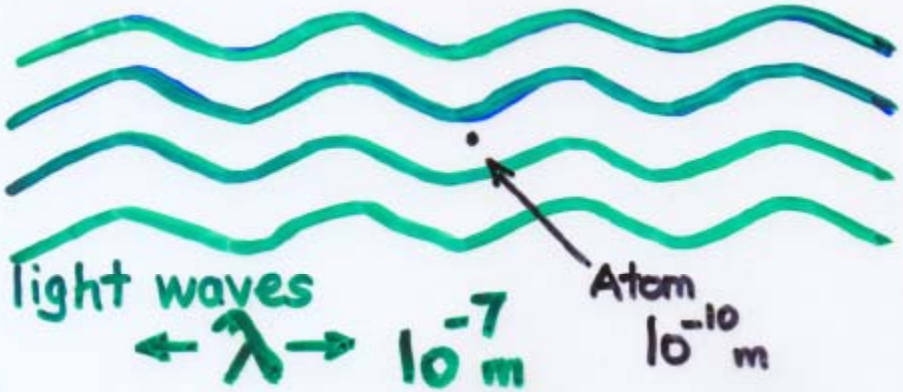
# How to learn what things are made of


resolution

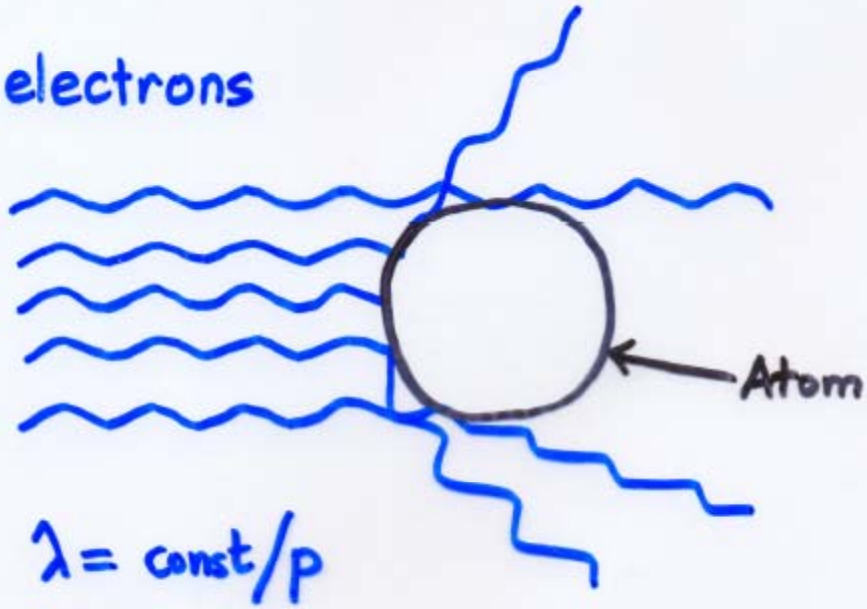
wave$\lambda$ength



# How to see small things

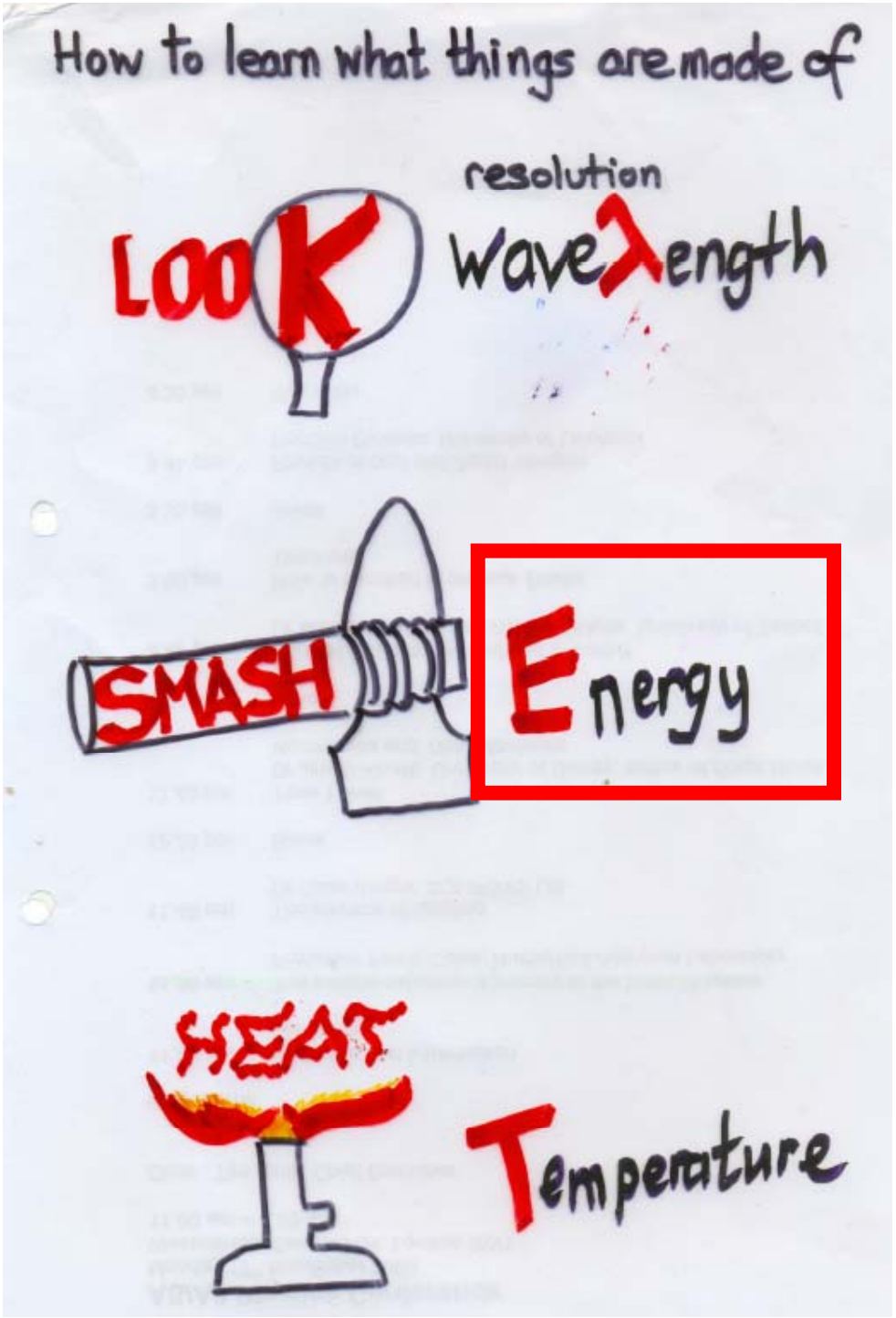



## Electron microscope




$\lambda = \text{const}/p$

**2. Smash**


How to learn what things are made of
LOOK
resolution
wavelength
SMASH
Energy
HEAT
Temperature

**…some definitions**
**for ENERGY.**

**Joules are too big**
**for particle energies….**

**and**

**0.00000000000000001**
**Joules is too messy….**

**So we need more**
**Practical Units**

**eV, keV,MeV,GeV**
**and welcome to TeV**

…some definitions for **ENERGY**

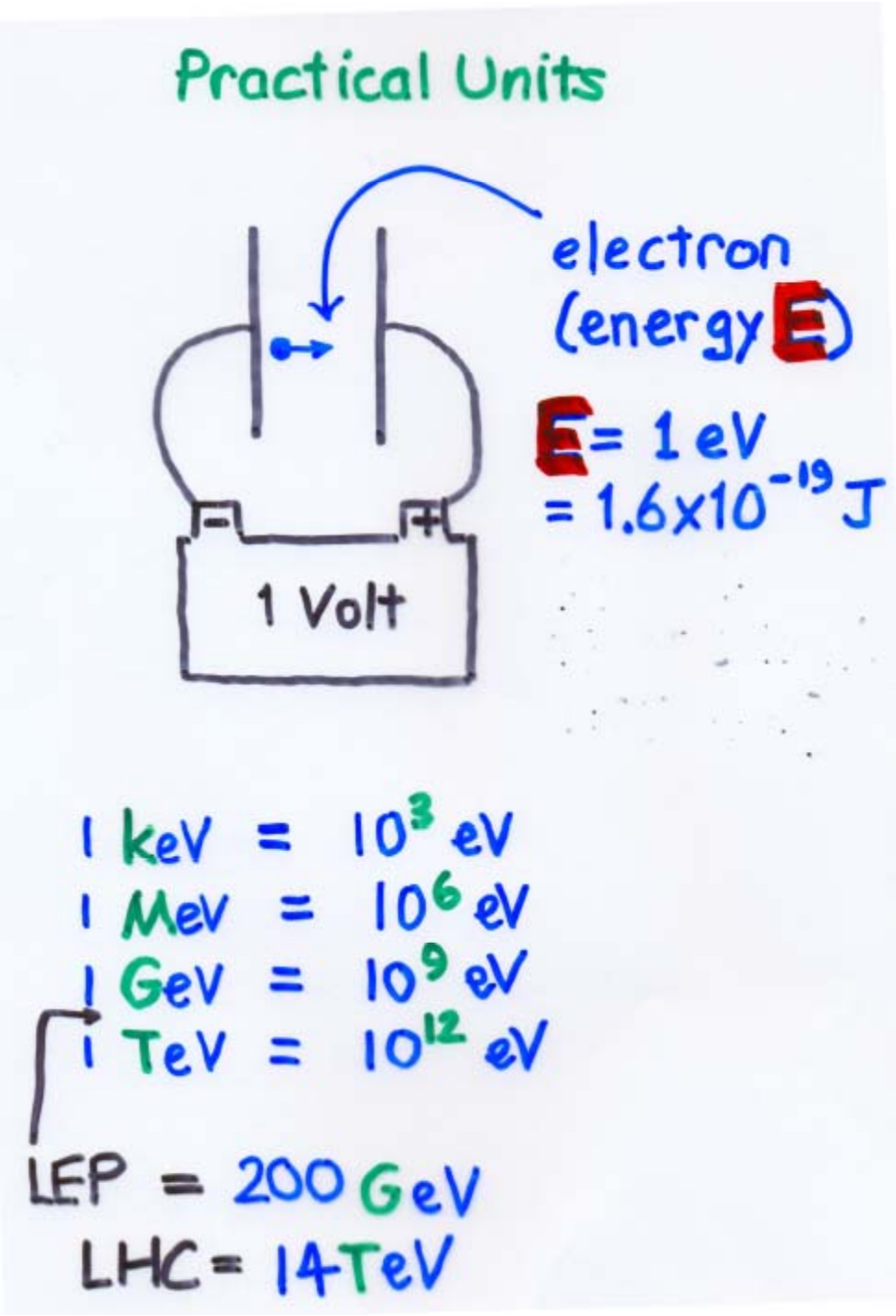
**Joules** are too big for particle energies….

and

0.00000000000000001 Joules is too messy….

So we need more **Practical Units**

**eV, keV,MeV,GeV and welcome to TeV**

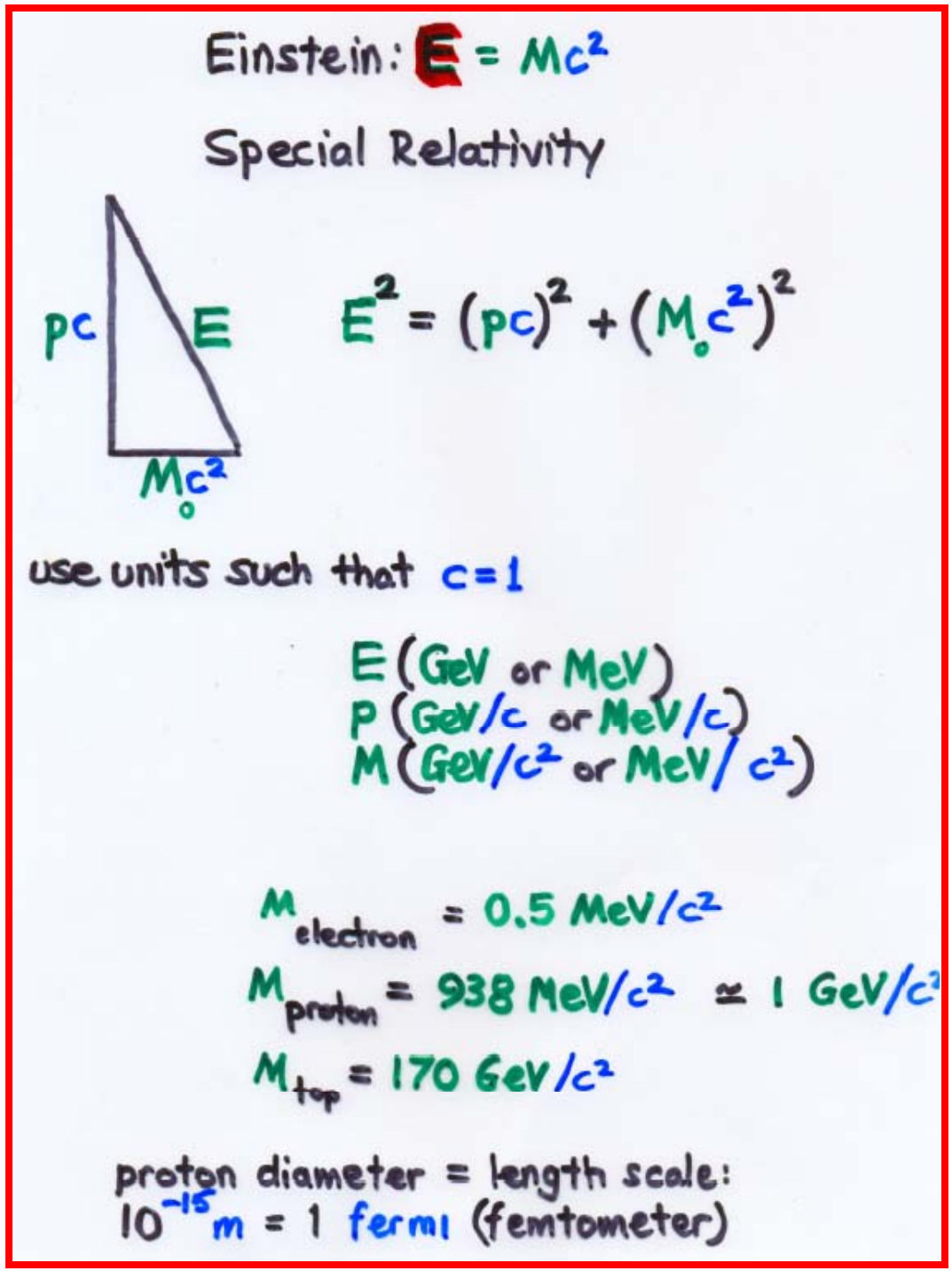


**E**instein

**E**nergy

and

$$E = mc^2$$



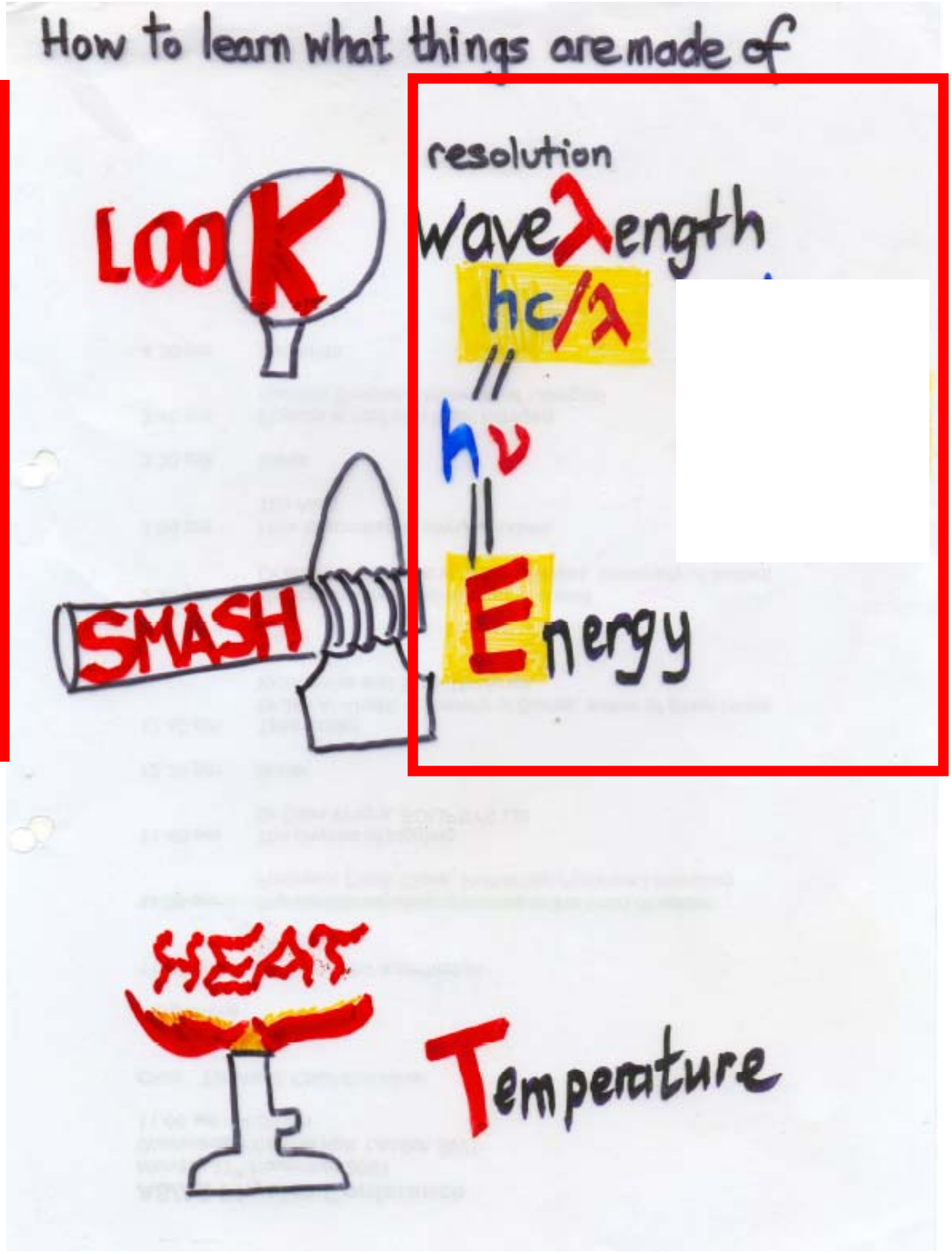
**LOOK or SMASH**

# Wavelength

**and**

# Energy

**profoundly related**



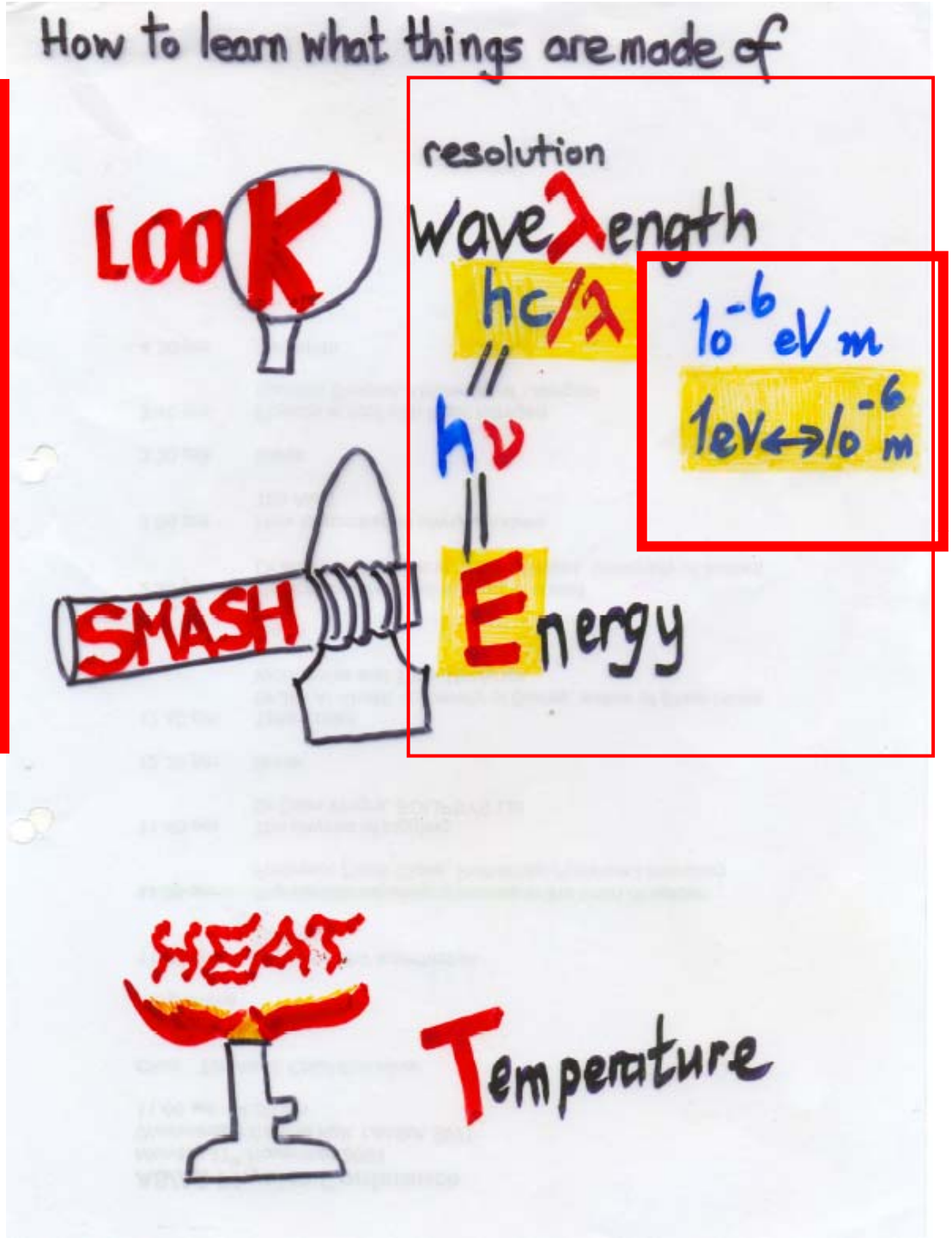
**LOOK or SMASH**

**Wavelength**

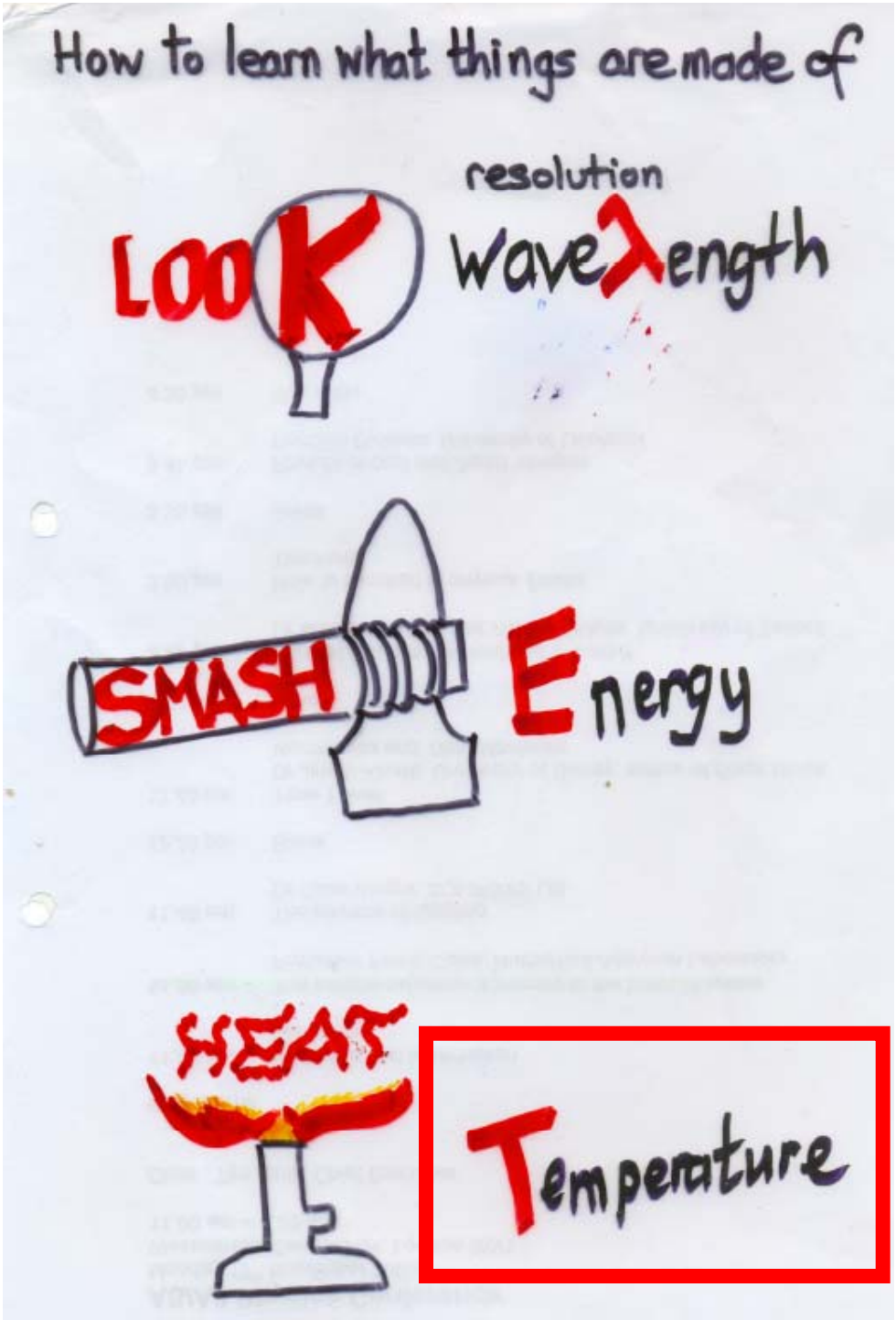
**and**

**Energy**

**profoundly related**



# 3. Heat



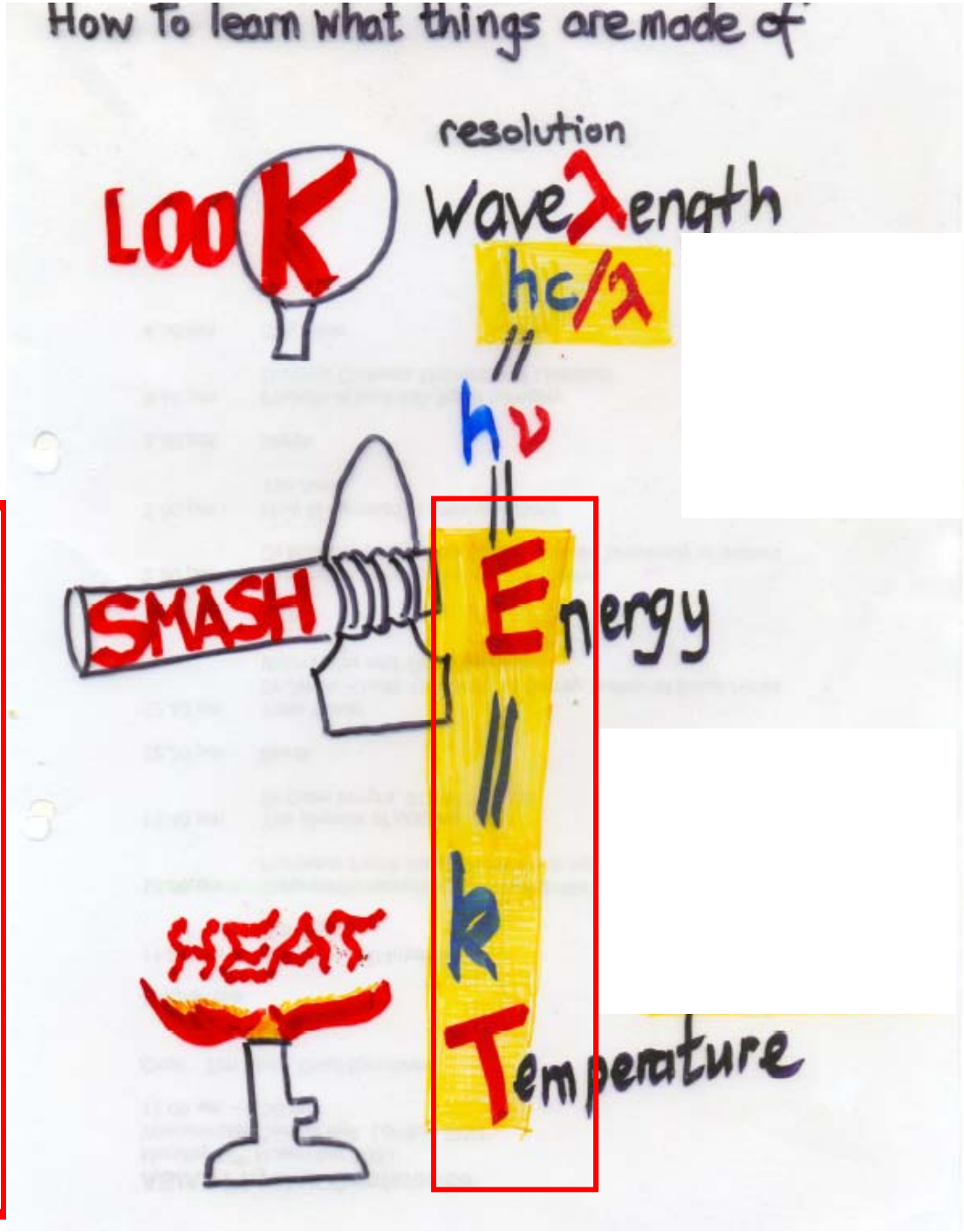

**… also profoundly related……**

**SMASH or HEAT**

**Energy**

**and**

**Temperature**

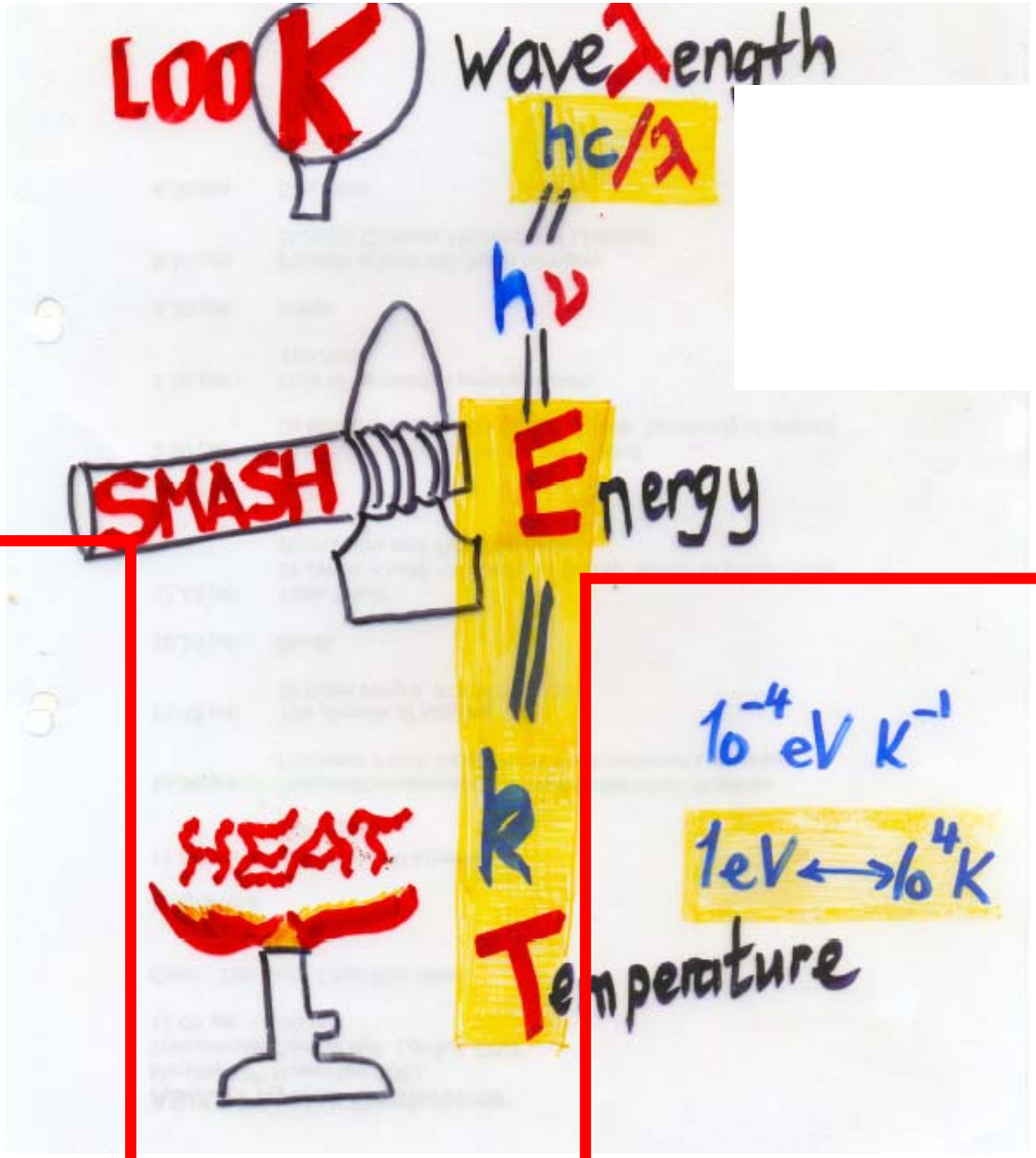


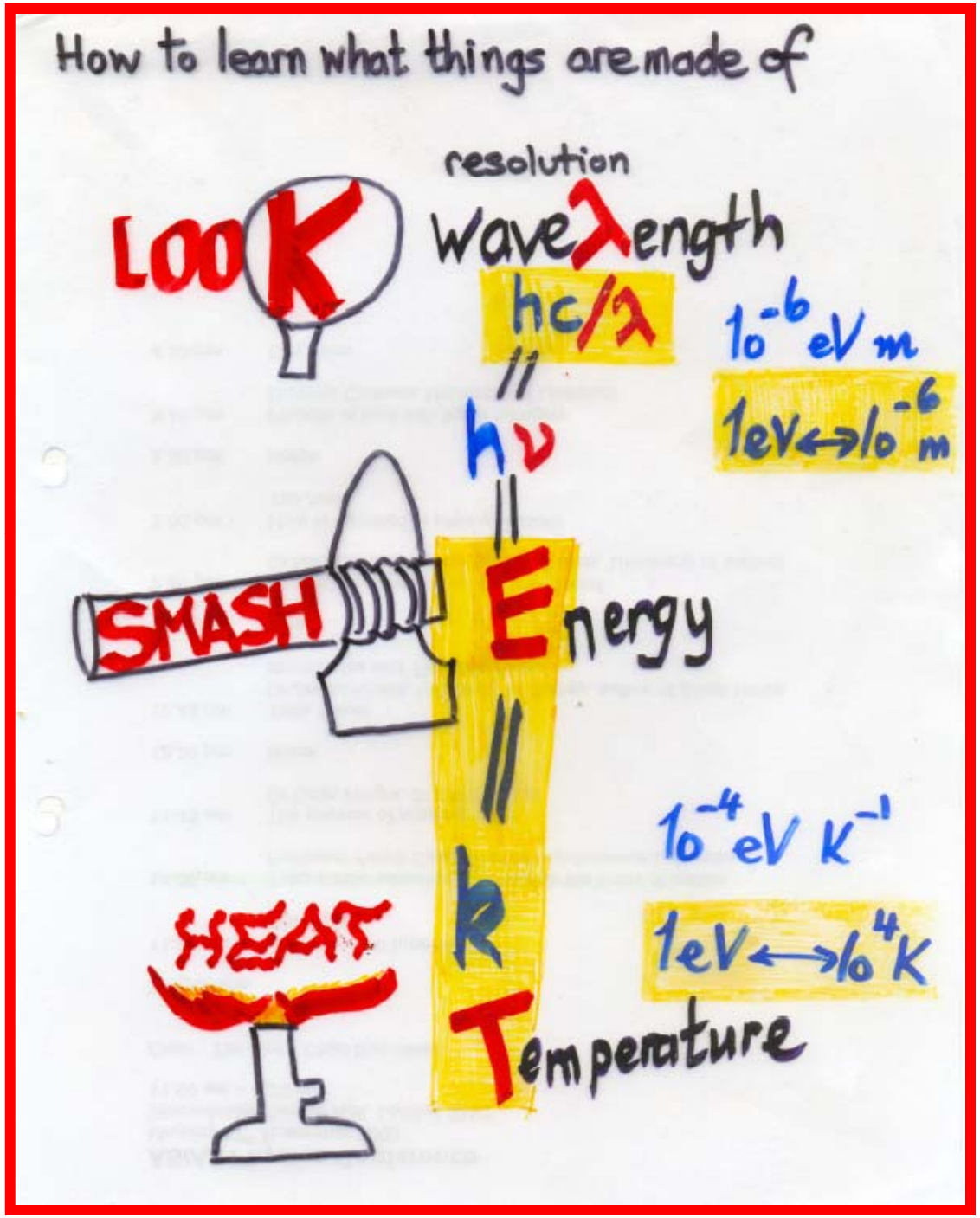
**SMASH or HEAT**

**Energy**

**and**

**Temperature**




How to learn what things are made of
resolution
LOOK
wavelength
hc/λ
10^-6 eV m
1eV ↔ 10^-6 m
hν
SMASH
Energy
10^-4 eV K^-1
HEAT
kT
1eV ↔ 10^4 K
Temperature

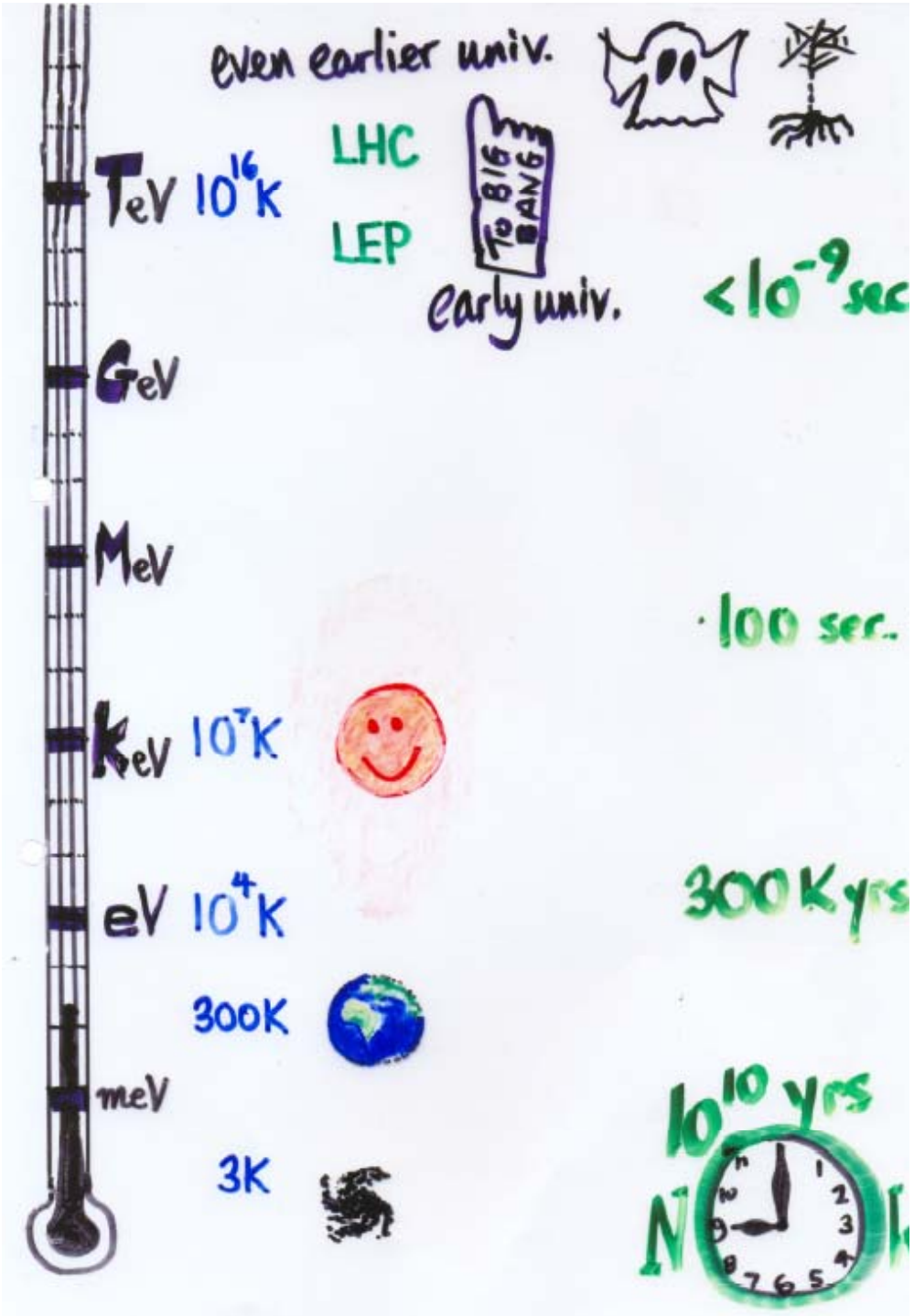
# Beyond (normal) vision

| | eV | m |
|---|---|---|
| Eye Limit | | $10^{-4}$ |
| Bacteria | | $10^{-5}$ |
| Wavelength of Light | 1-10eV | $10^{-6-7}$ |
| Atom | | $10^{-10}$ |
| Nucleus | 100MeV-1GeV | $10^{-14-15}$ |
| Quarks and Electrons | 1TeV | $10^{-18}$ |
| . | | |
| . | | |
| . | | |
| Planck Length $\sqrt{\frac{Gh}{c^3}}$ | $10^{20}$ GeV | $10^{-35}$ |

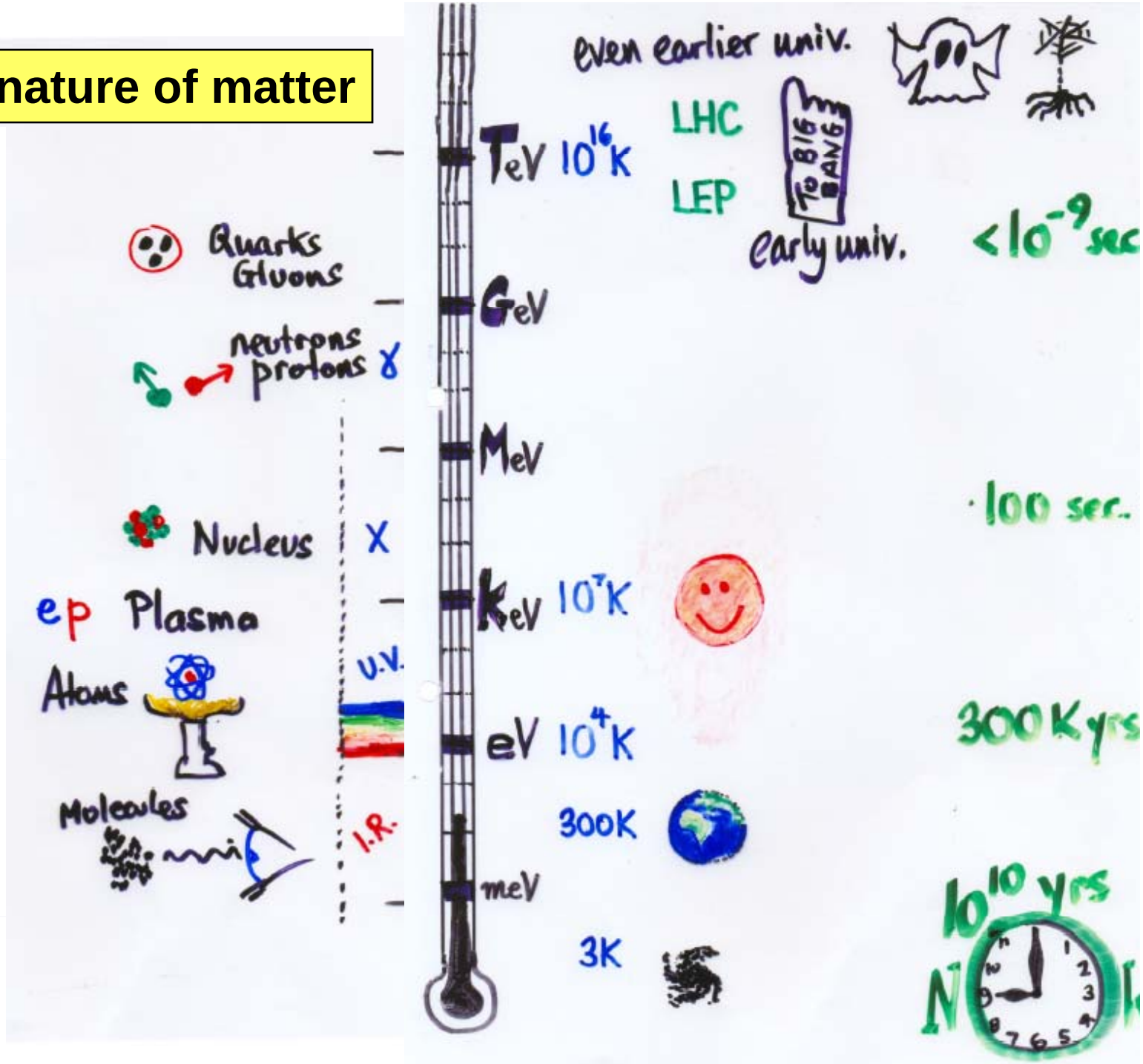
# The Universe

in

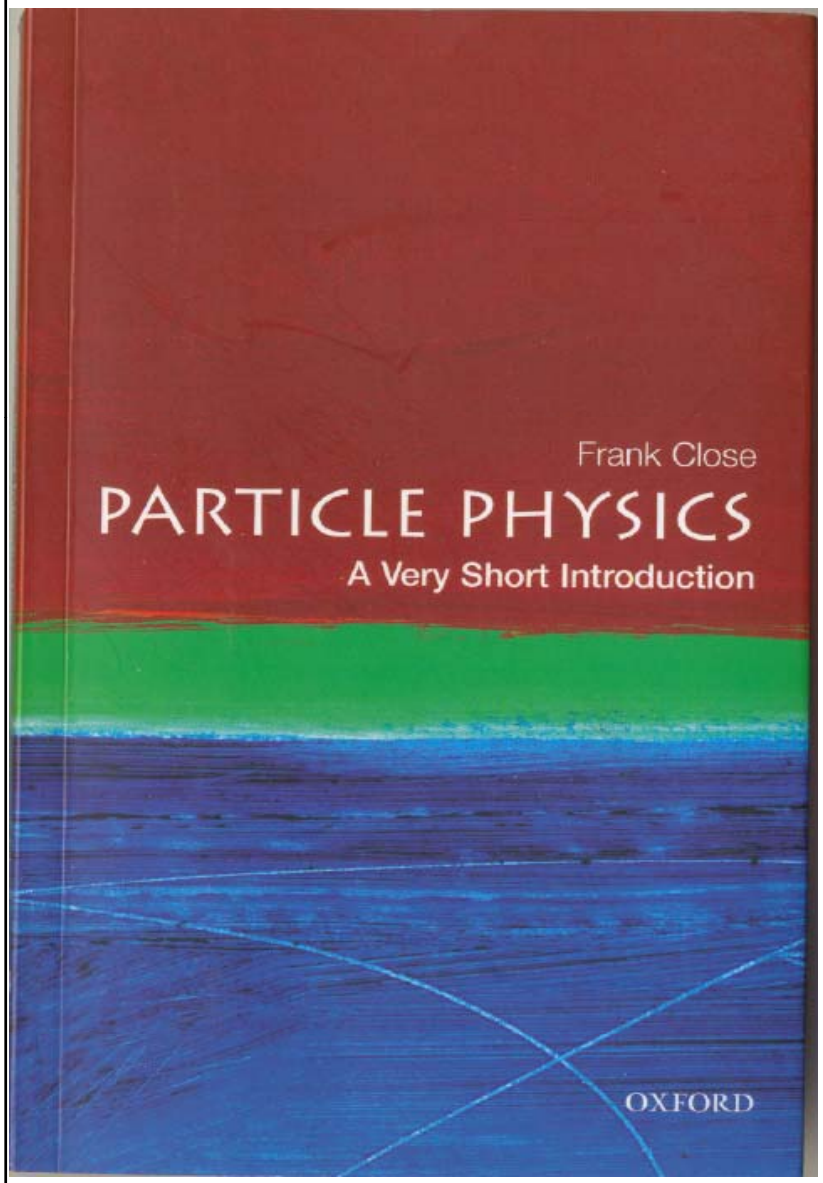
# Temperature Energy and Time



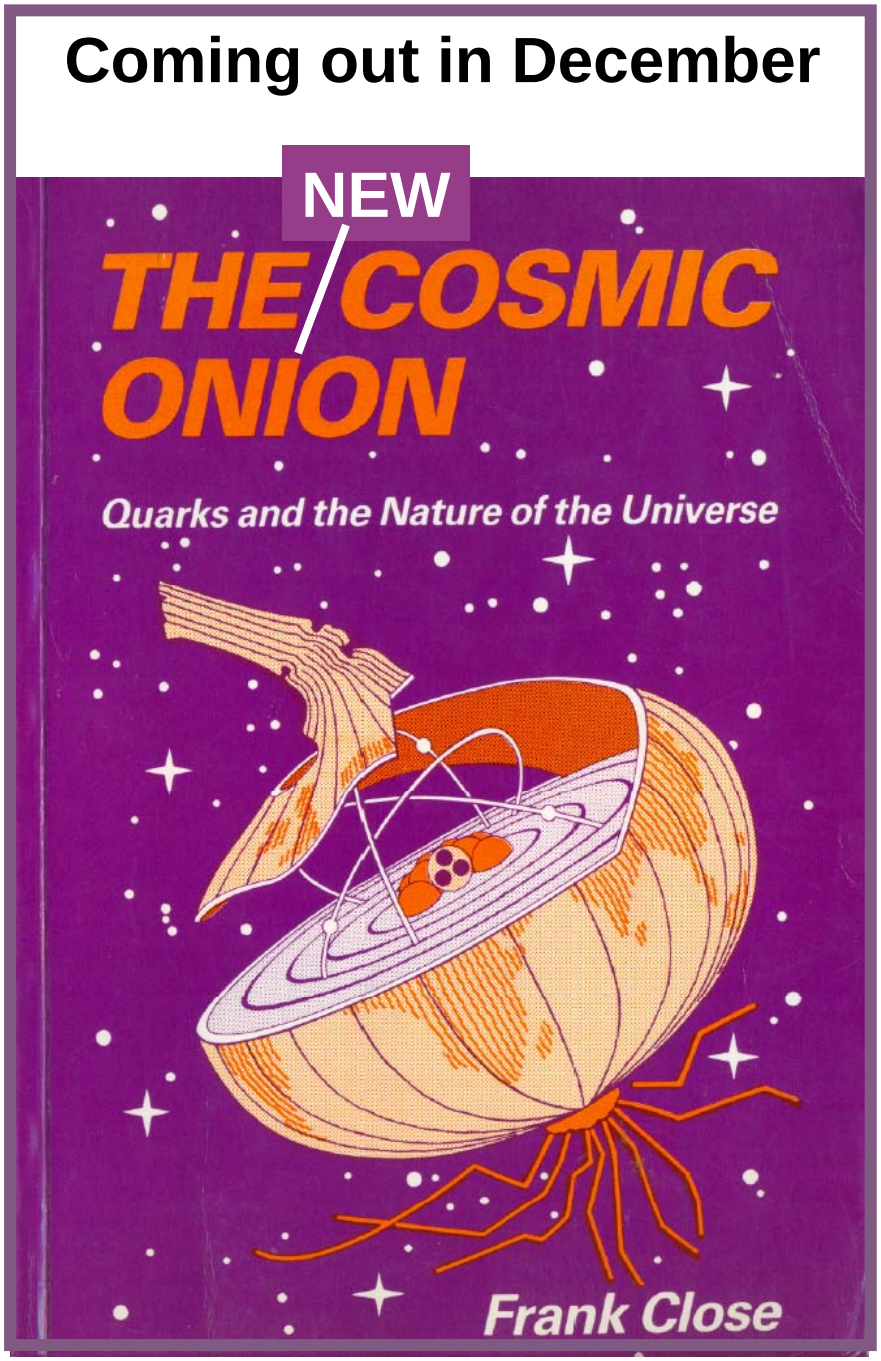
# …and the nature of matter



## A Very Short Introduction



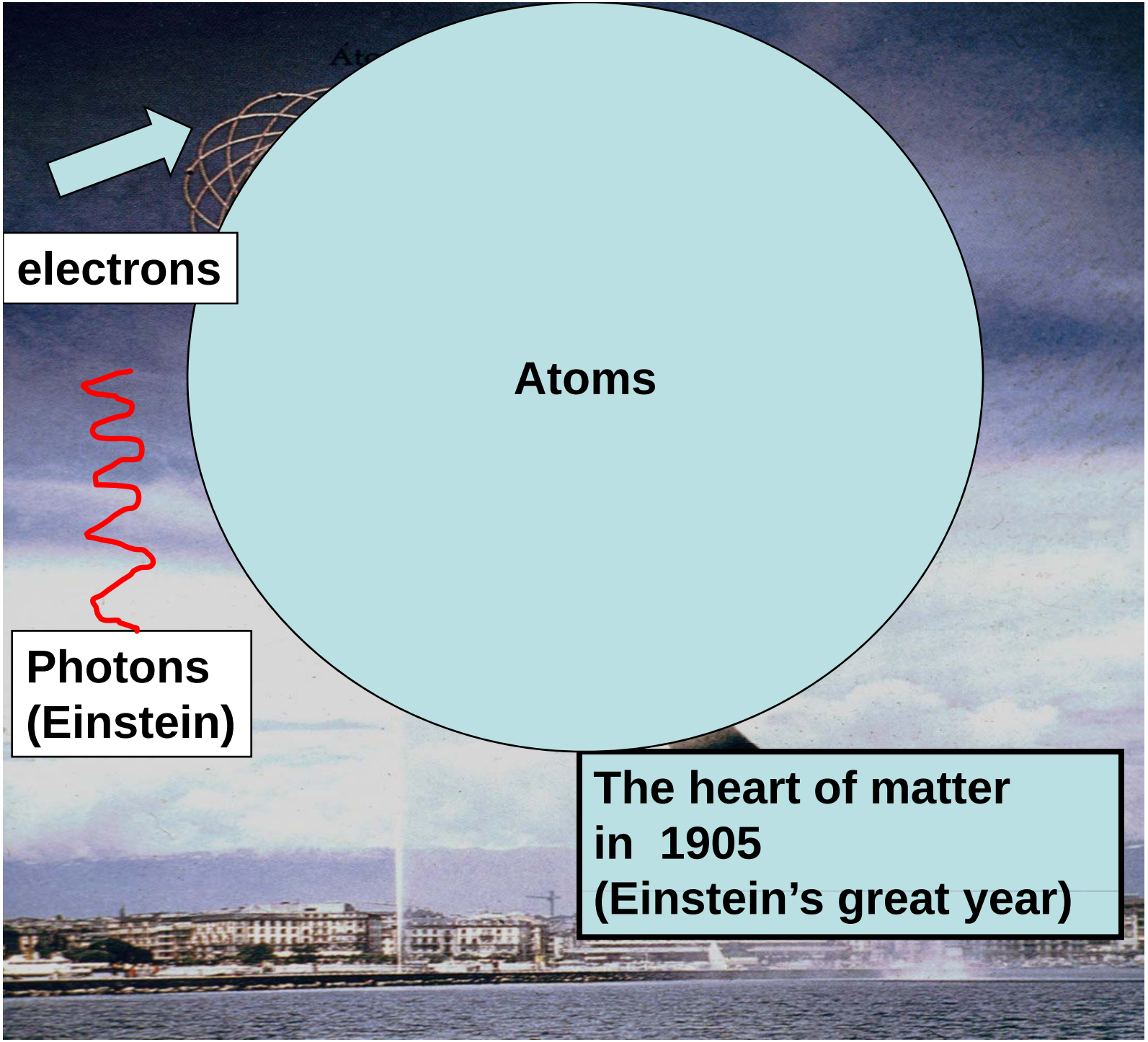

## Coming out in December

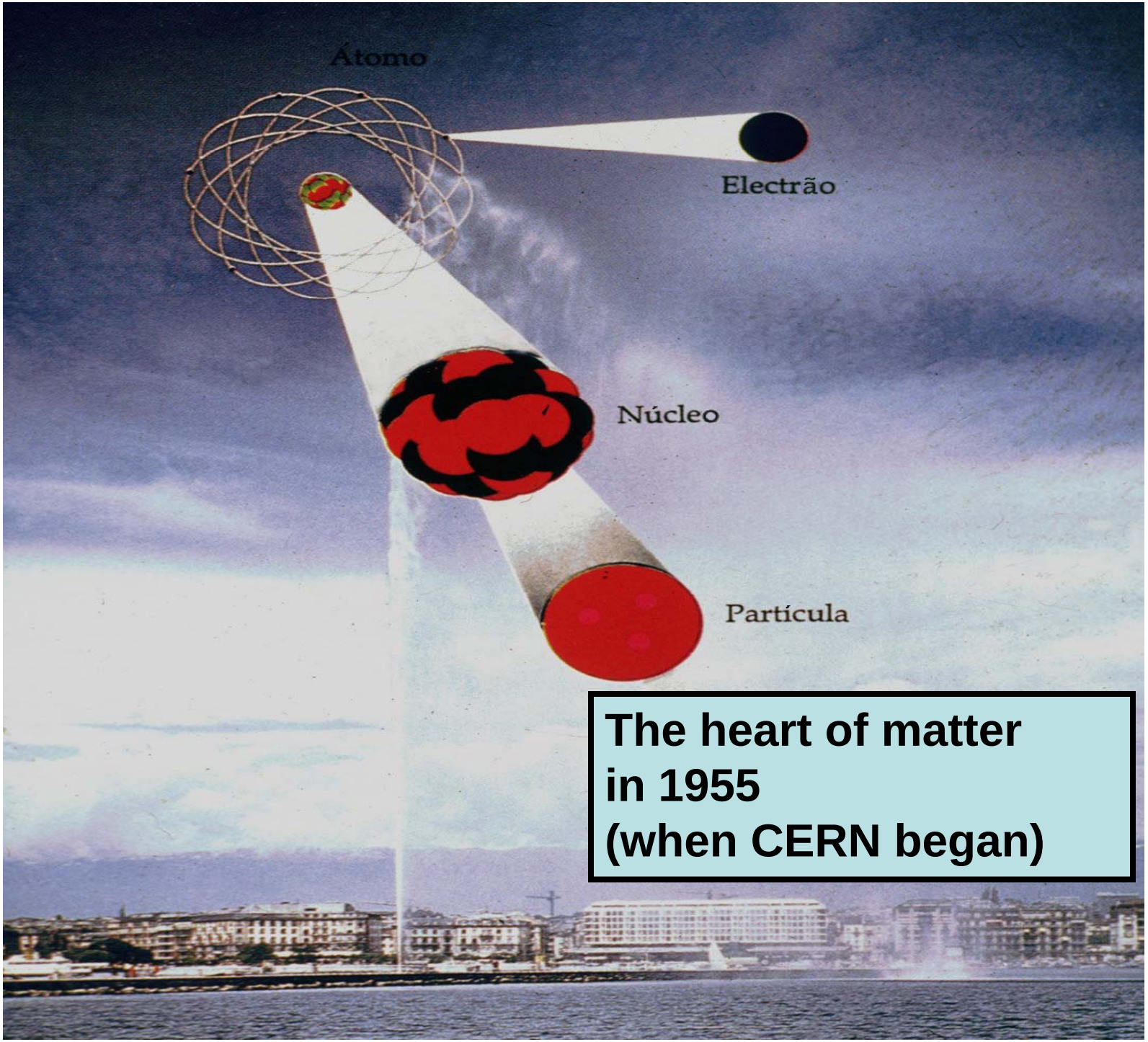


# Particles in Three Minutes

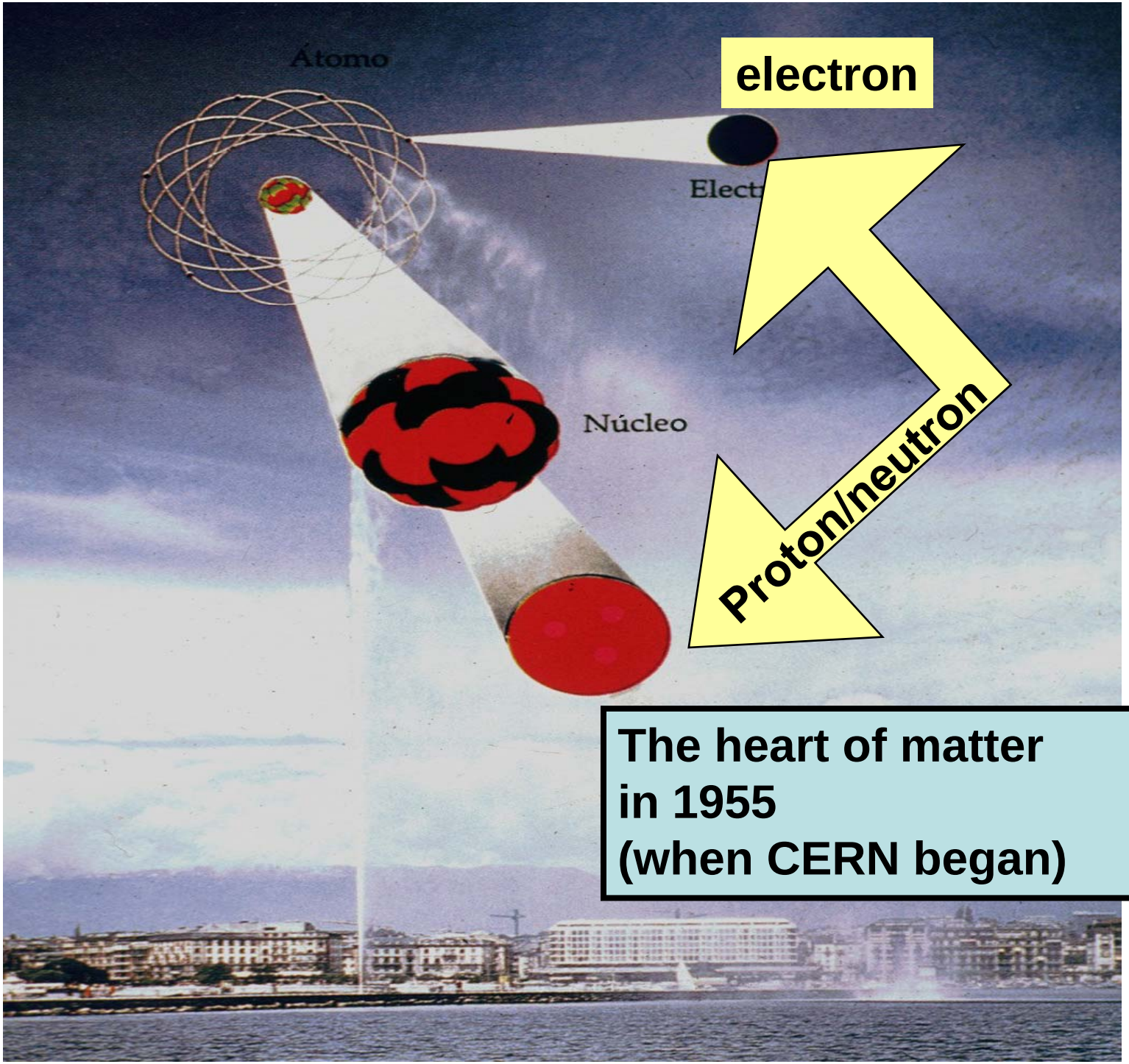
A quick survey of how we got here….

….and where we think we're going next.


electrons
Atoms
Photons
(Einstein)
The heart of matter
in 1905
(Einstein's great year)




**The heart of matter in 1955 (when CERN began)**




**The heart of matter in 1955 (when CERN began)**

**Electron and Proton utterly different.**

**proton 2000 times heavier**

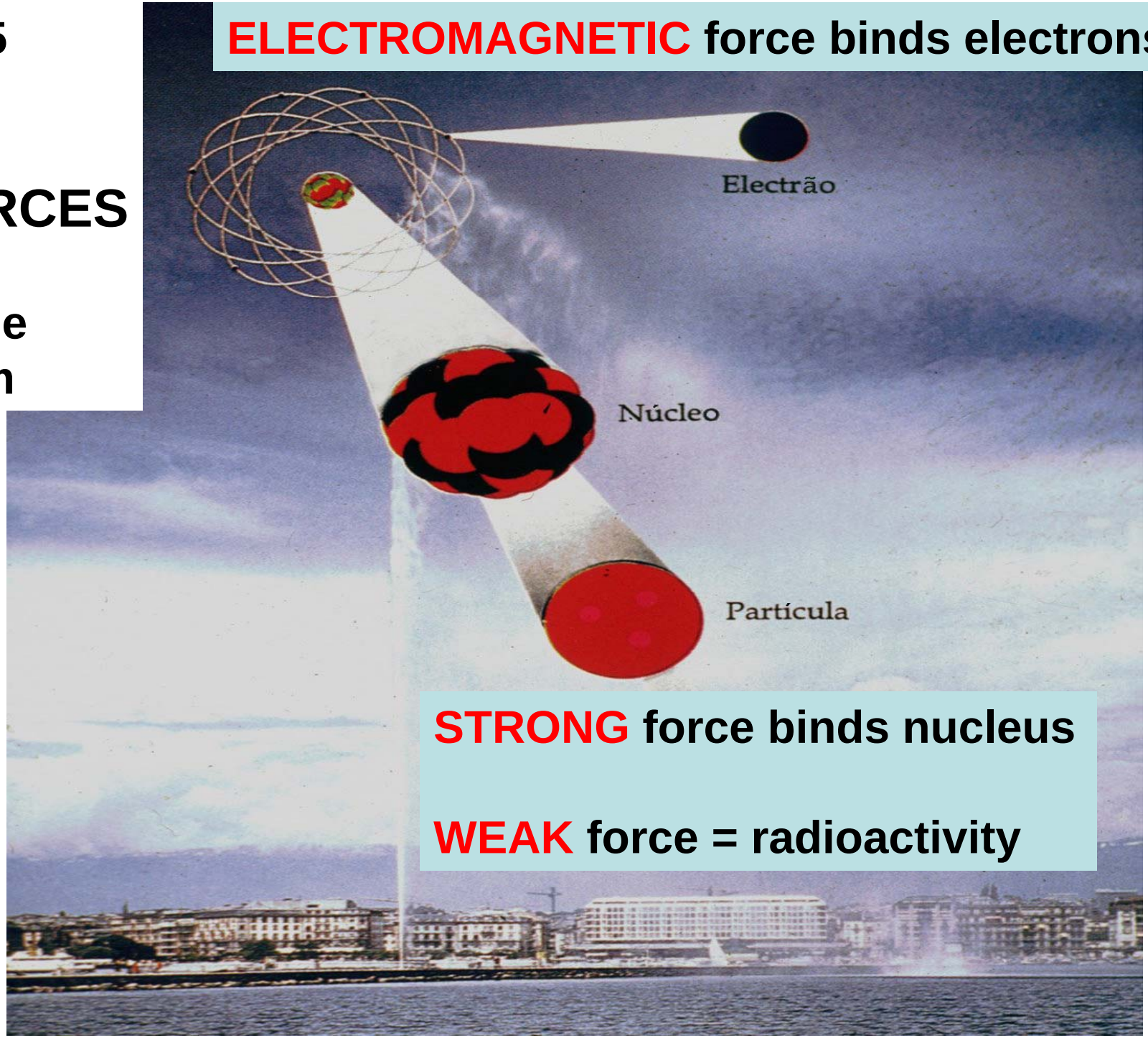
**10000 times bigger**

1955

# FORCES

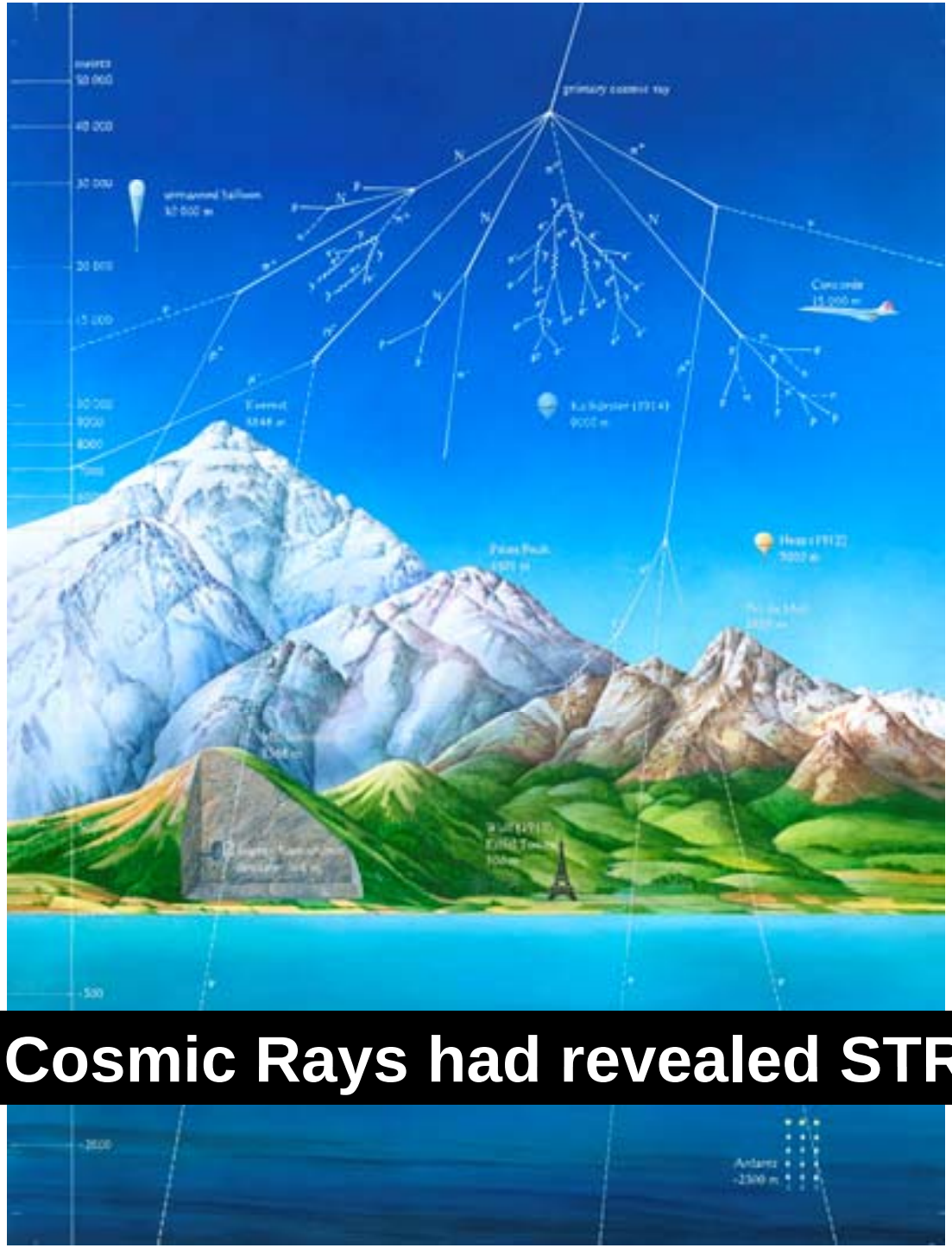
in the atom

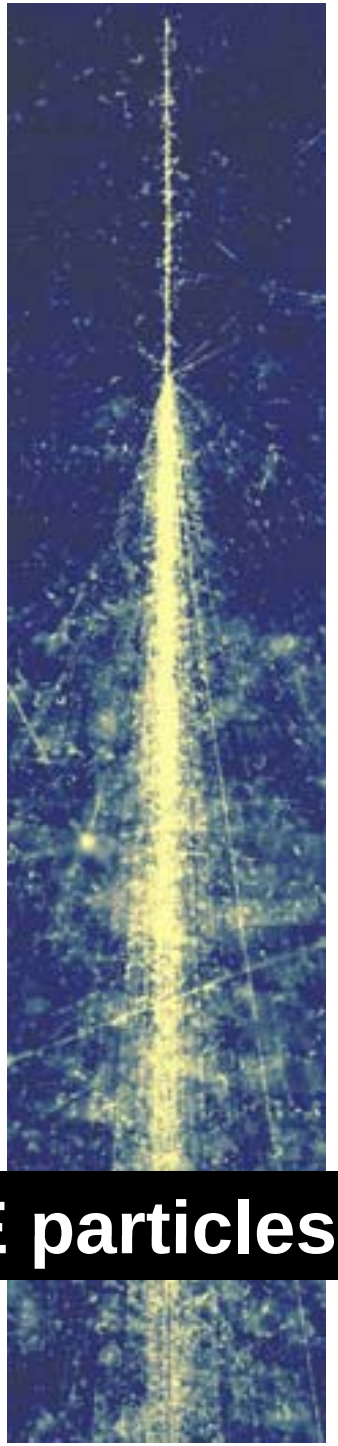
**ELECTROMAGNETIC force binds electrons**




**STRONG force binds nucleus**

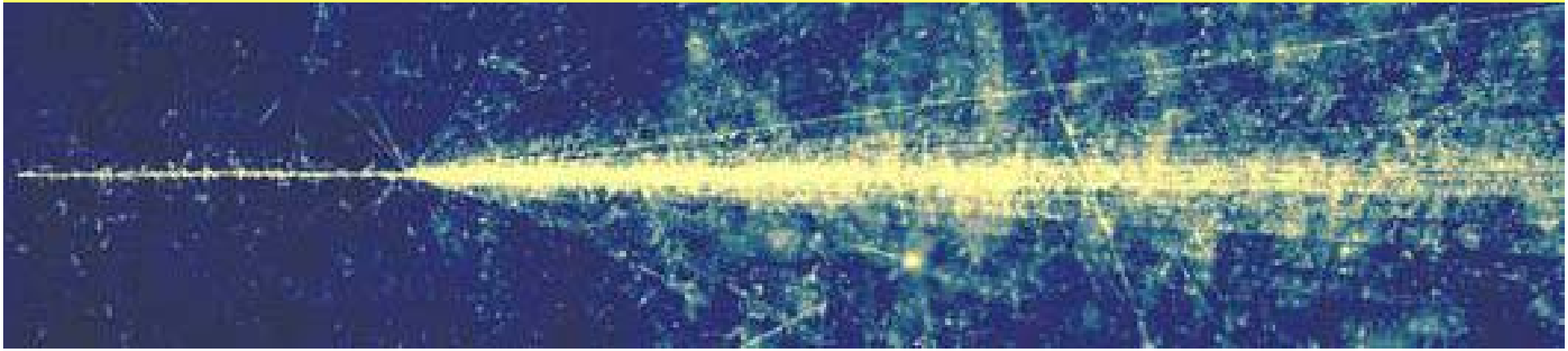
**WEAK force = radioactivity**



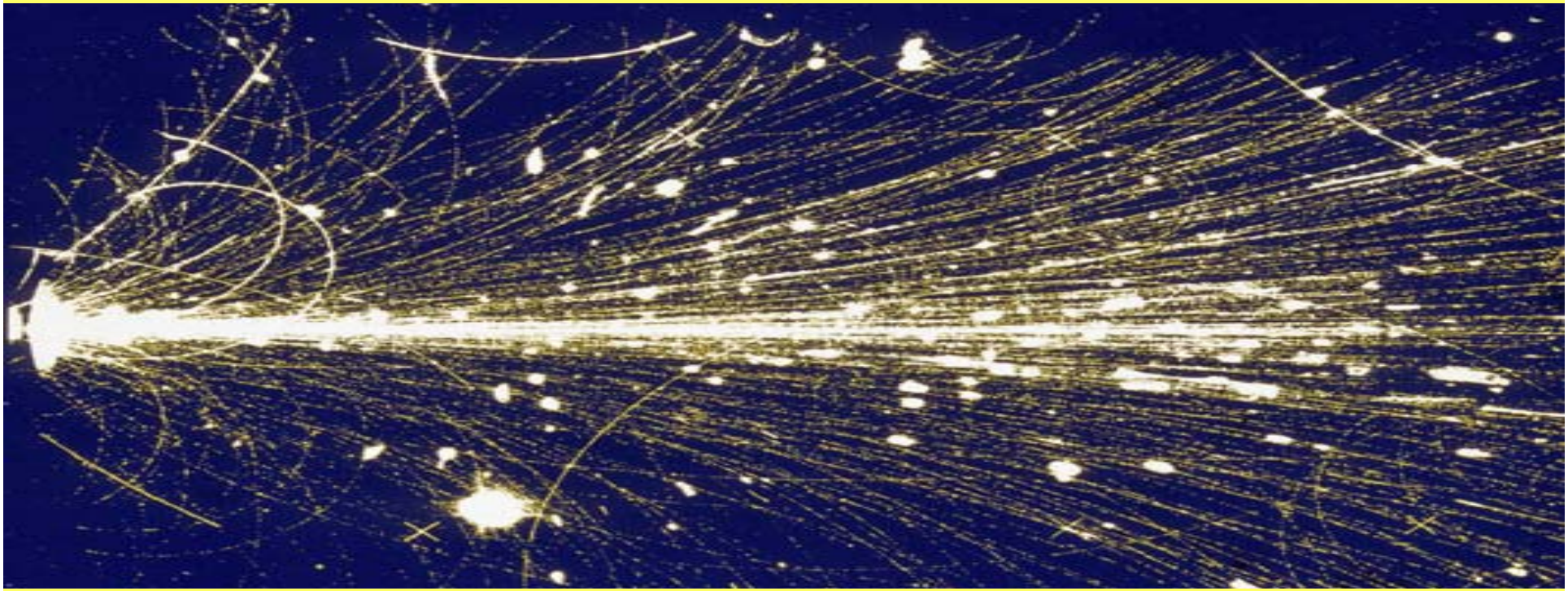


**Cosmic Rays had revealed STRANGE particles**

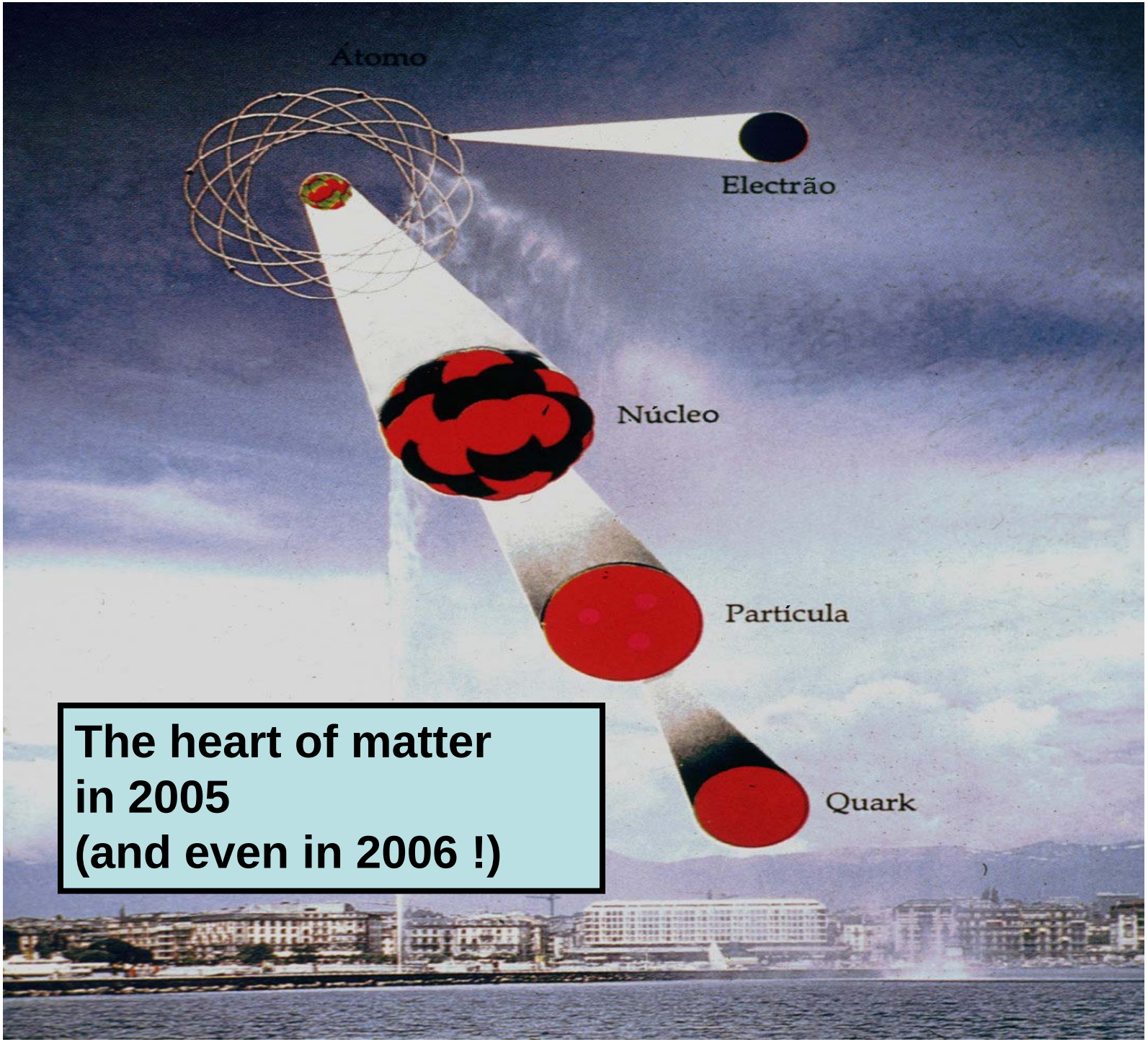
**1955 CERN accelerators replicate cosmic rays on Earth…**



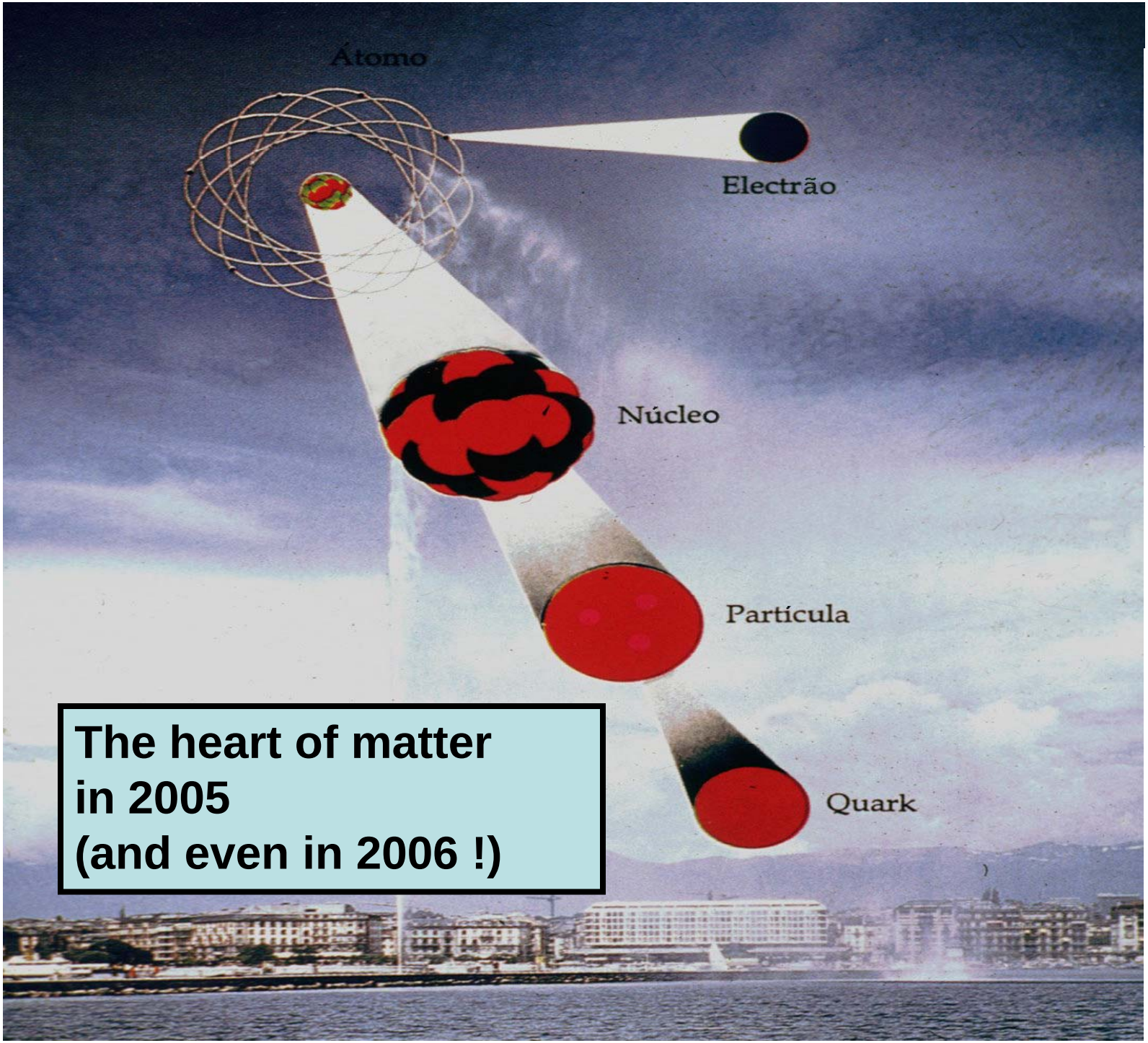
**..record the images and reveal the real heart of matter….**



**…..the beginnings of modern high energy particle physics**




**The heart of matter**
**in 2005**
**(and even in 2006 !)**




**The heart of matter in 2005 (and even in 2006 !)**

**Electron and quark very similar in**

**Mass**
**Size**
**Spin**

and in how they respond to the **FORCES**

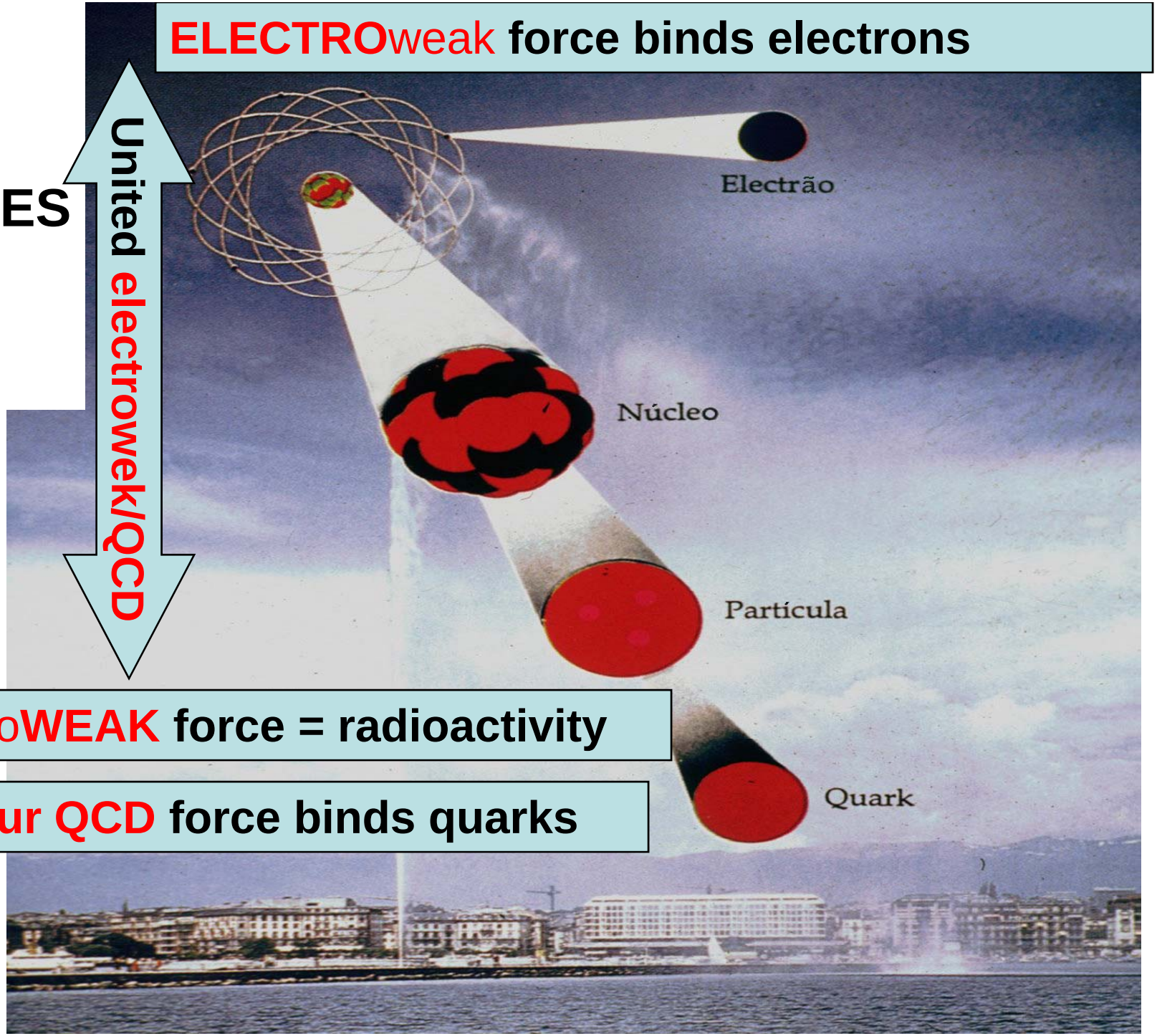
2005

**FORCES**

**in the atom**

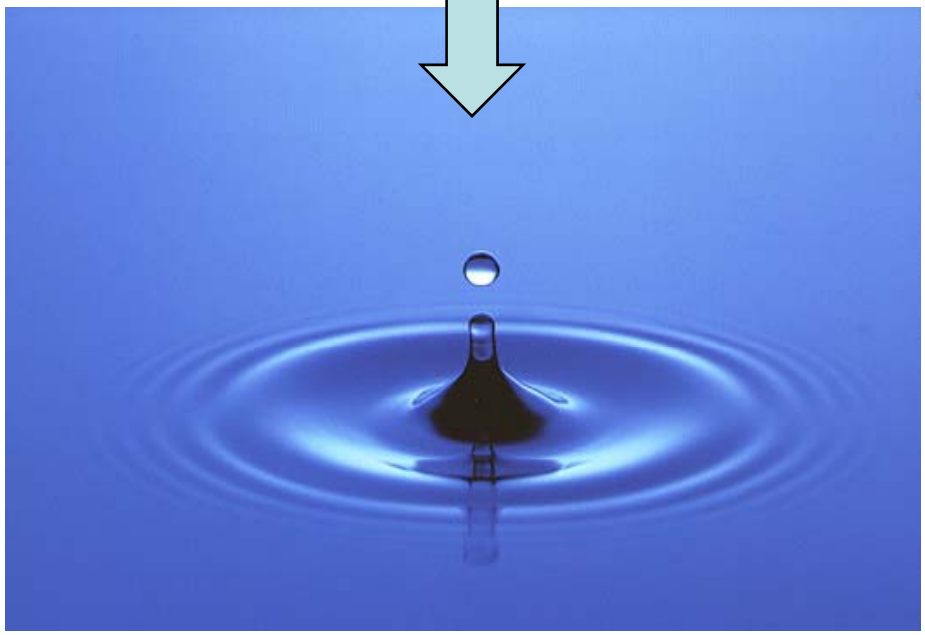
**ELECTROweak force binds electrons**

United electrowek/QCD



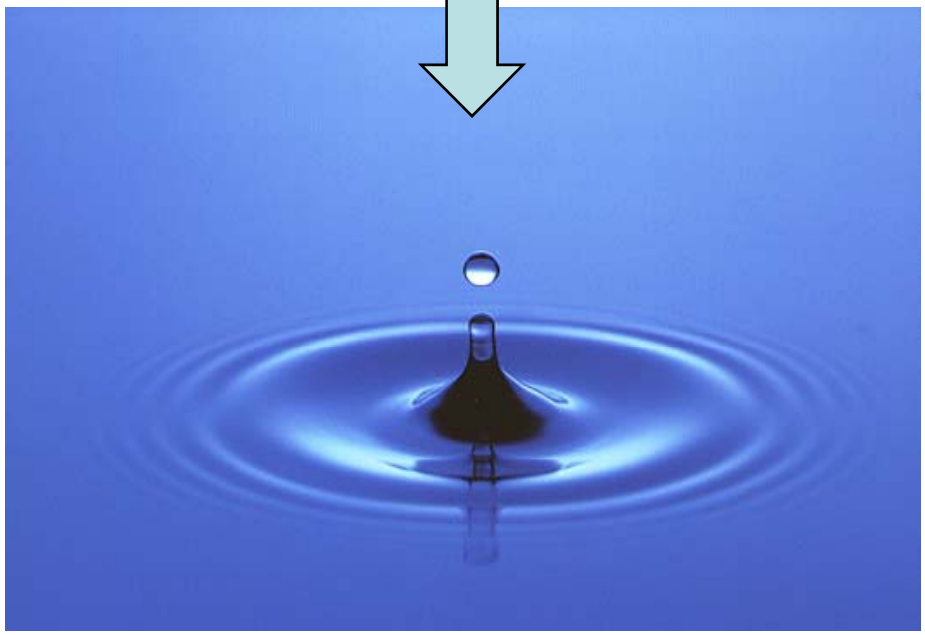

**electroWEAK force = radioactivity**

**Colour QCD force binds quarks**



**patterns and structures when cold (low energy)**

**Symmetry when warm (high energy)**



**FORCES 1955-2005**

COLD

**Electromagnetic**
**Weak**
**Strong**

WARM

**ElectroWeak**
**Strong (QCD)**

HOT

**GrandUnified**
**Force**

**Standard Model** of **Quarks Leptons and forces**

**= pattern** based on **mass**

**“cold”** =“low” energy

= **below 1 TeV**

**Standard Model** of **Quarks Leptons and forces**

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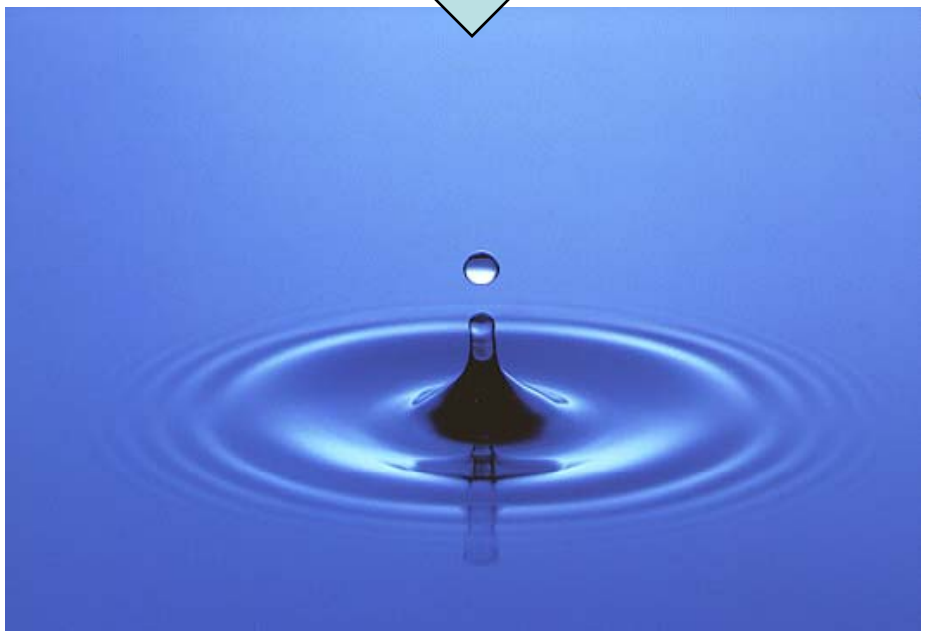


super**Symmetry**

when **"warm"**

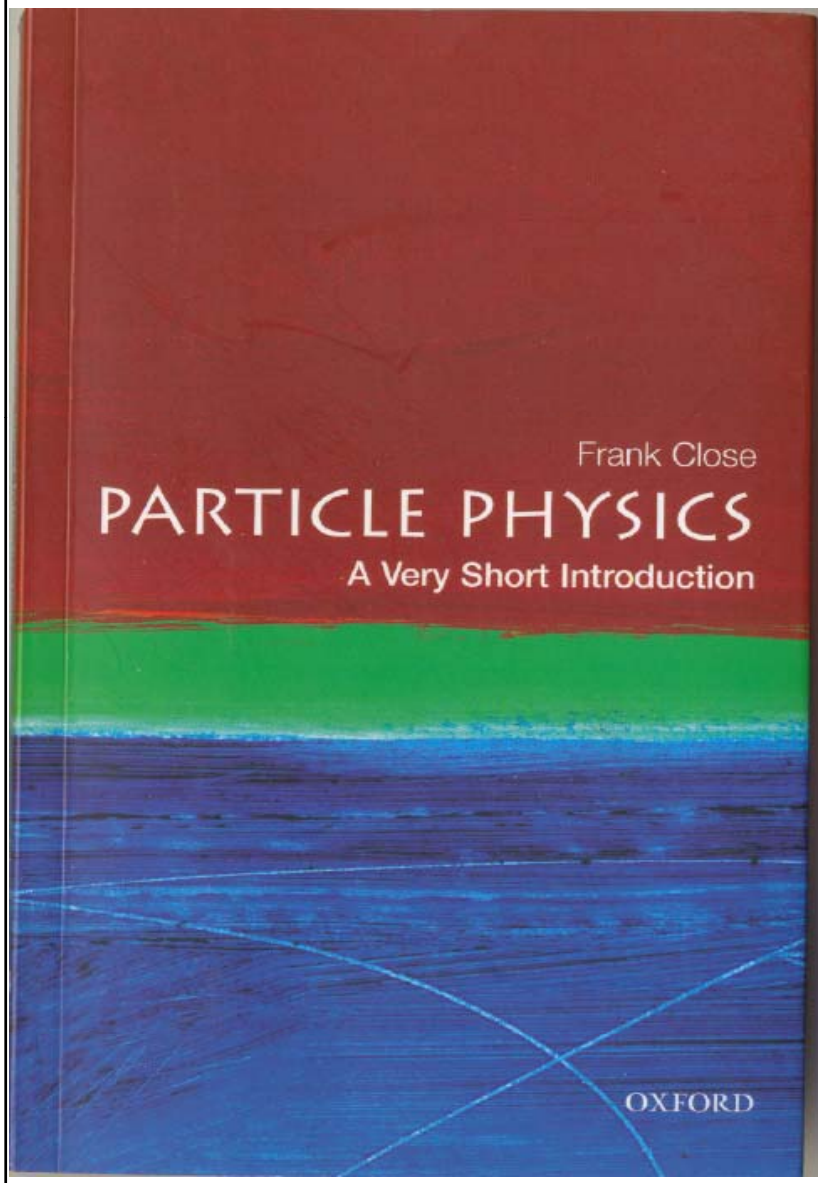
**(=** high energy **> 1TeV)**

**Higgs Boson**

**Supersymmetry**

**Nature of Reality**

## A Very Short Introduction

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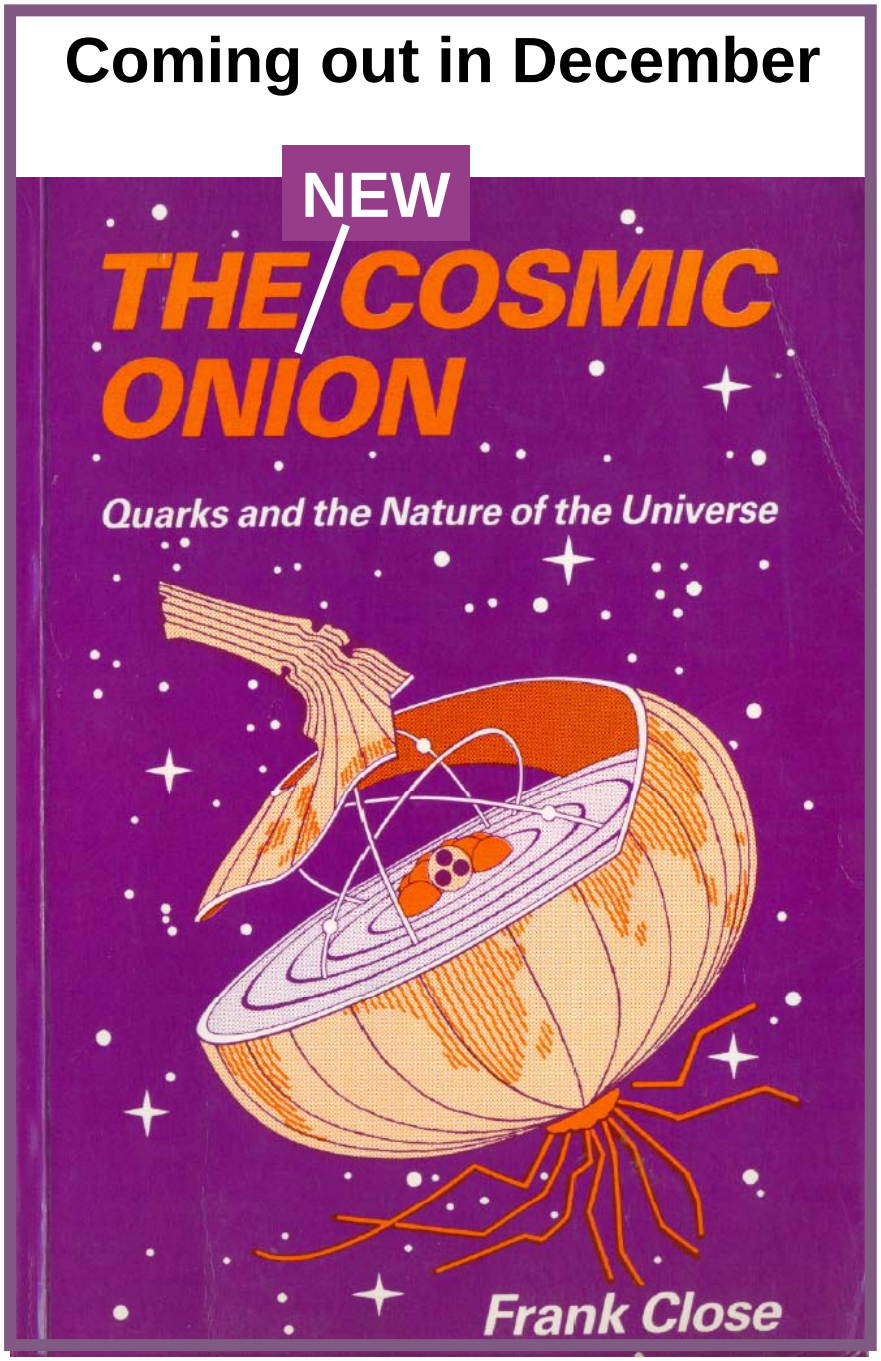

# …and patterns (that change)

QG Plasma

Quarks Gluons

neutrons protons γ

Nuclei melt
↓exist

Nucleus X

ep Plasma

H melt: plasma
↓exist

Atoms

U.V.

Molecules

I.R.

ice melt
↓exist

TeV

GeV

MeV

keV

eV

meV

No mass. Unified Theory

Standard Model MASS

| | | | | |
|---|---|---|---|---|
| t | b | τ | ν | W |
| c | s | μ | ν | Z |
| u | d | e | ν | $\gamma_g$ |

Nuclear Isotopes

Mendeleev

Snowflake pattern

No mass. Unified Theory

Standard Model MASS

| | | | | |
|---|---|---|---|---|
| t | b | τ | ν | W |
| c | s | μ | ν | Z |
| u | d | e | ν | $\gamma_g$ |

Nuclear Isotopes

Mendeleev

Snowflake pattern


even earlier univ.

LHC

LEP


early univ. $< 10^{-9}$ sec

$10^{16}$K

·100 sec.

$10^{7}$K

$10^{4}$K

300 Kyrs

300K

$10^{10}$ yrs

3K