Introduction to Particle Physics

(for non physics students)

PROFESSOR FRANK CLOSE
EXETER COLLEGE
UNIVERSITY OF OXFORD

How Old is the Universe?

20.00 Creation Big Bang

world cup 1st half;2nd half; sleep

05.00 SUN → EARTH 06.00

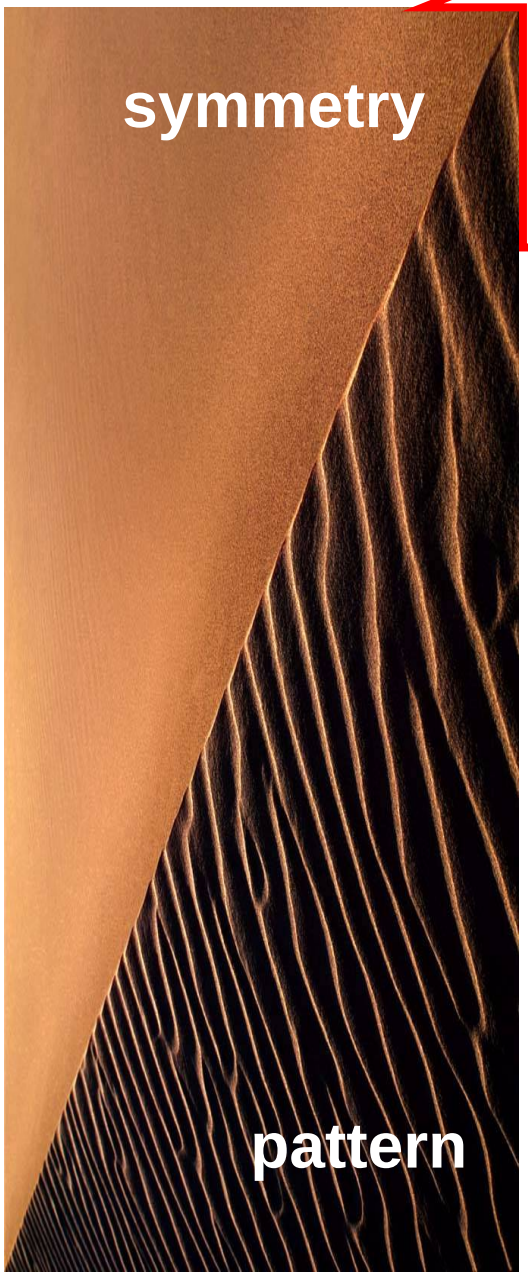
breakfast; come to lectures

09.30 Oldest Fossils

09.59;30" rst Humanoids

09.59 - The Millenium

10.00 NOW



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

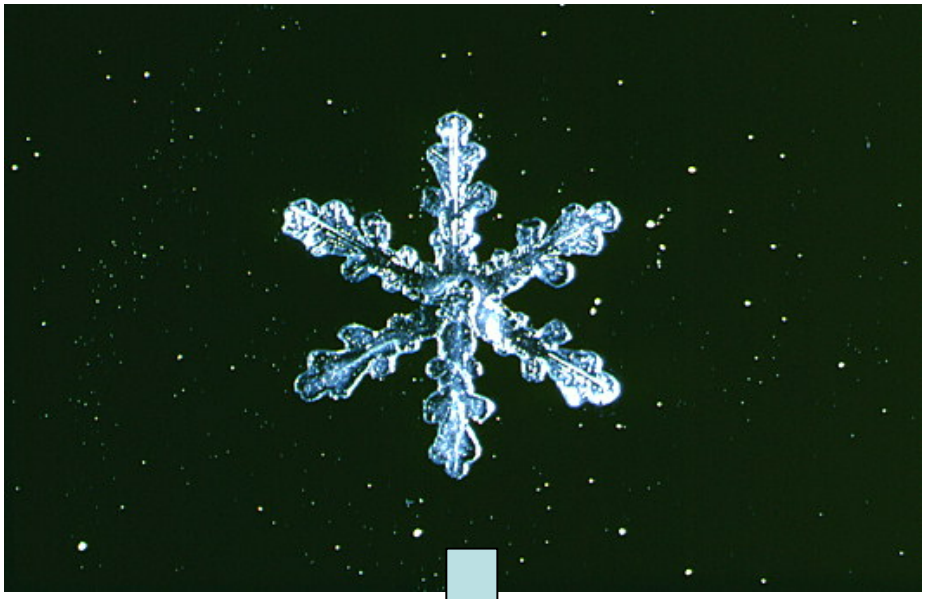
300 K yrs.

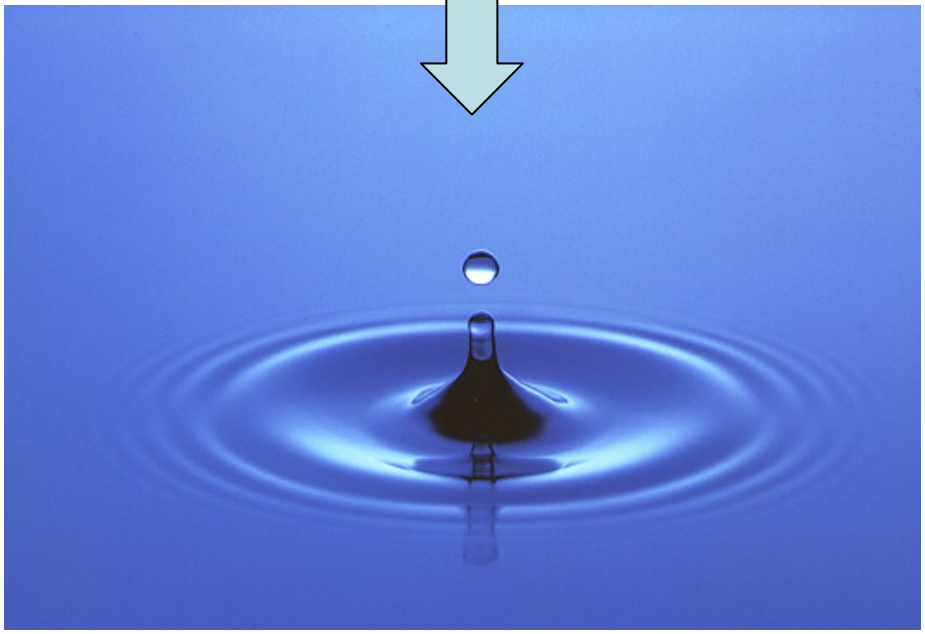
300K

meV

3K

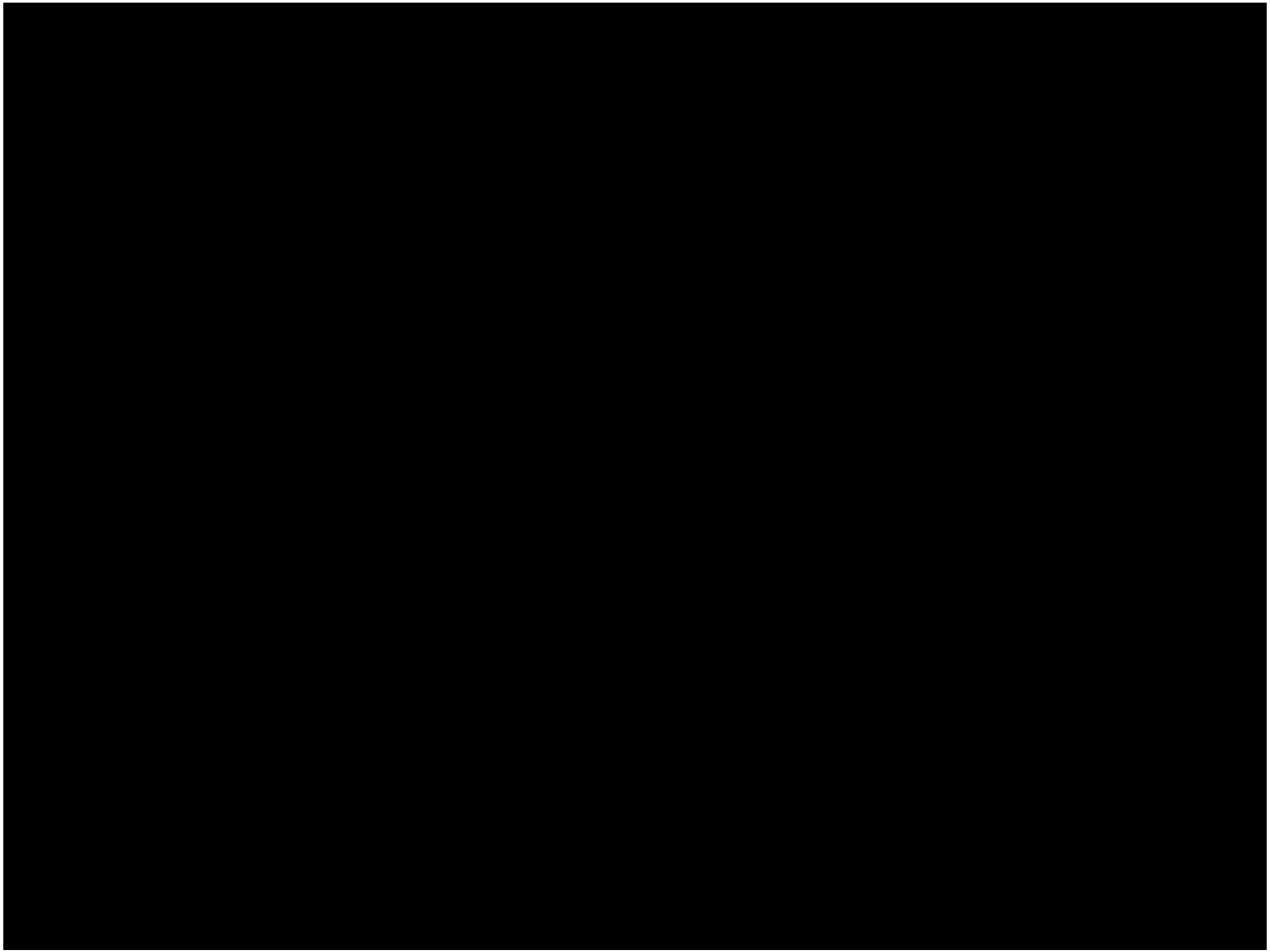
10^{10} yrs

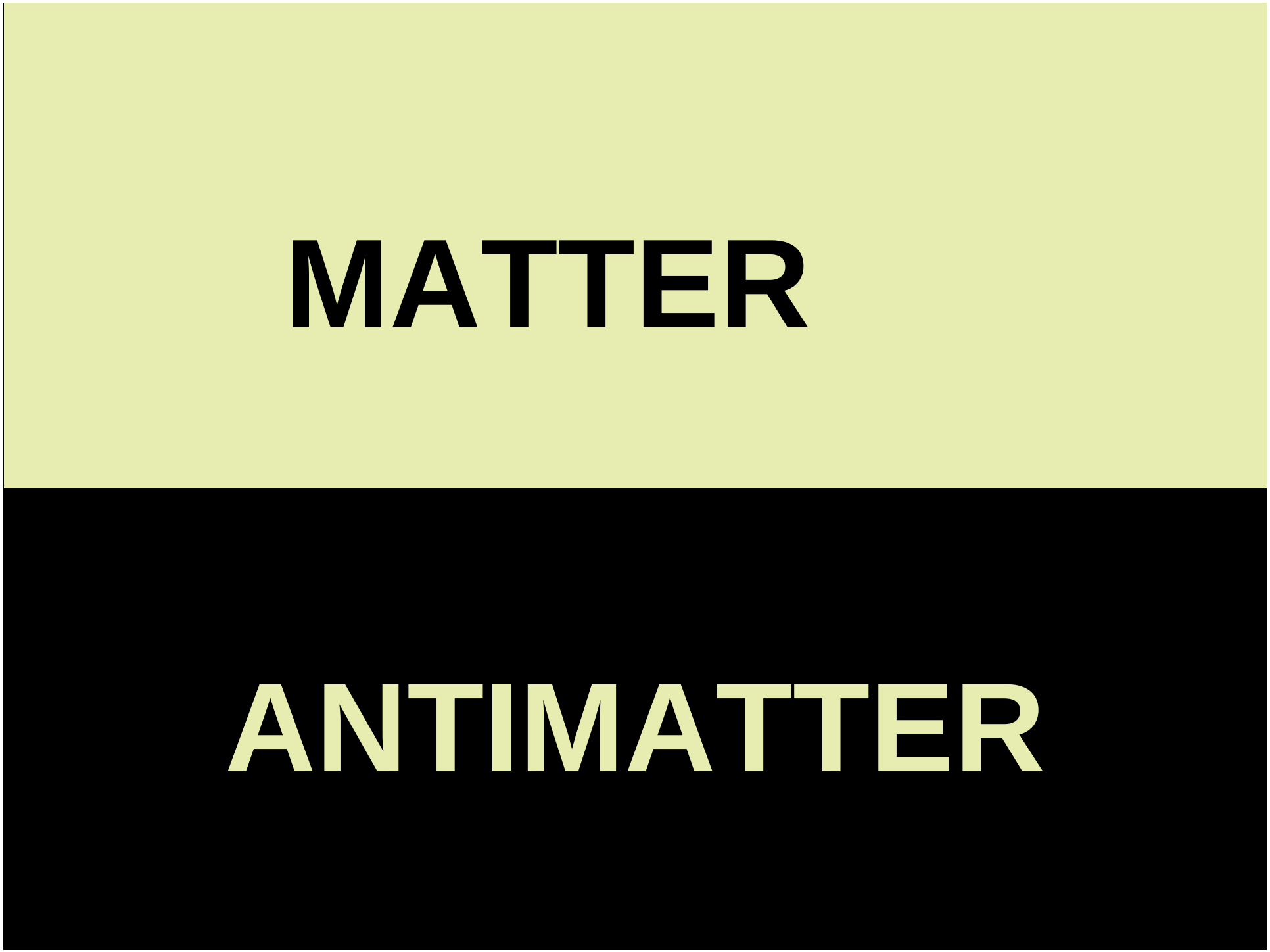




patterns and structures when cold (low energy)

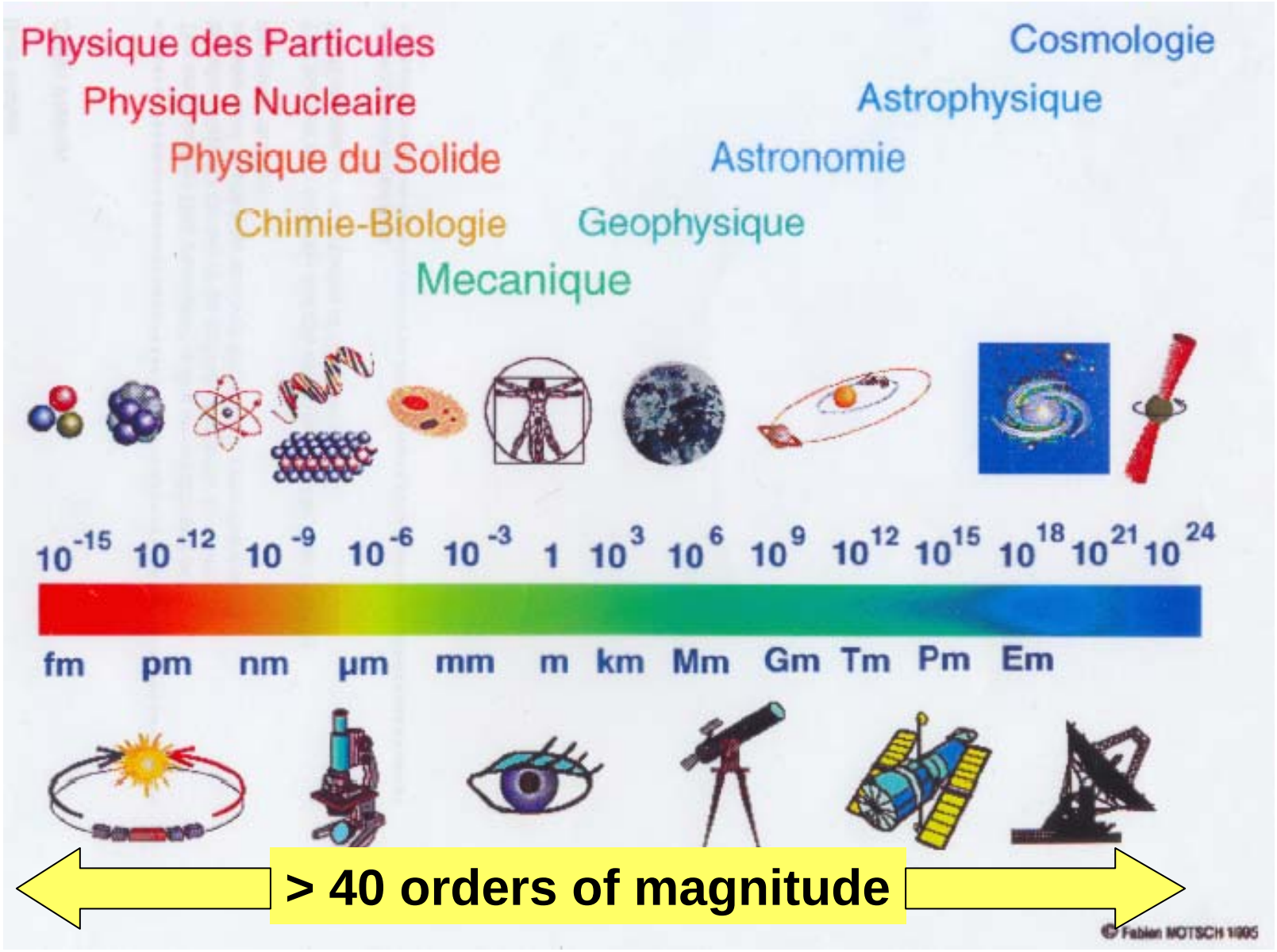
Symmetry when warm (high energy)



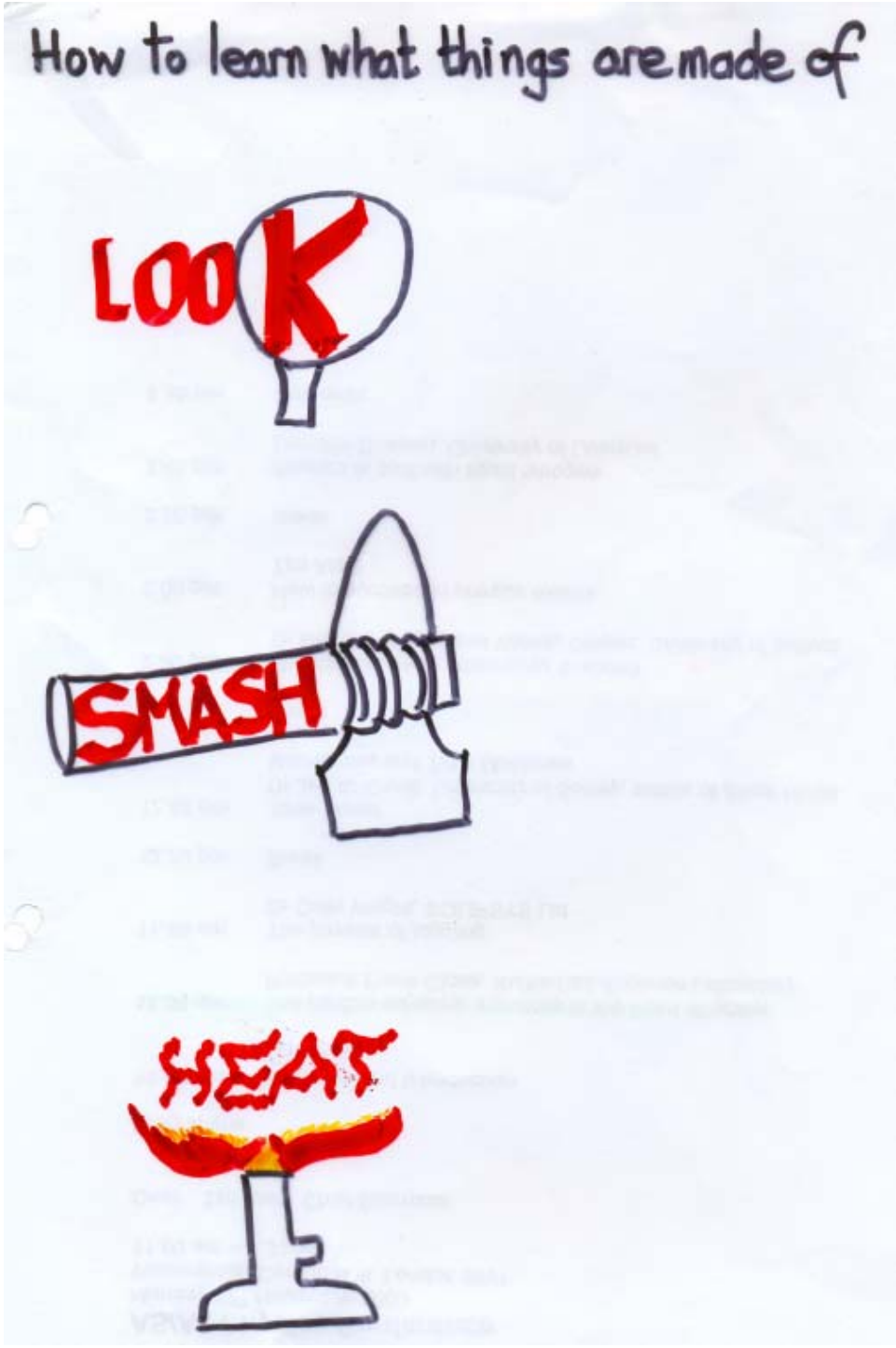

MATTER
ANTIMATTER

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

Matter and the Universe



What is matter made of ?

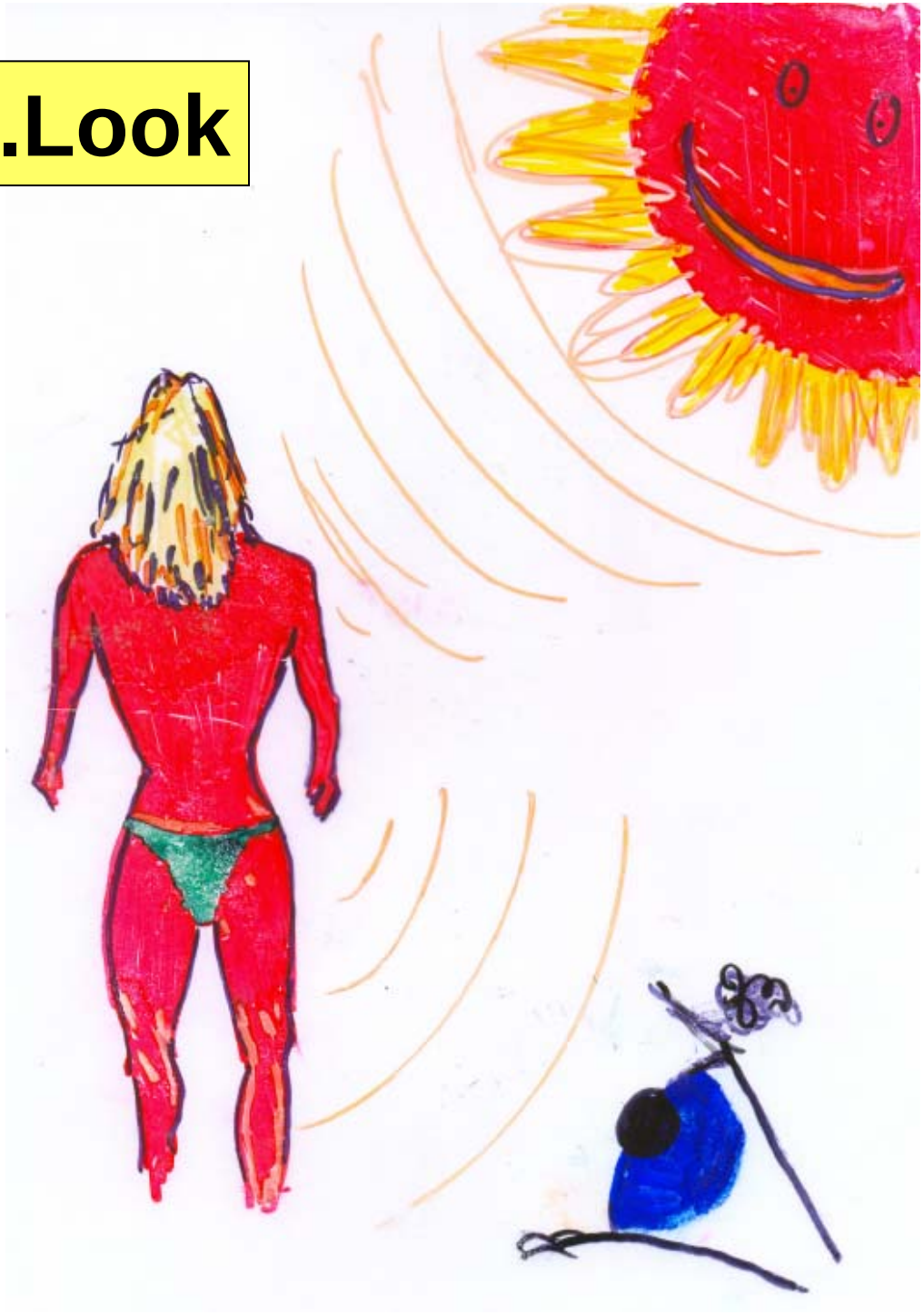


1.Look

Light source

Object

Eye



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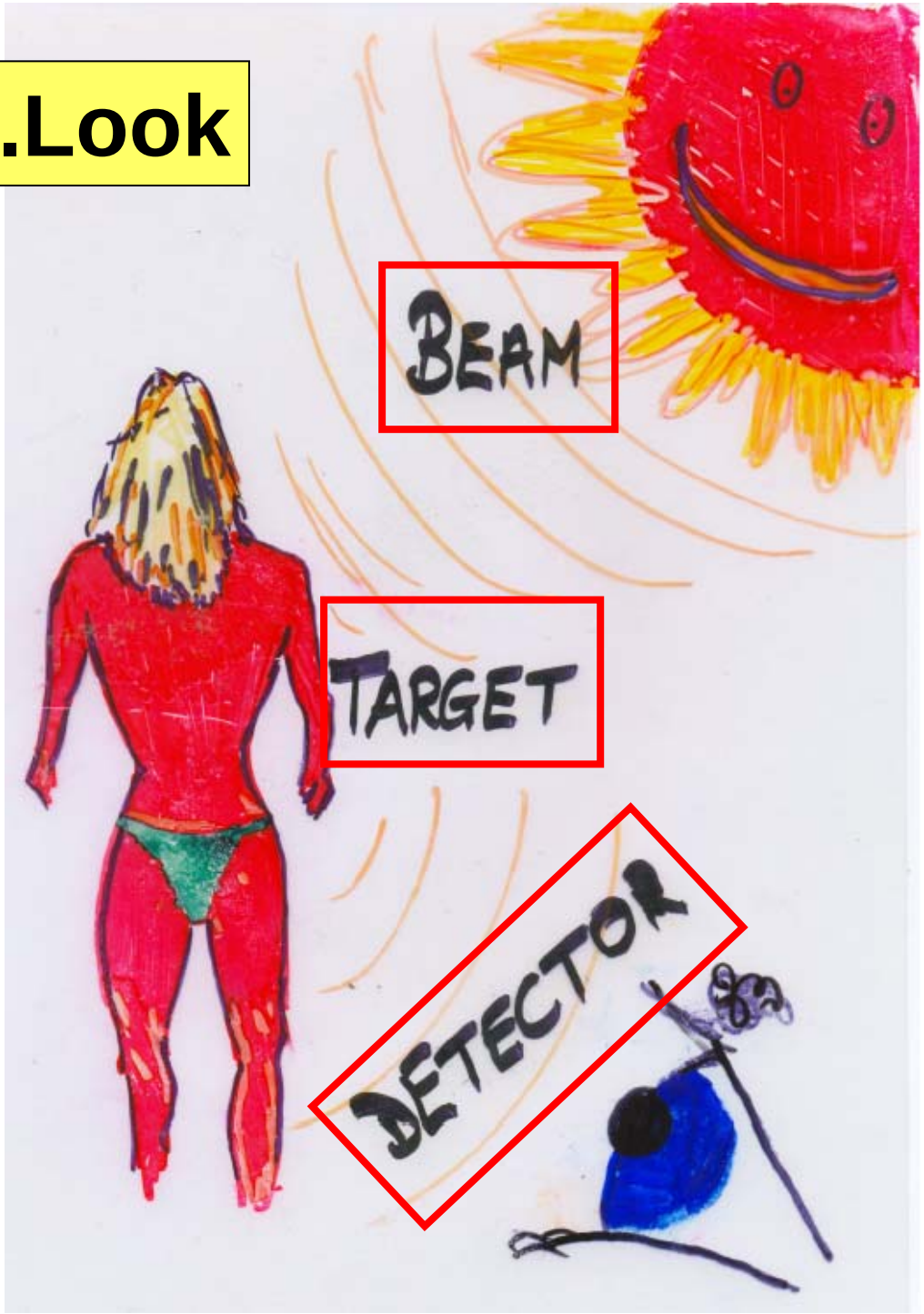
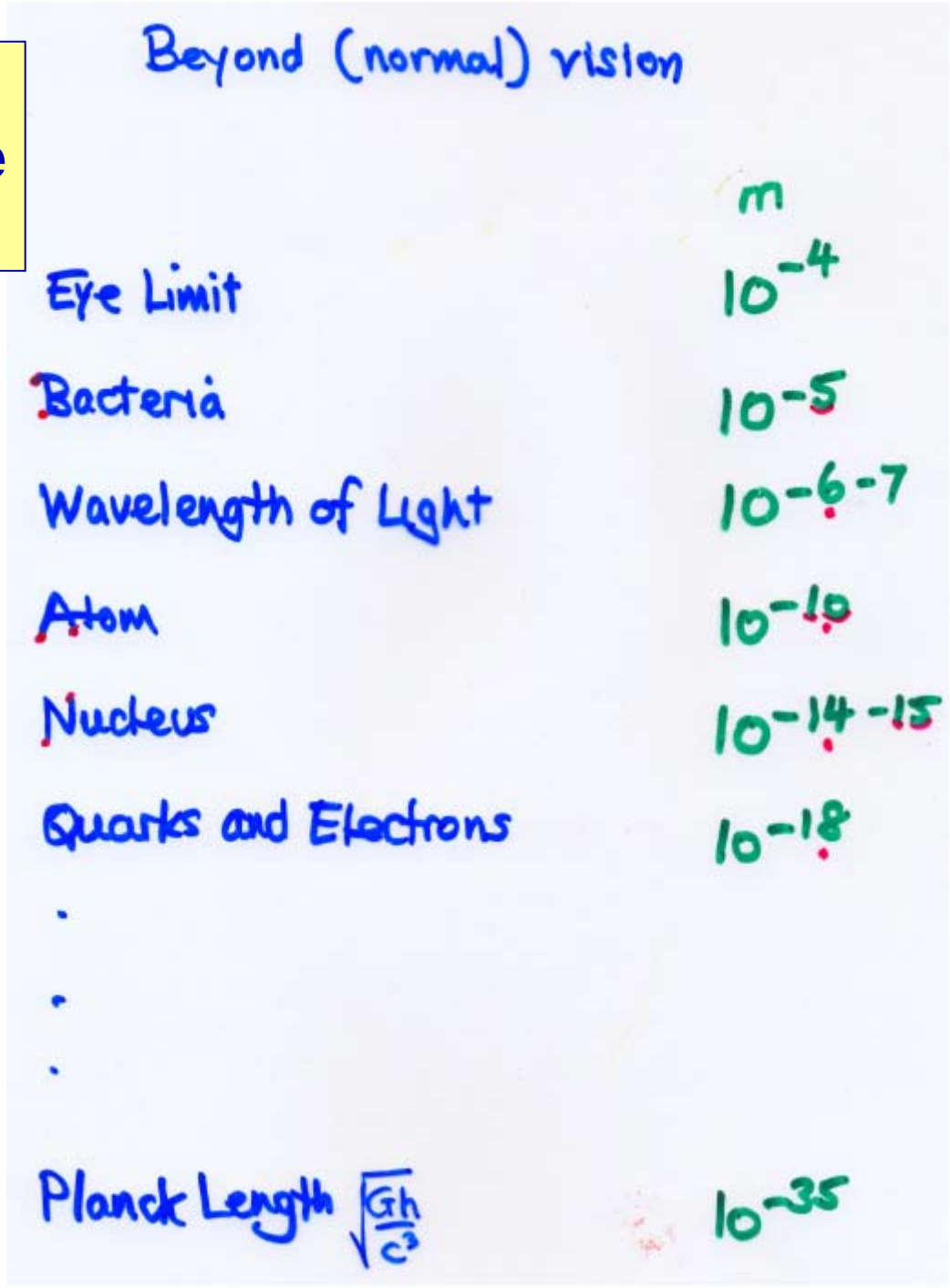
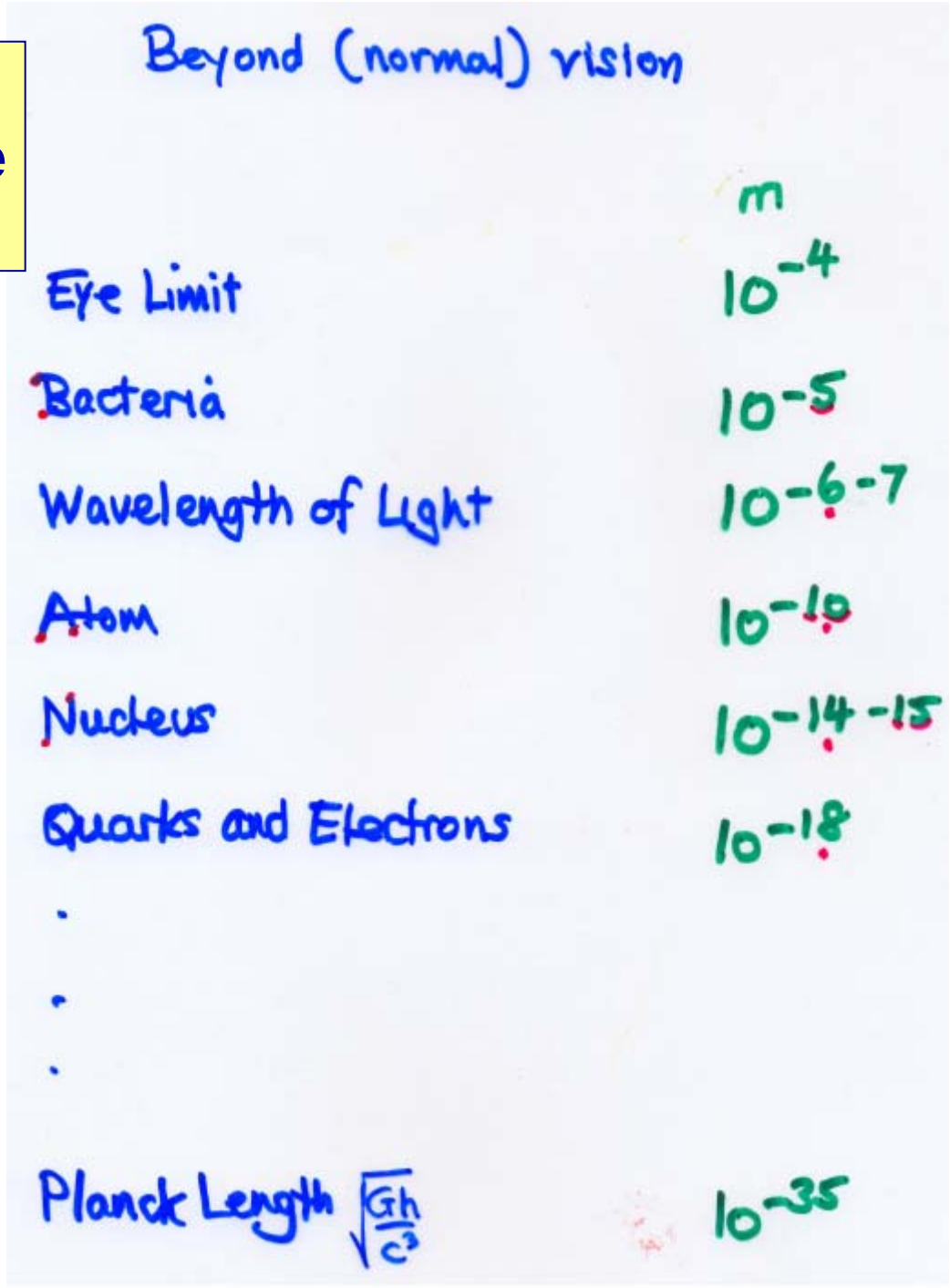


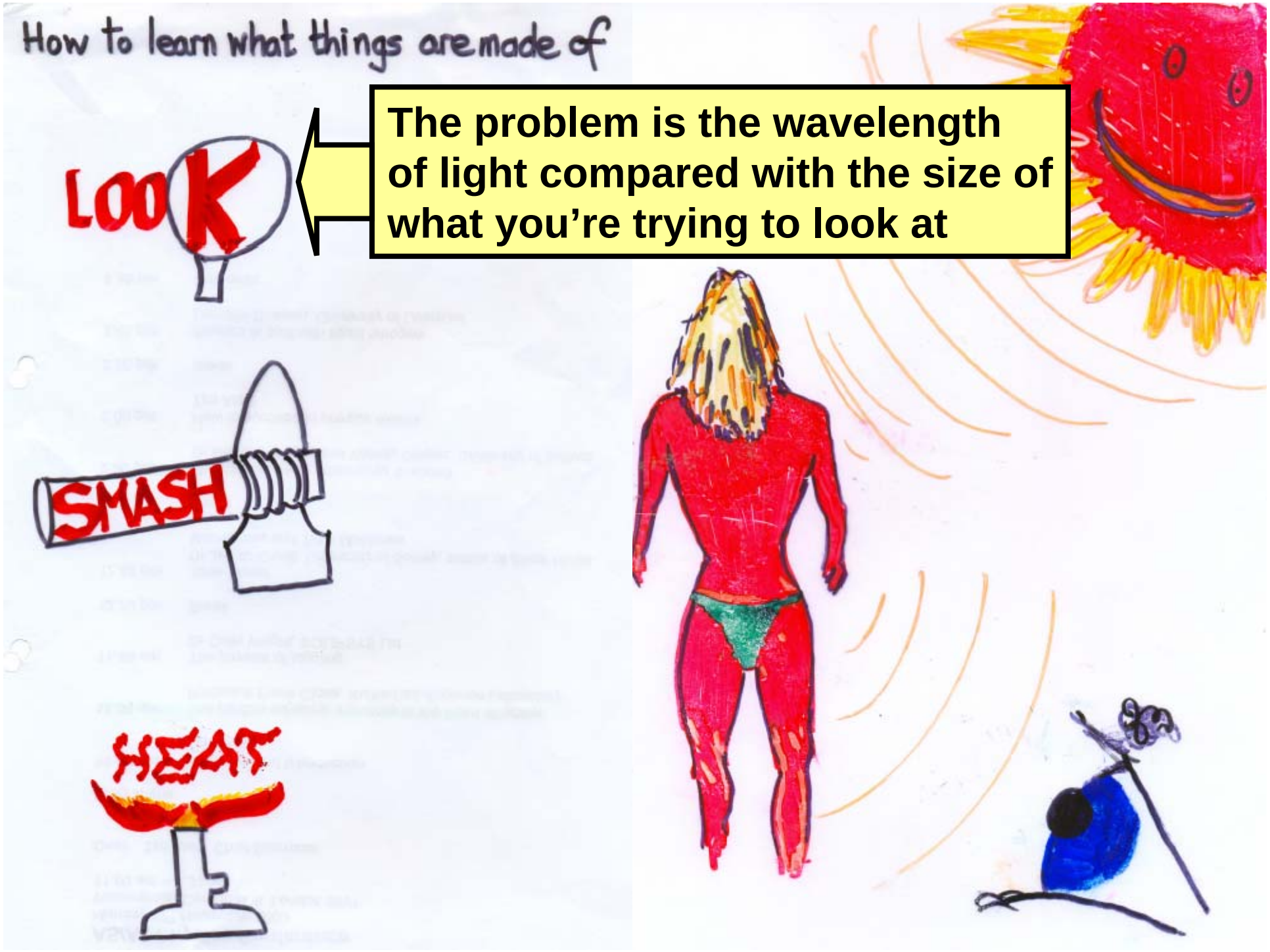
Catch 22:
There's a limit to what we can see with our eye



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



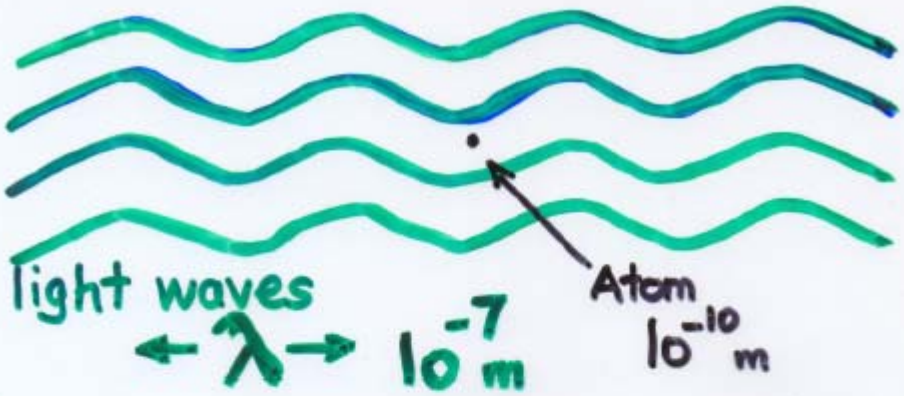

How to learn what things are made of
LOOK
SMASH
HEAT
The problem is the wavelength of light compared with the size of what you're trying to look at

How to learn what things are made of

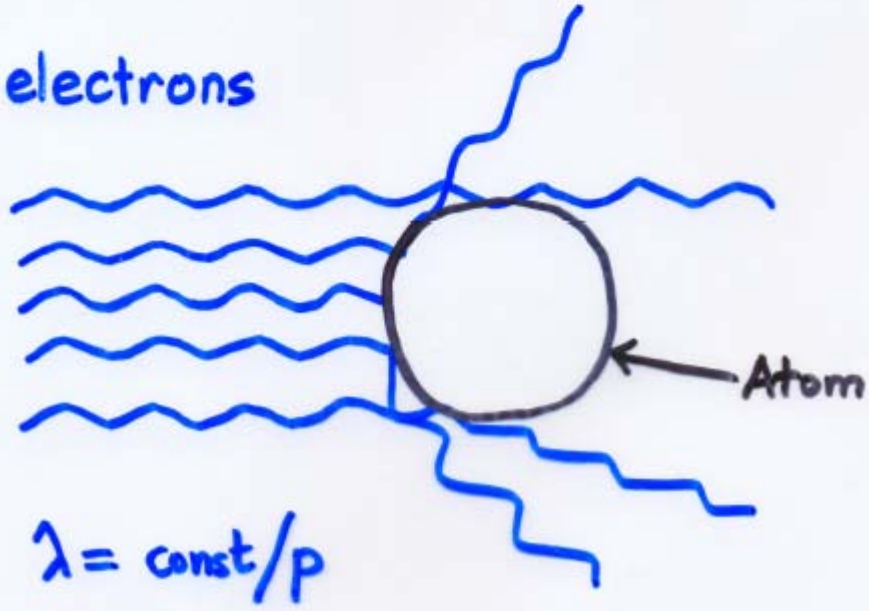
resolution

waveλength

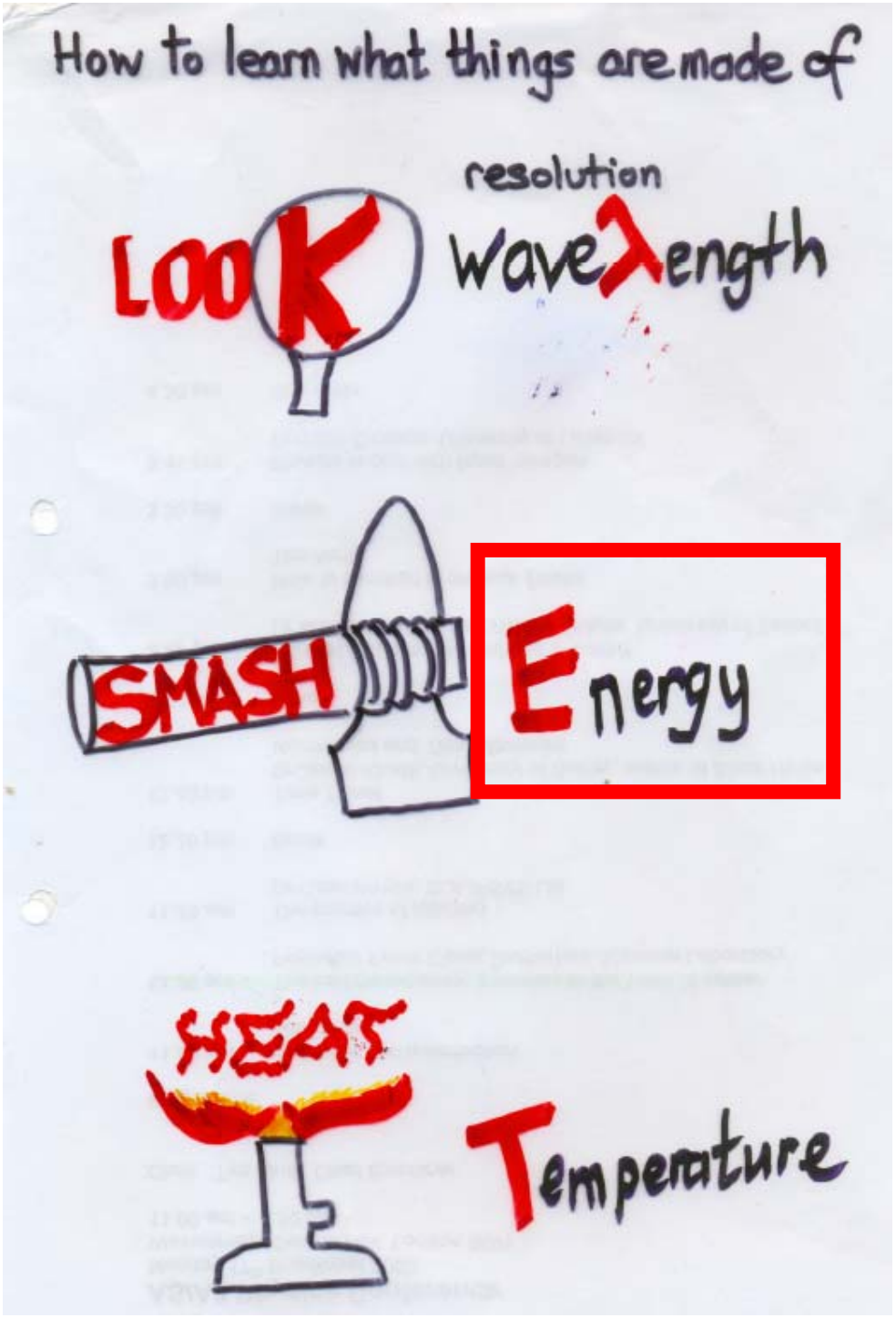
How to see small things



Electron microscope



2. Smash


How to learn what things are made of
resolution
LOOK
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**

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Practical Units

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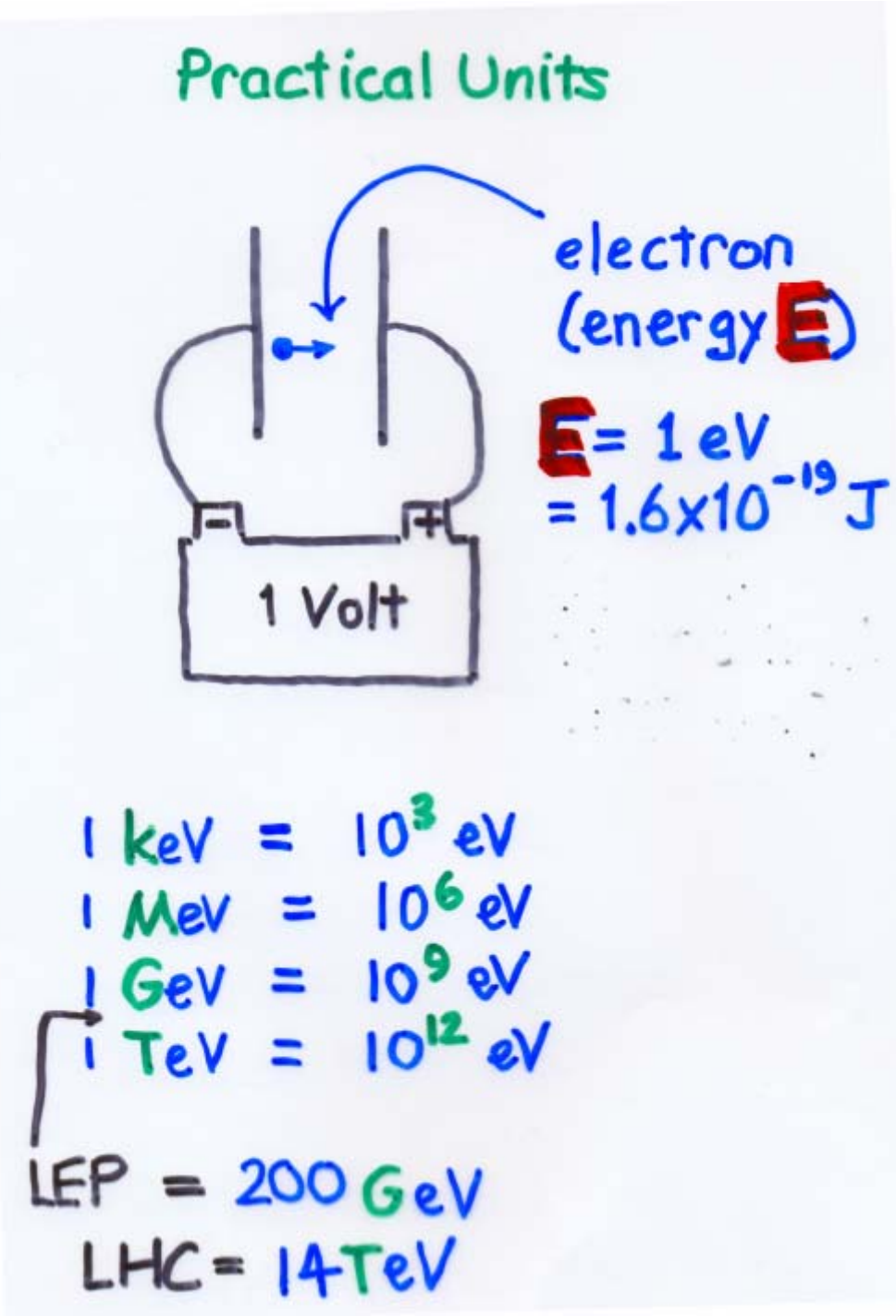


Einstein

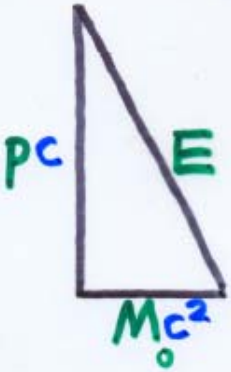
Energy

and

$$E=mc^2$$

Einstein: $E = Mc^2$

Special Relativity



$$E^2 = (pc)^2 + (M_0c^2)^2$$

use units such that $c=1$

E (GeV or MeV)
P (GeV/c or MeV/c)
M (GeV/c^2 or MeV/c^2)

$M_{electron} = 0.5\ MeV/c^2$

$M_{proton} = 938\ MeV/c^2 \simeq 1\ GeV/c^2$

$M_{top} = 170\ GeV/c^2$

proton diameter = length scale:
10^{-15} m = 1 fermi (femtometer)

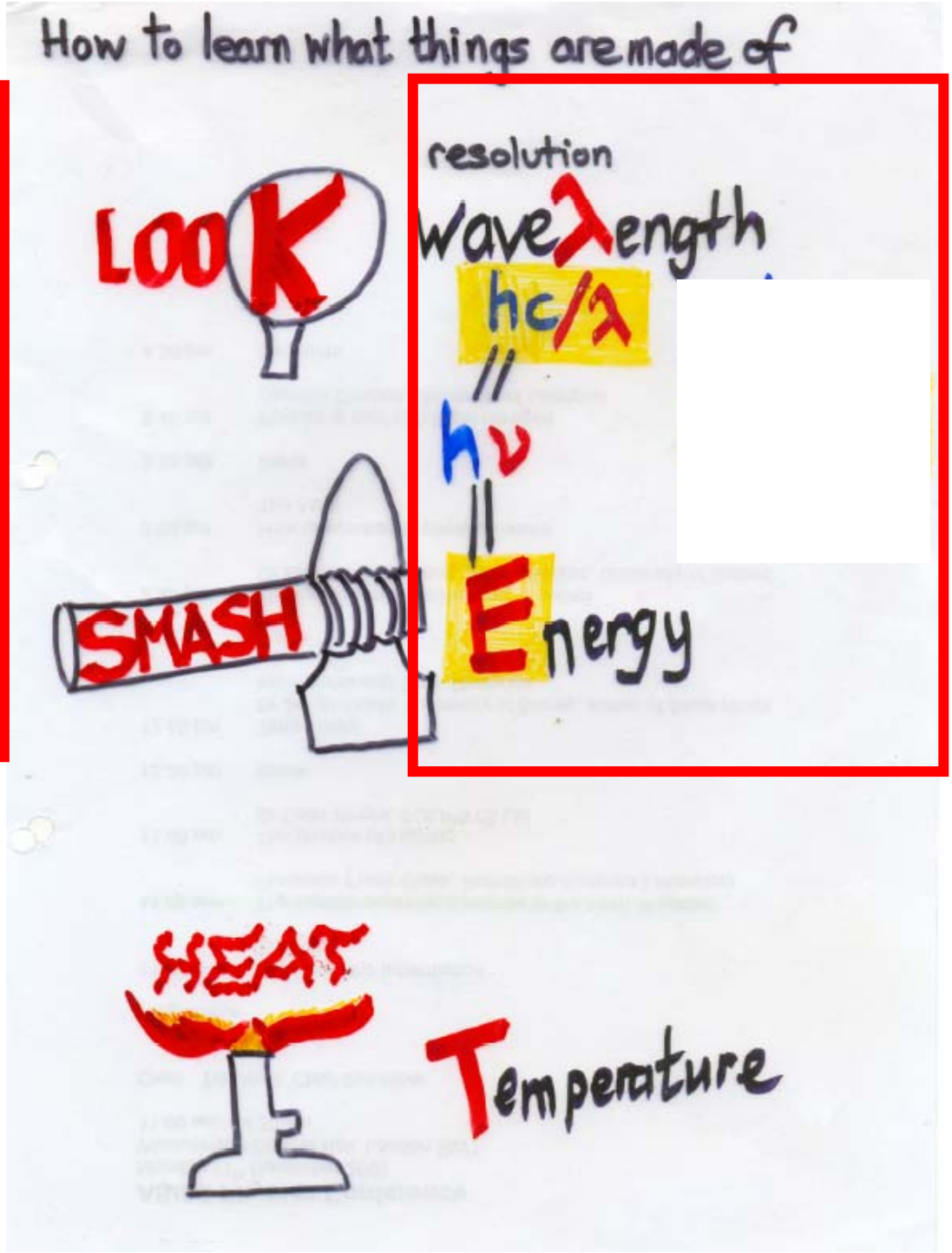
LOOK or SMASH

Wavelength

and

Energy

profoundly related



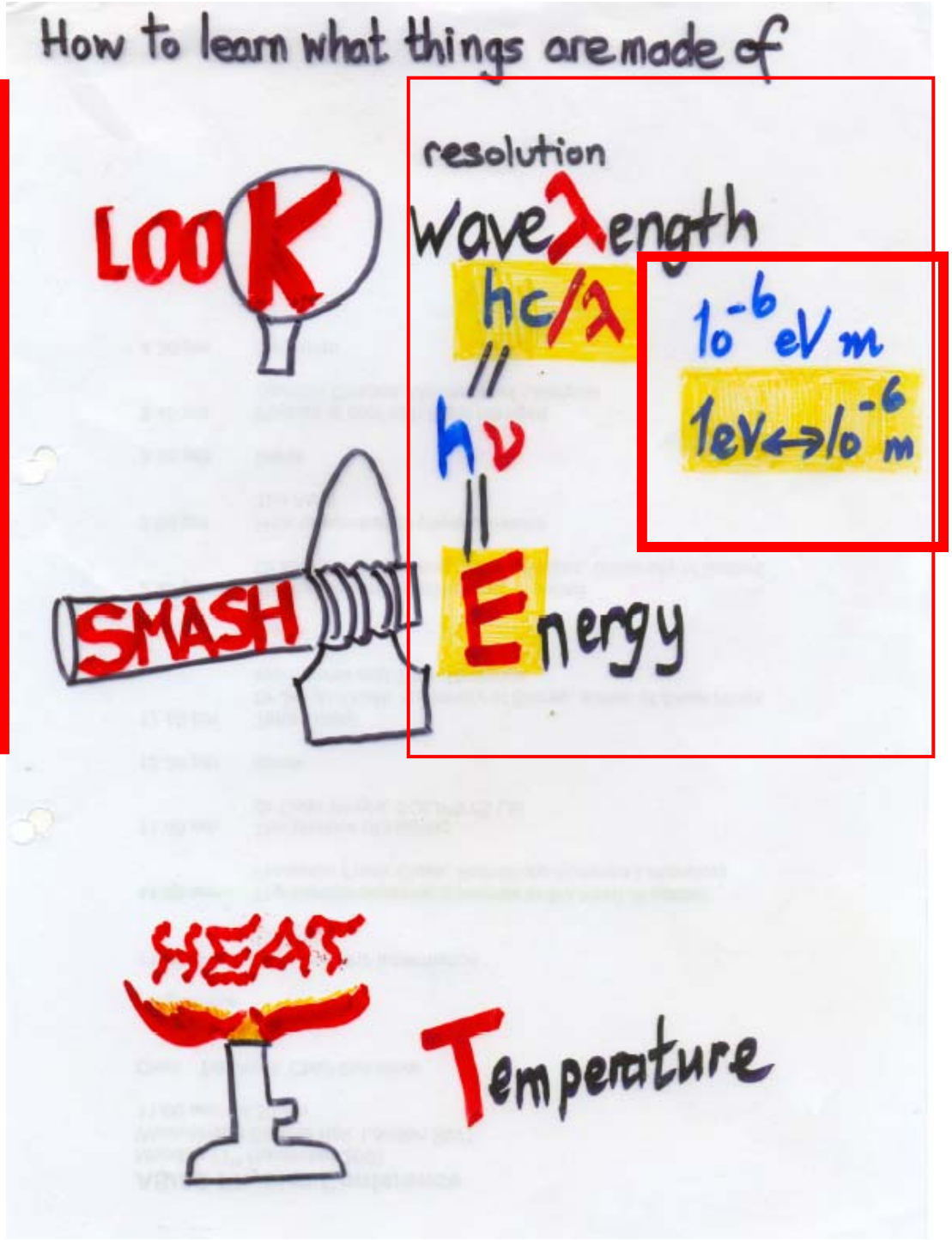
LOOK or SMASH

Wavelength

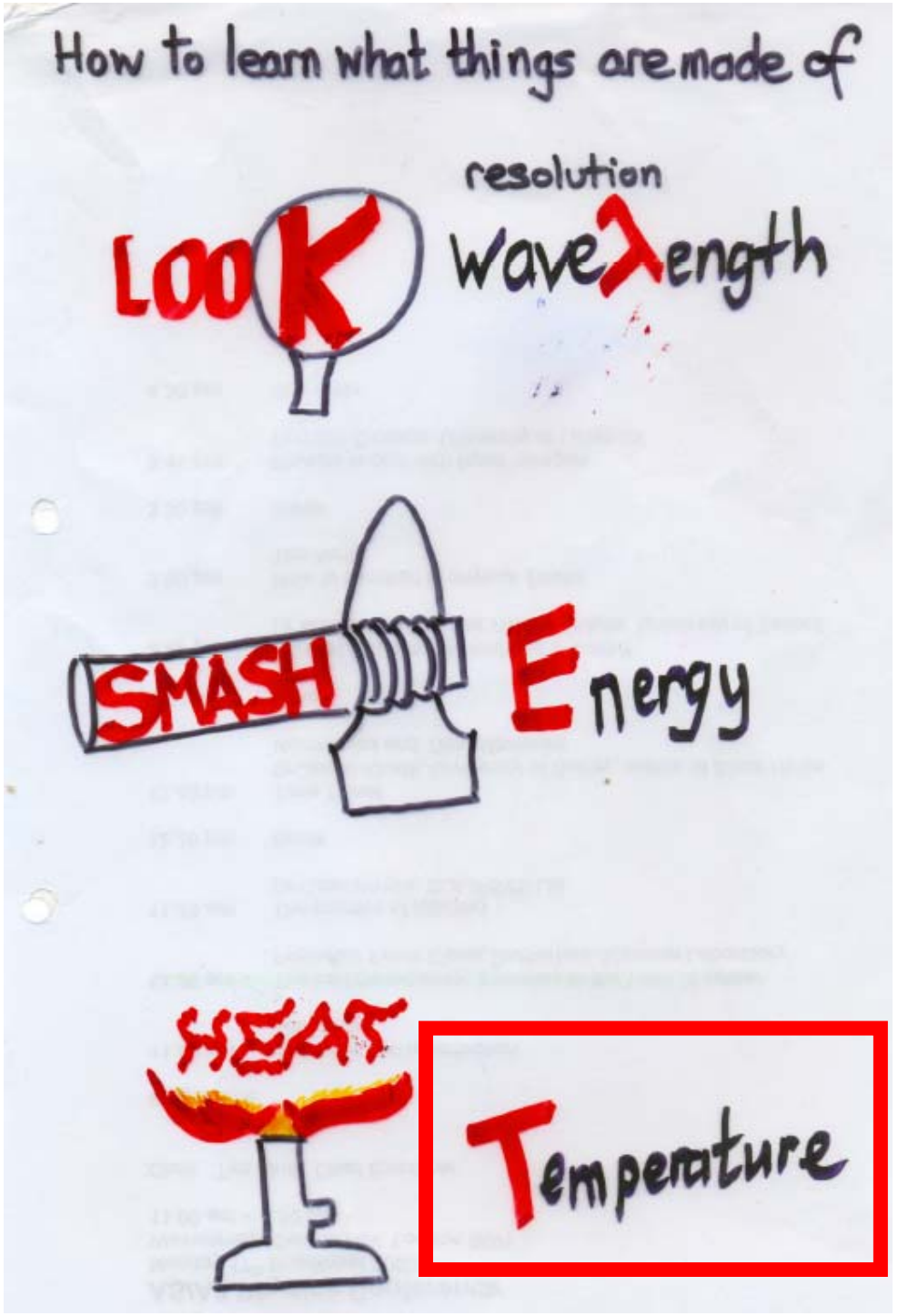
and

Energy

profoundly related



3. Heat



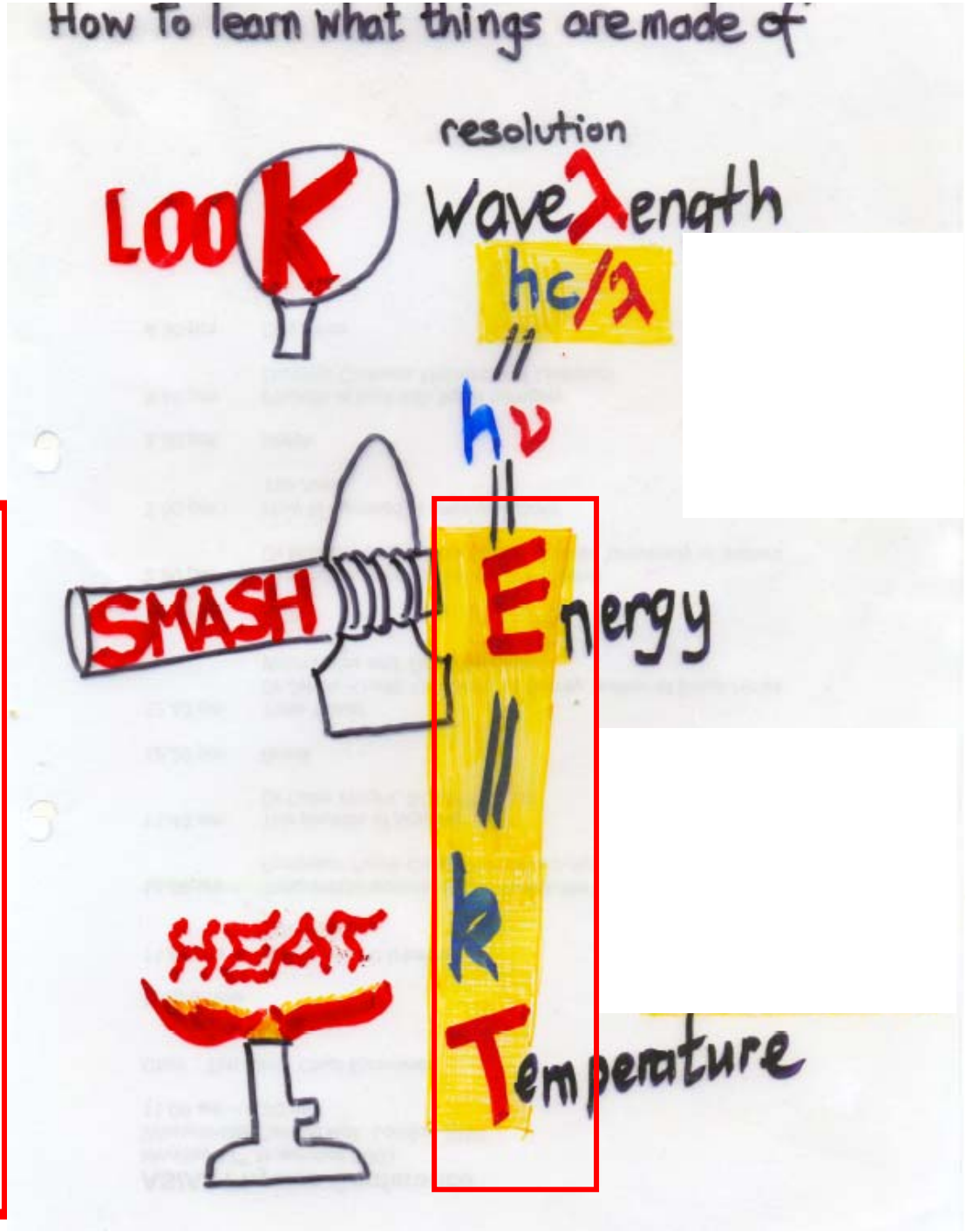
… also profoundly related……

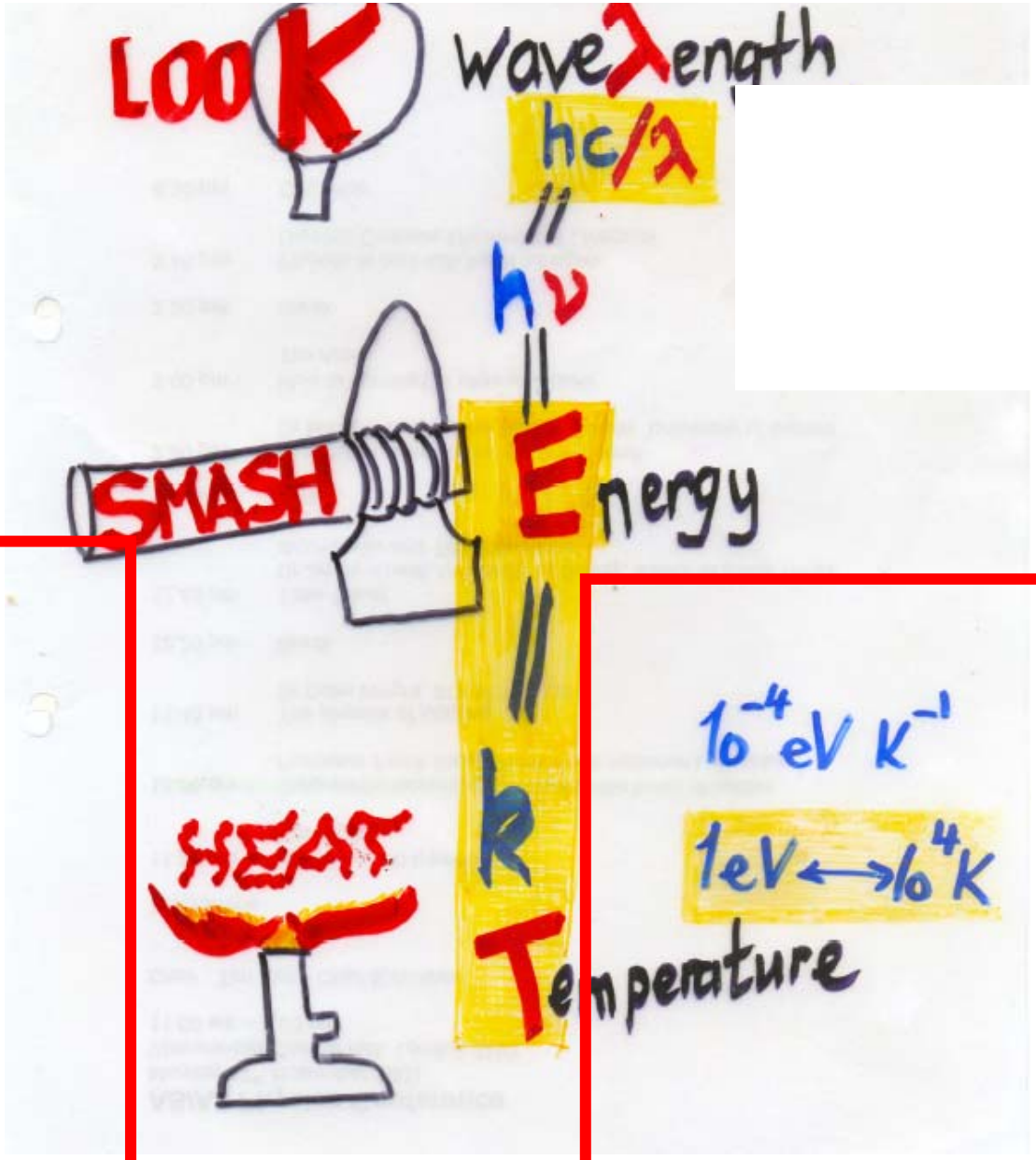
SMASH or HEAT

Energy

and

Temperature





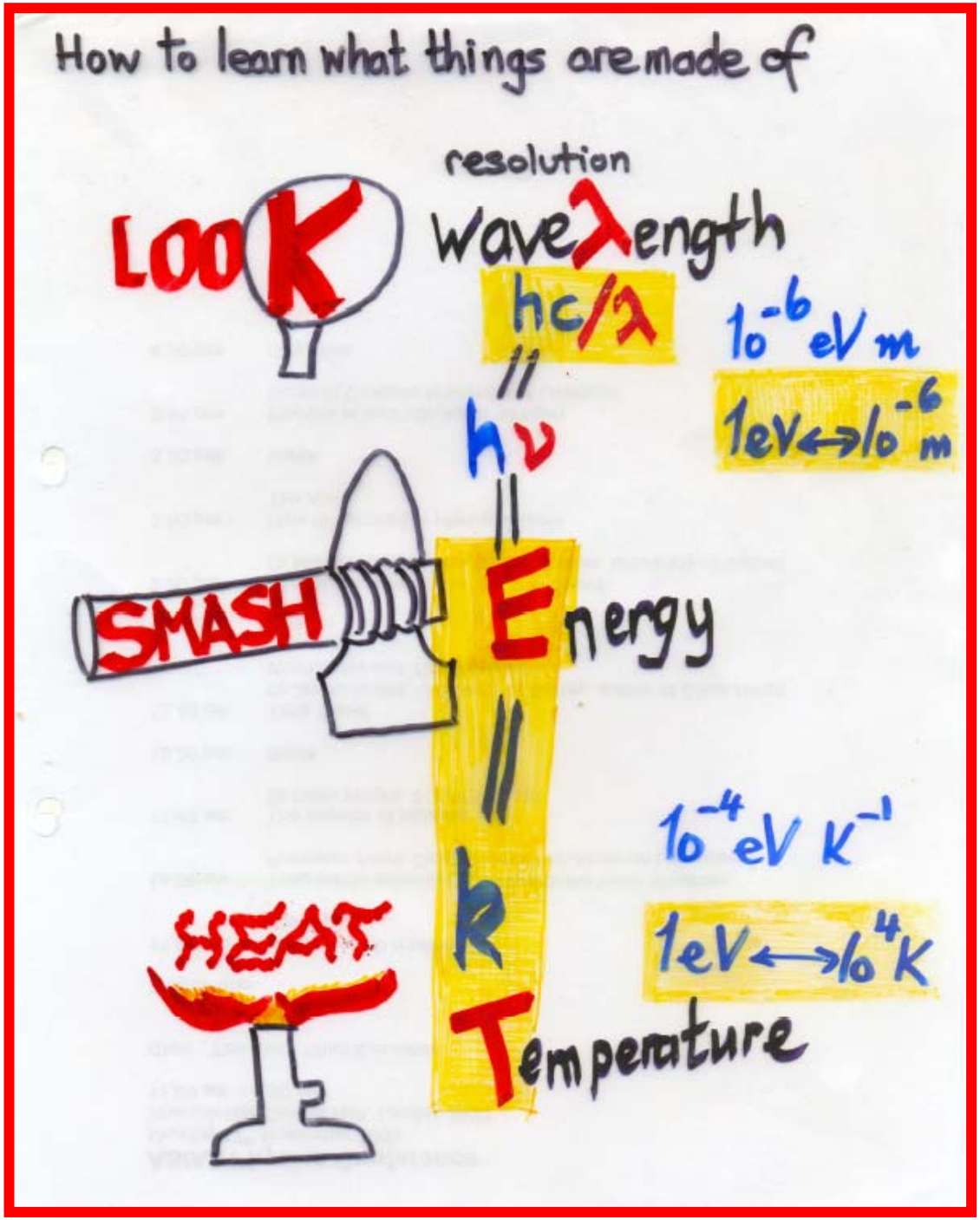
SMASH or HEAT

Energy

and

Temperature

How to learn what things are made of



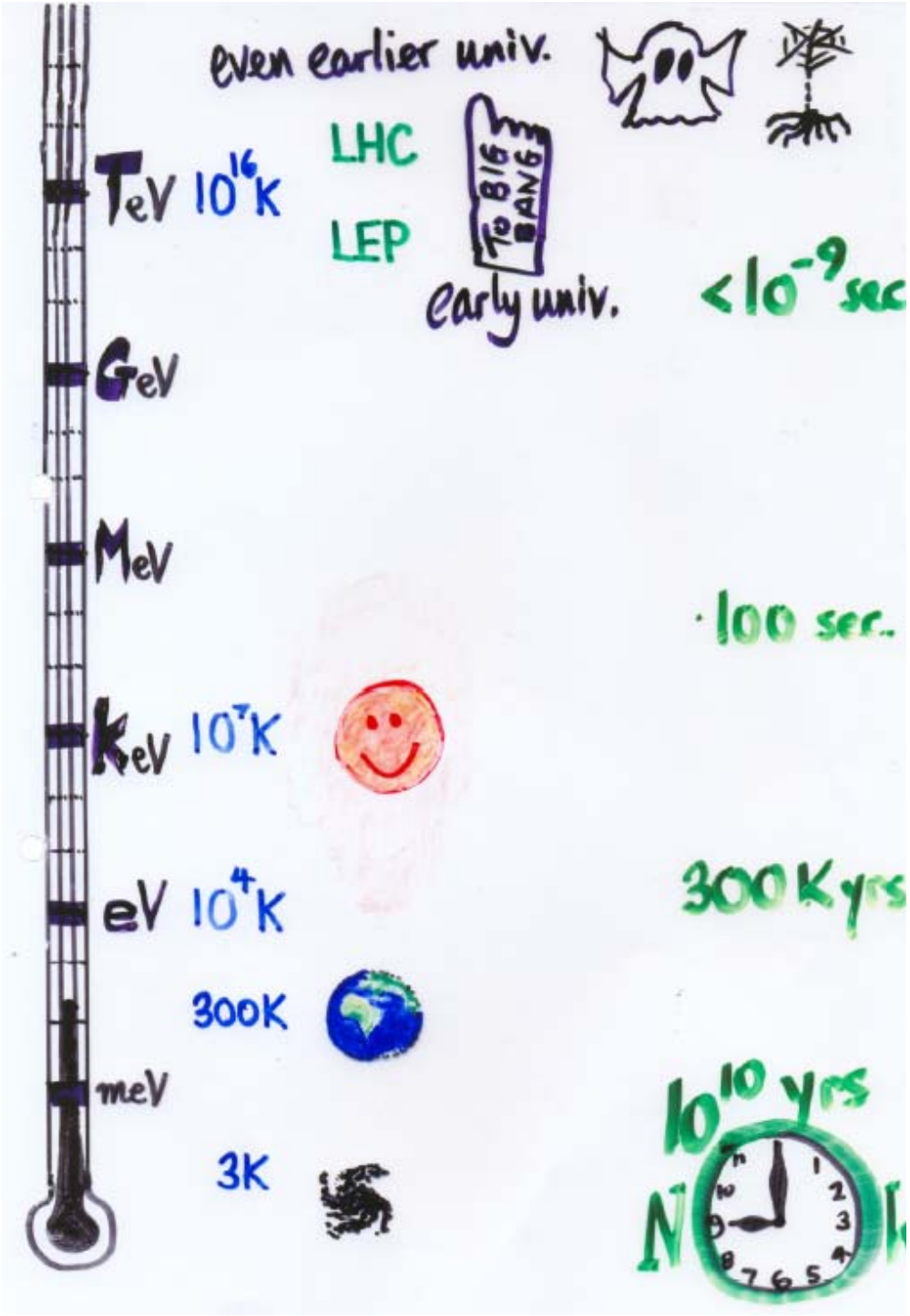
Beyond (normal) vision

	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}

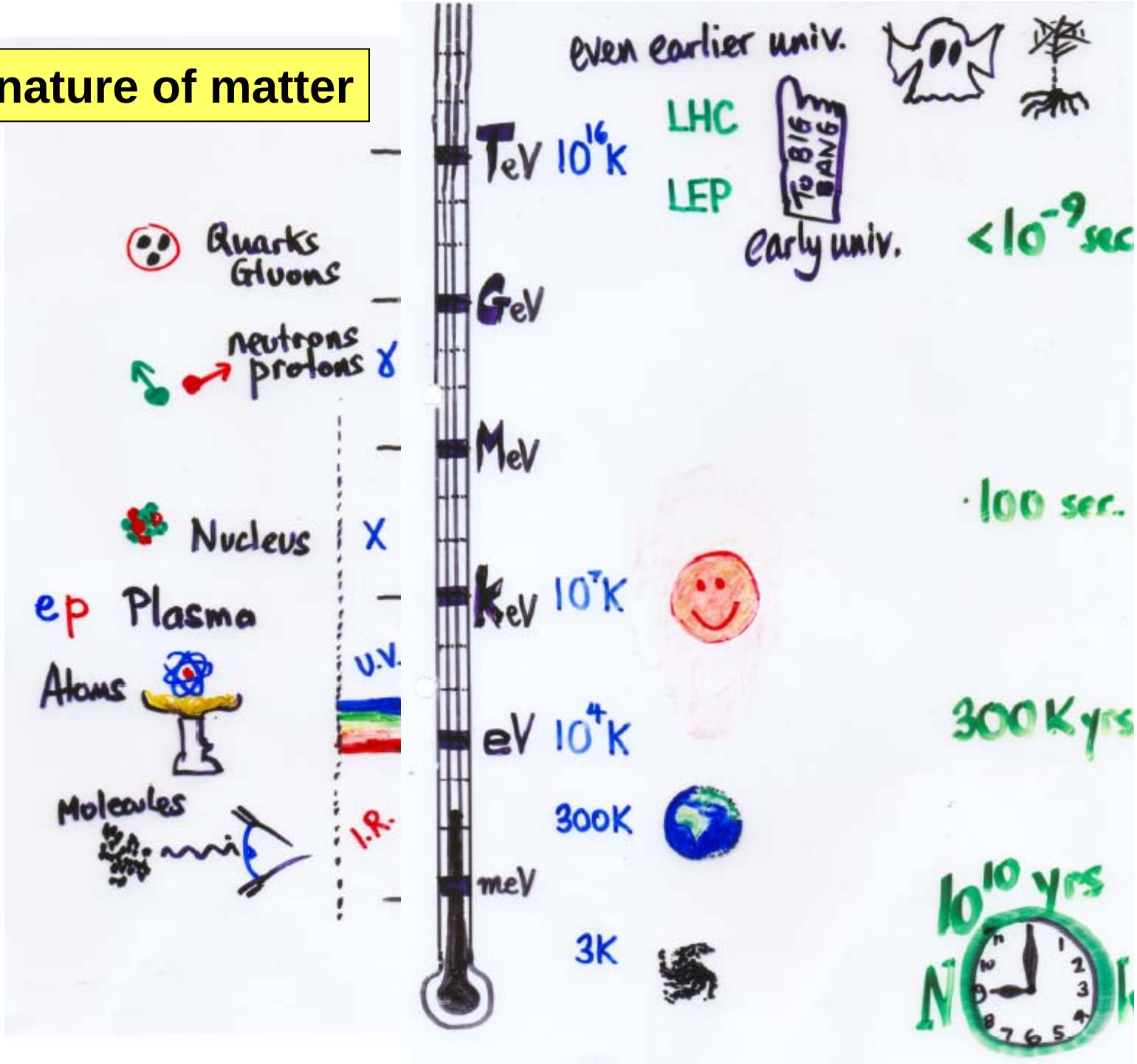
The Universe

in

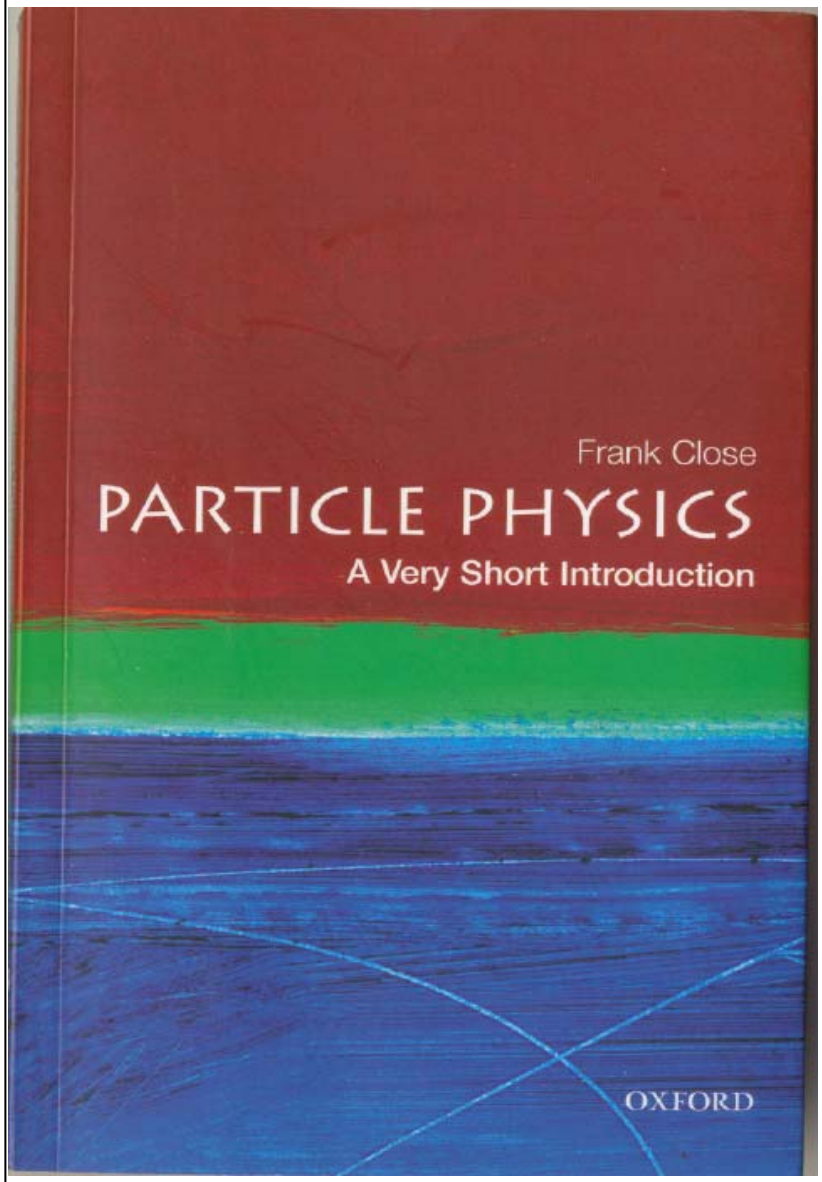
Temperature
Energy and
Time



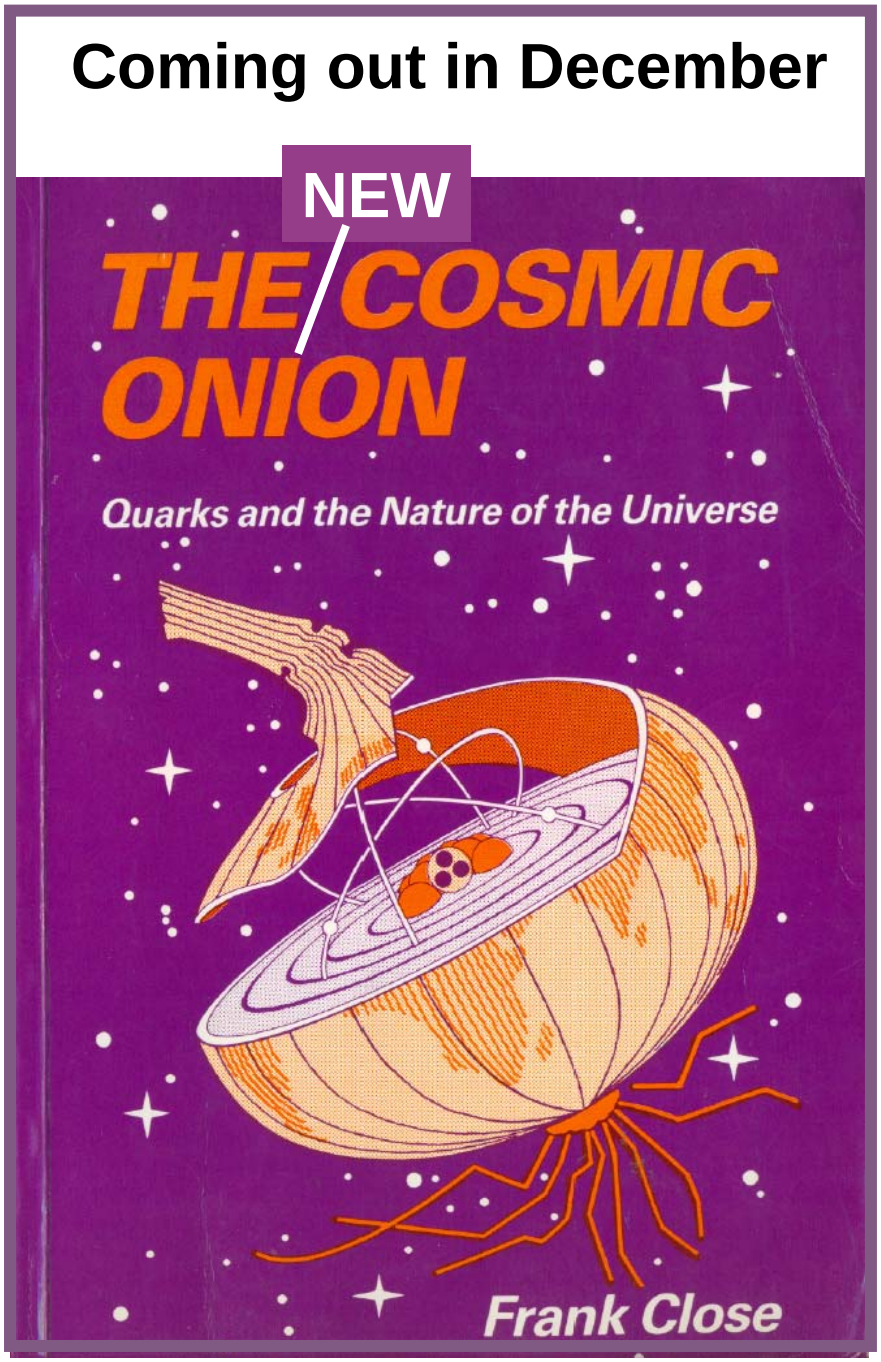
…and the nature of matter



A Very Short Introduction



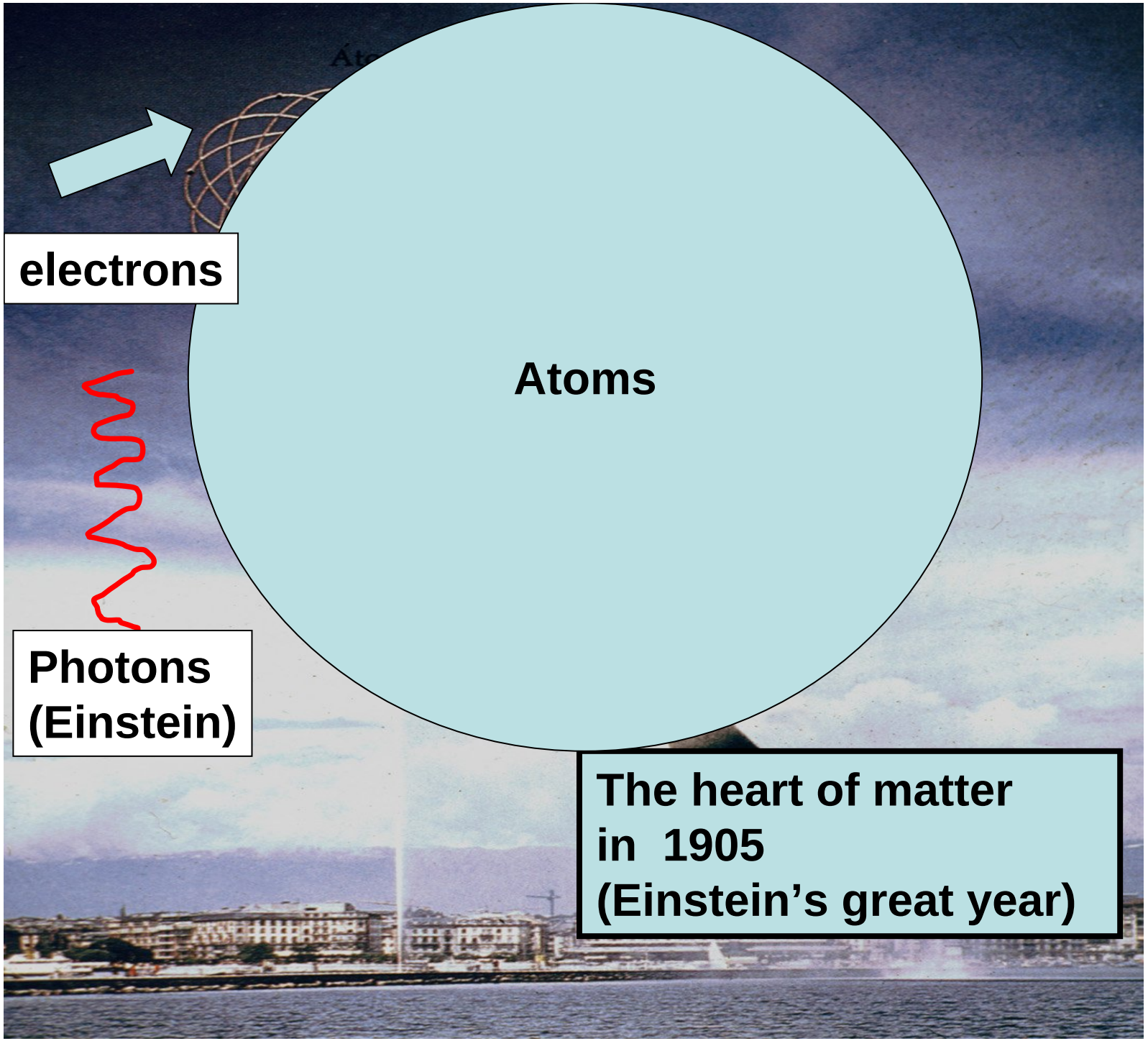
Coming out in December

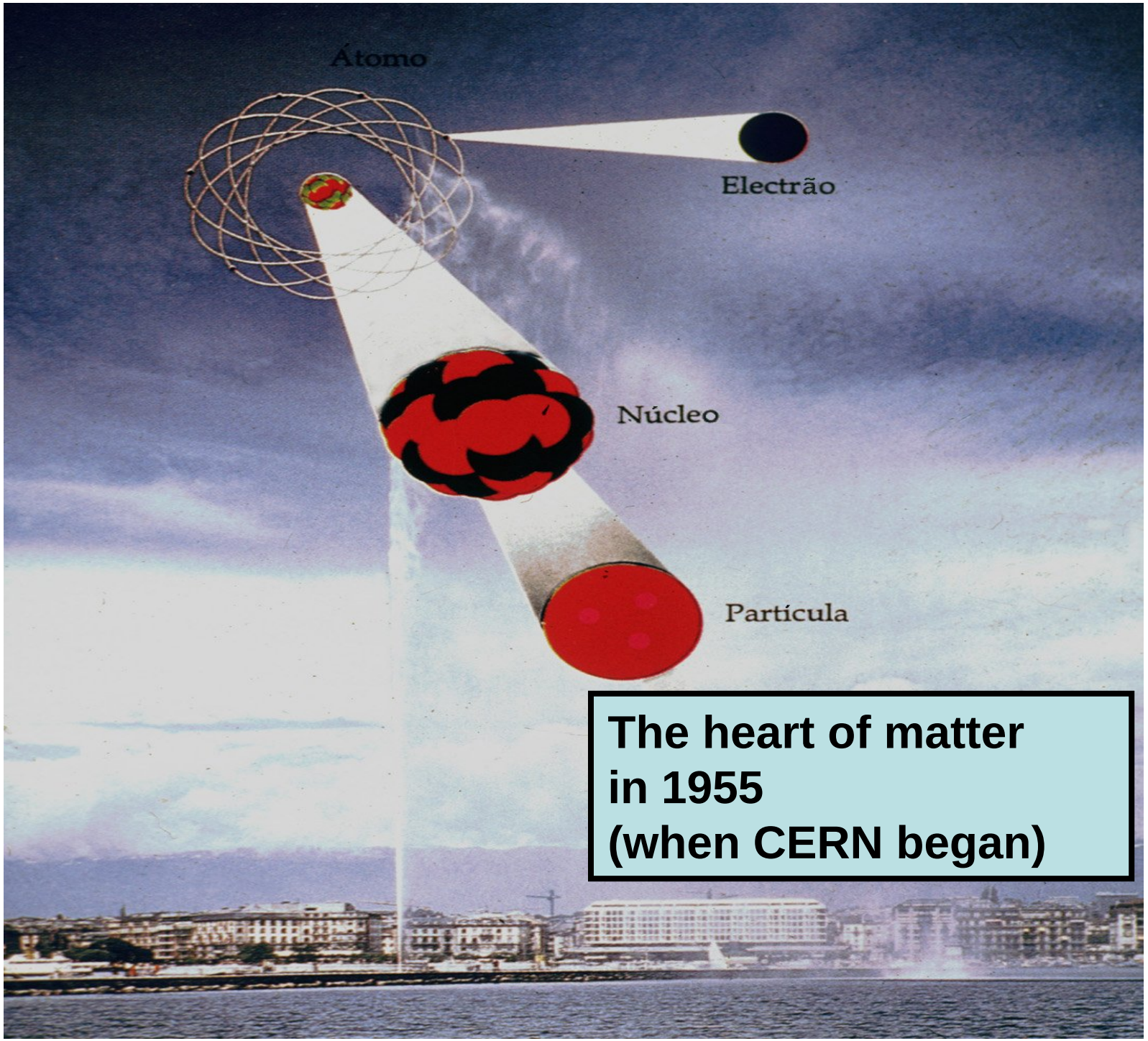


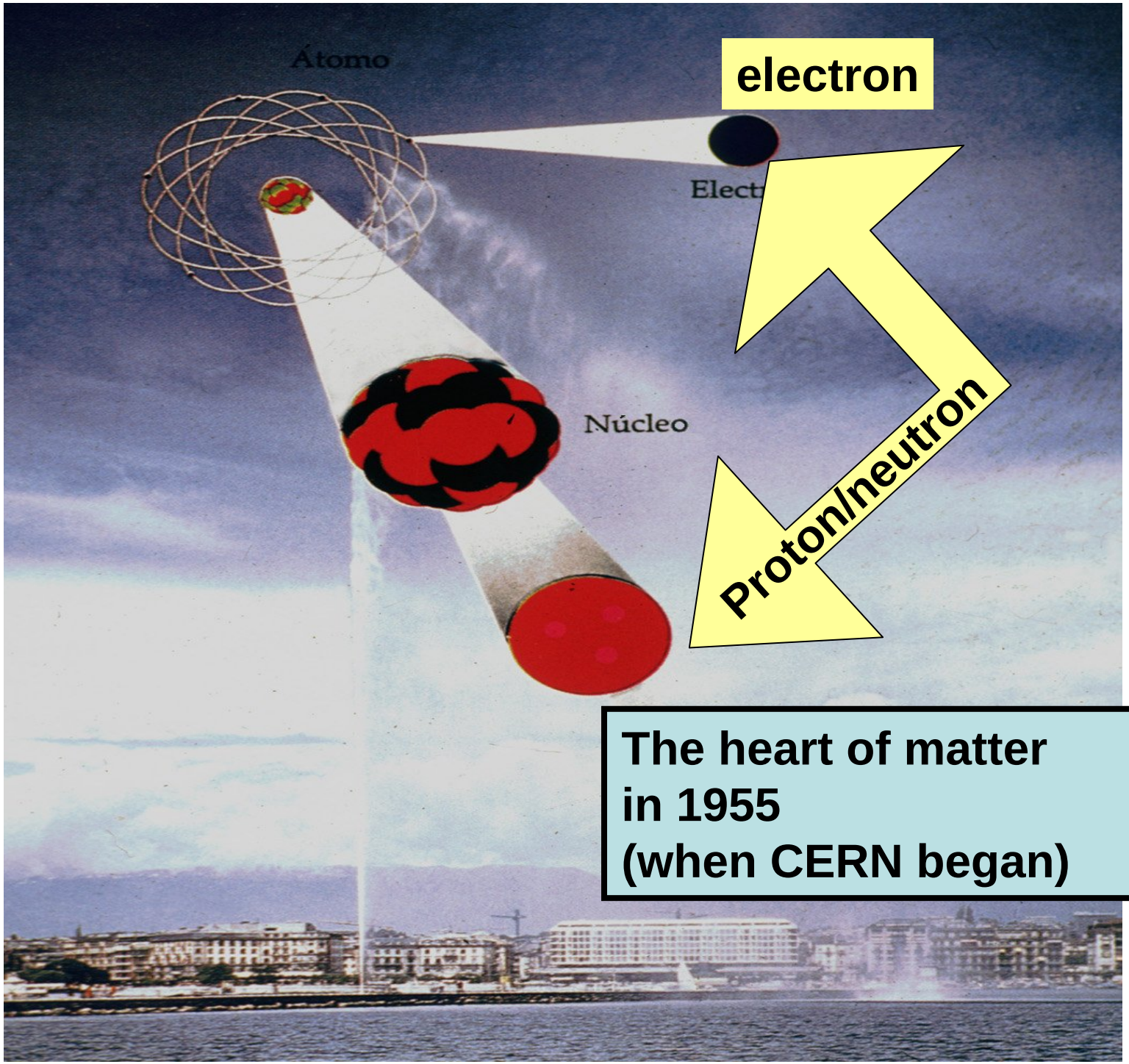
Particles in Three Minutes

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)


Átomo
Electrão
Núcleo
Partícula
The heart of matter
in 1955
(when CERN began)



Electron
and
Proton
utterly
different.

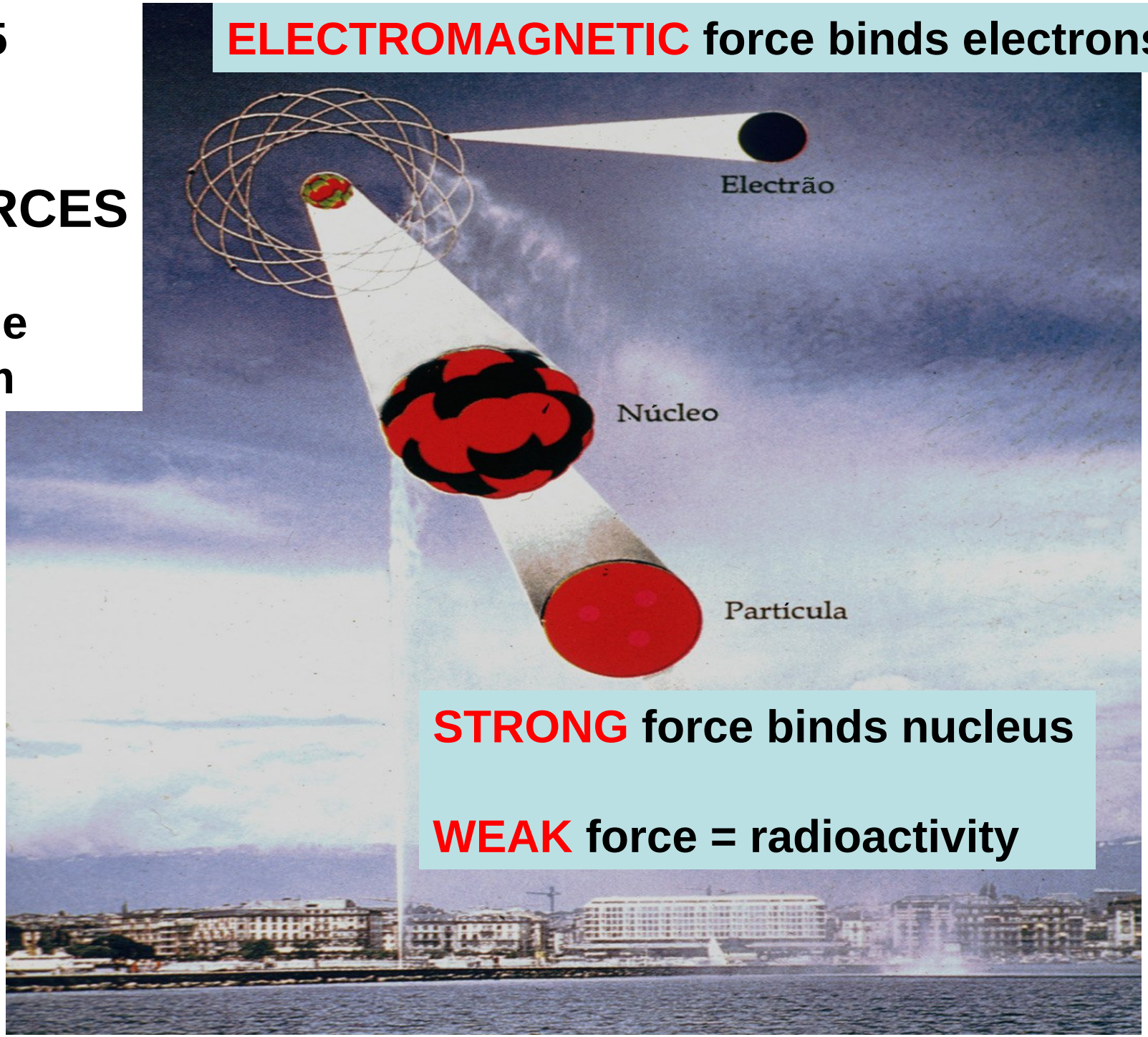
proton
2000
times
heavier

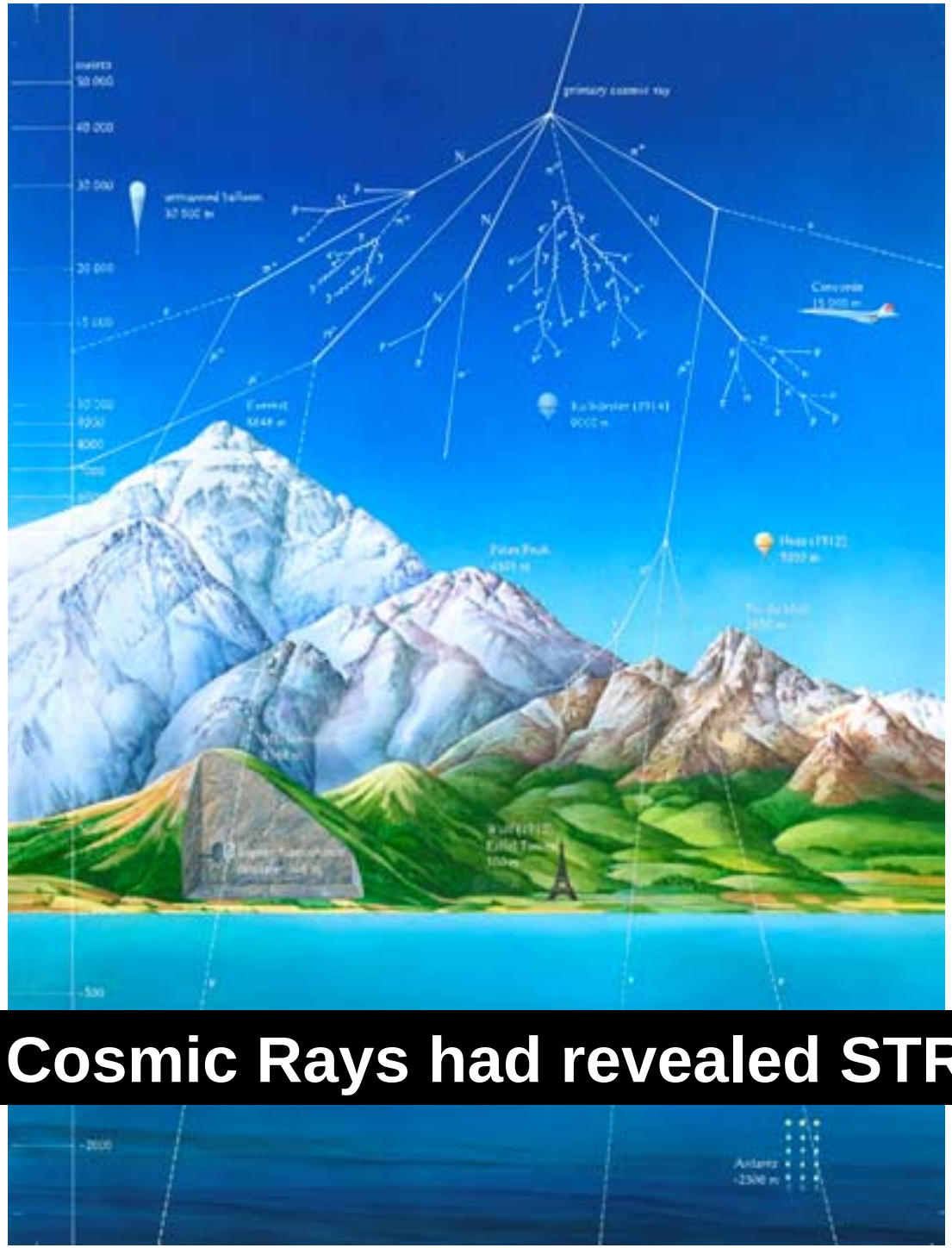
10000
times
bigger

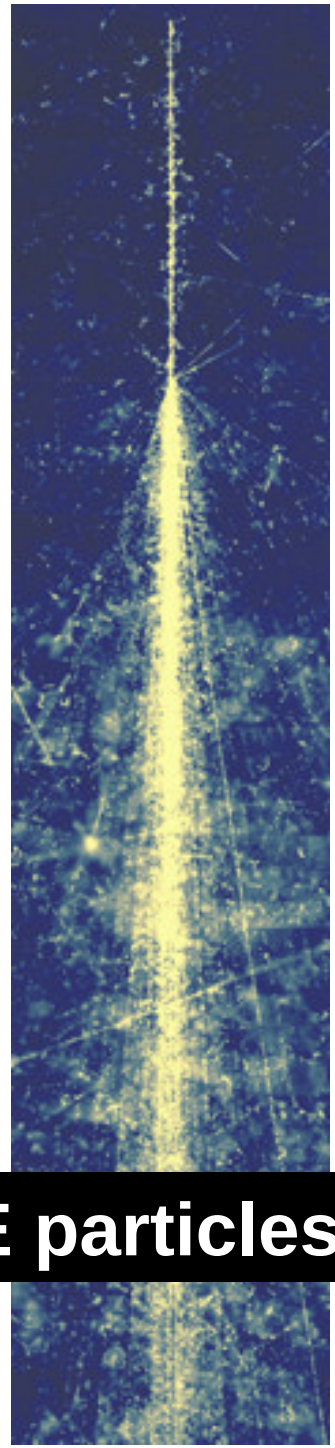
1955

FORCES

in the atom

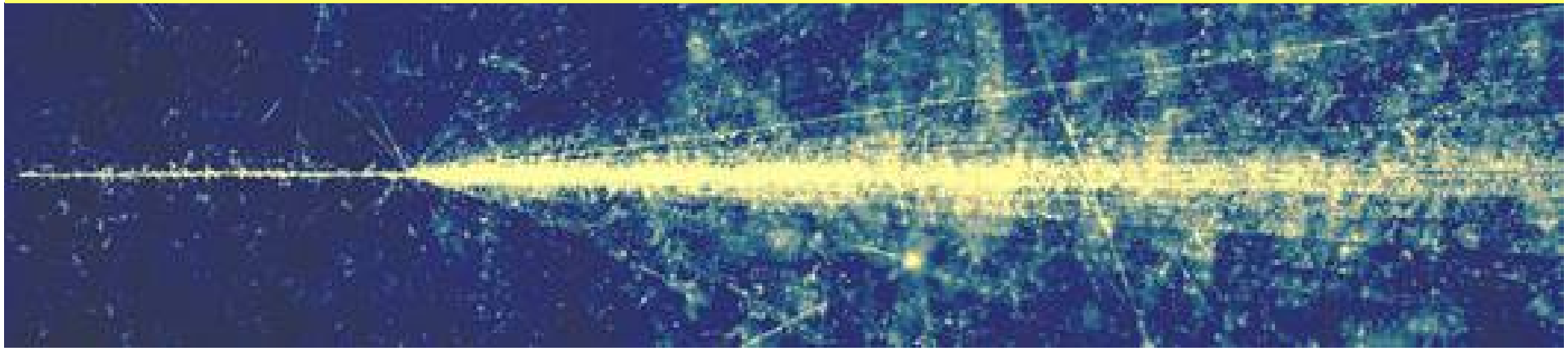




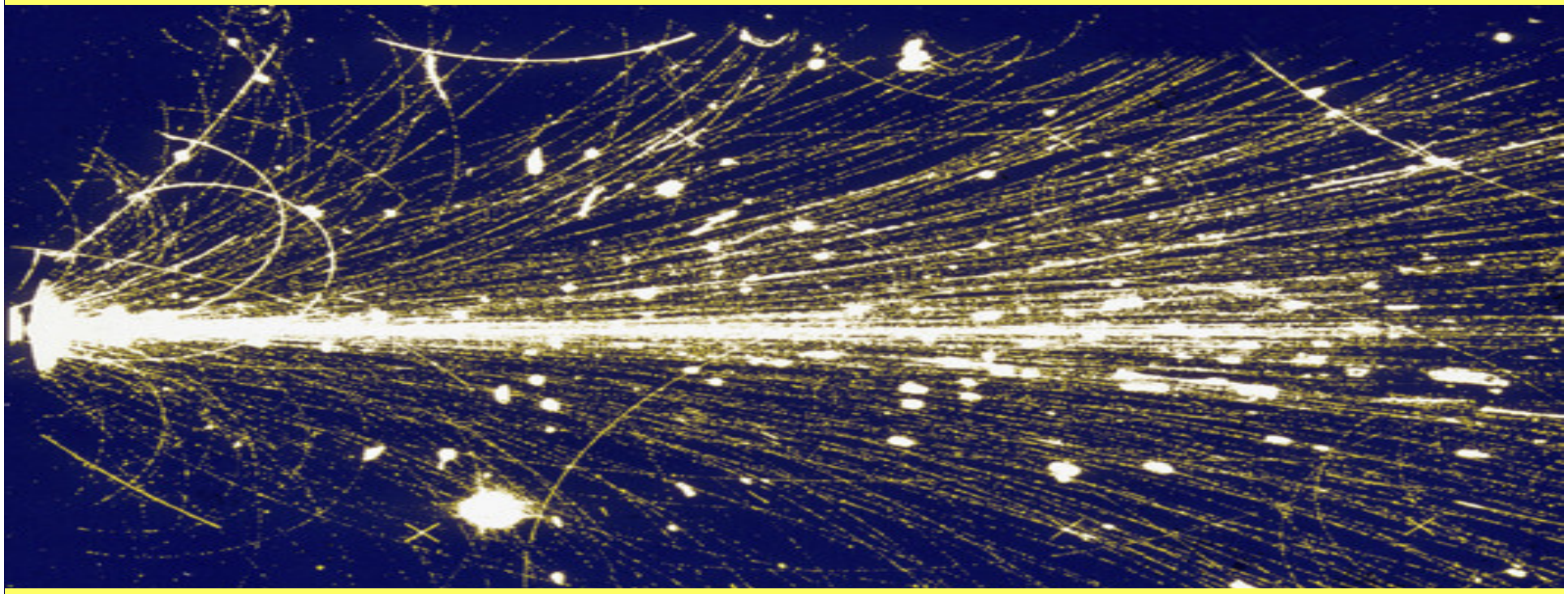


Cosmic Rays had revealed STRANGE particles

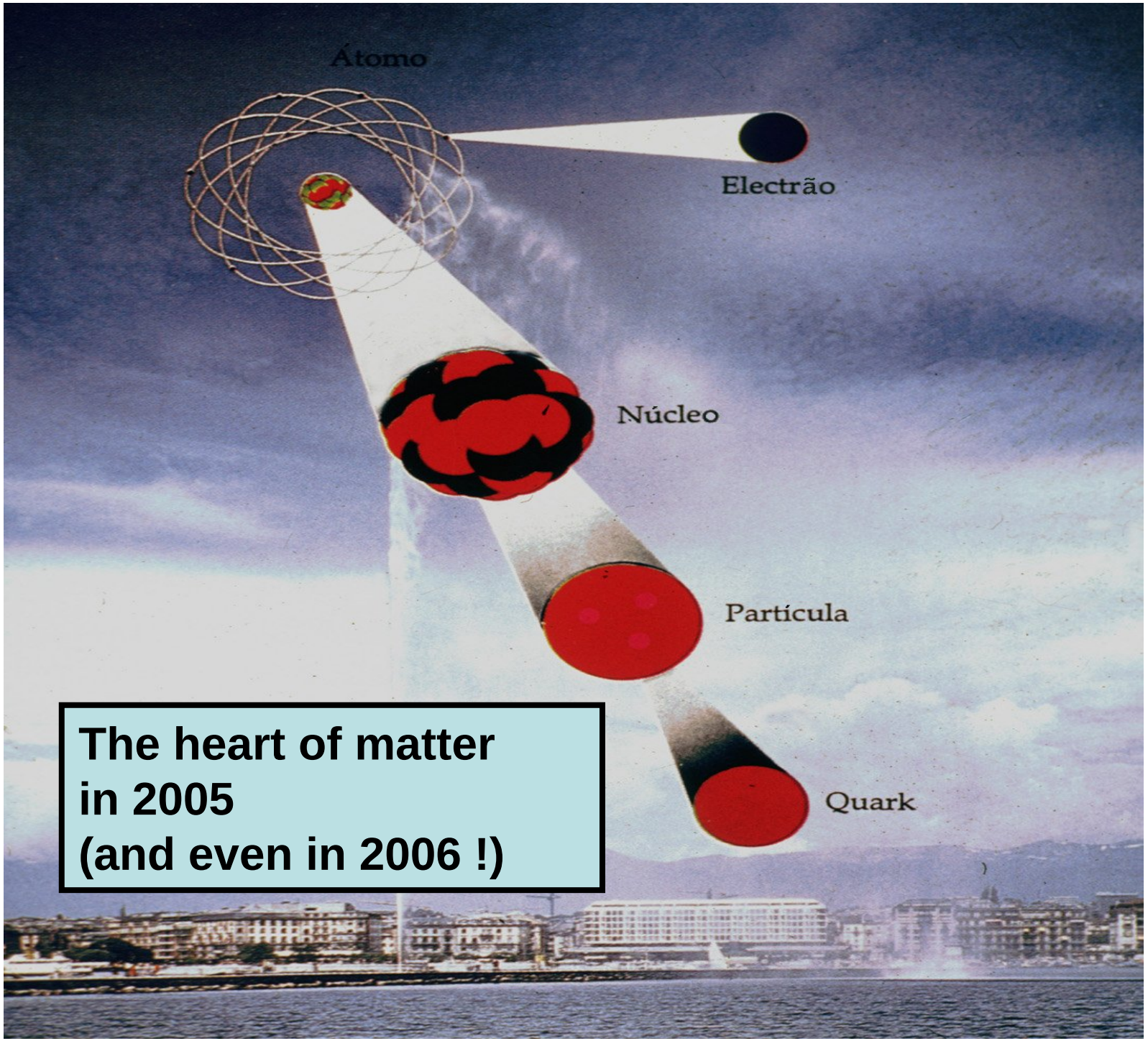
1955 CERN accelerators replicate cosmic rays on Earth…

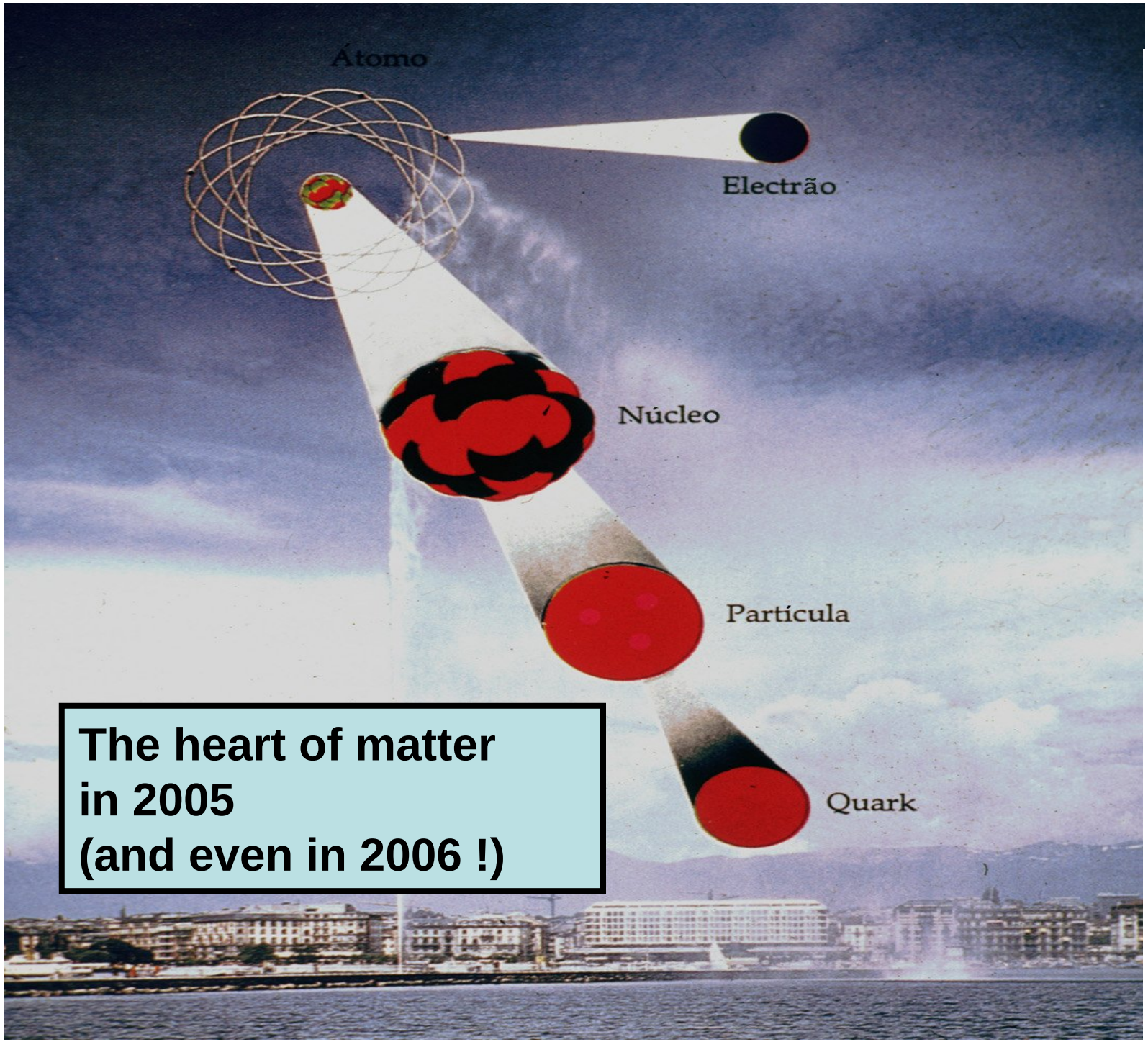


..record the images and reveal the real heart of matter….



…..the beginnings of modern high energy particle physics


Átomo
Electrão
Núcleo
Partícula
Quark
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

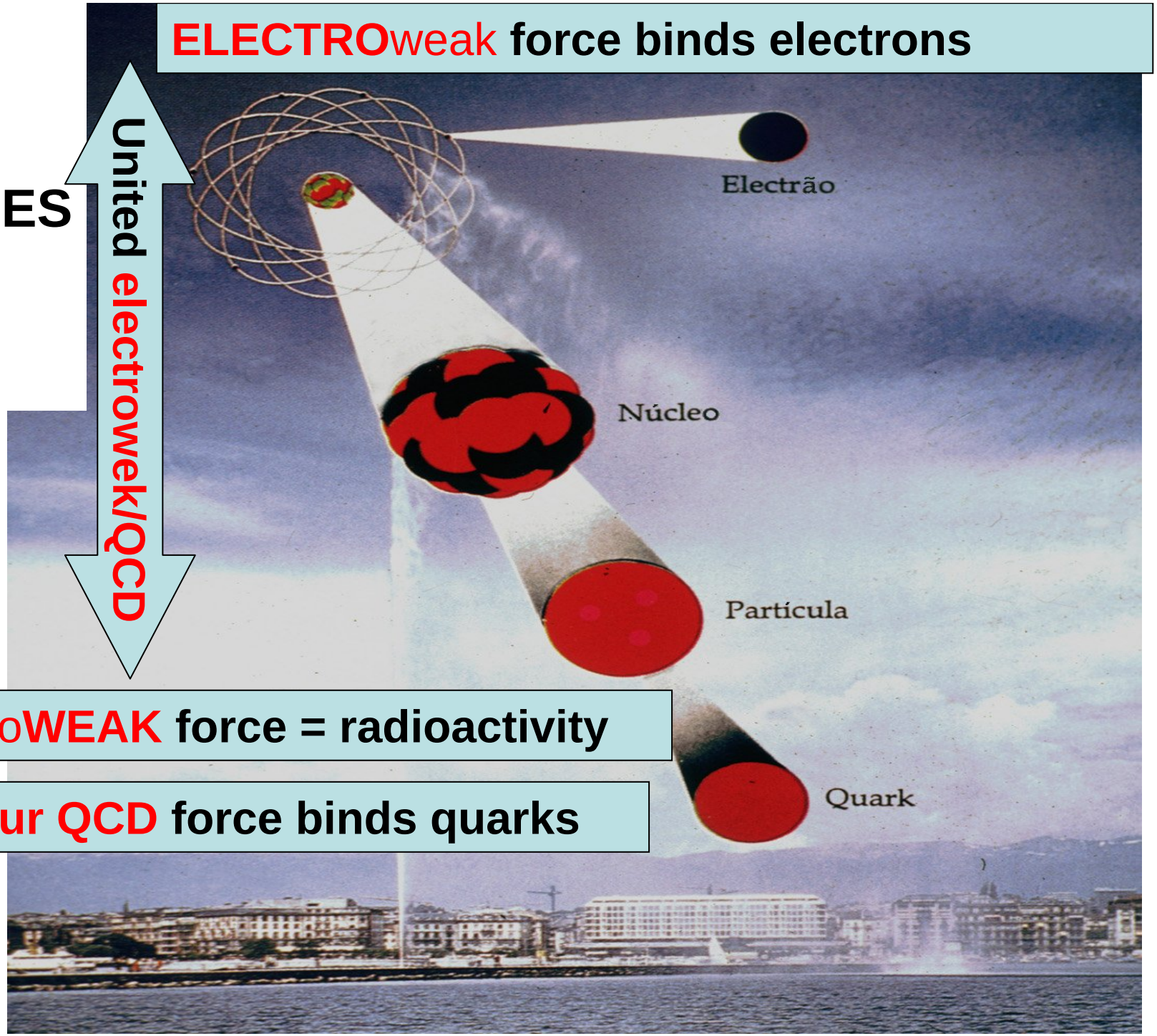
2005

FORCES

in the atom

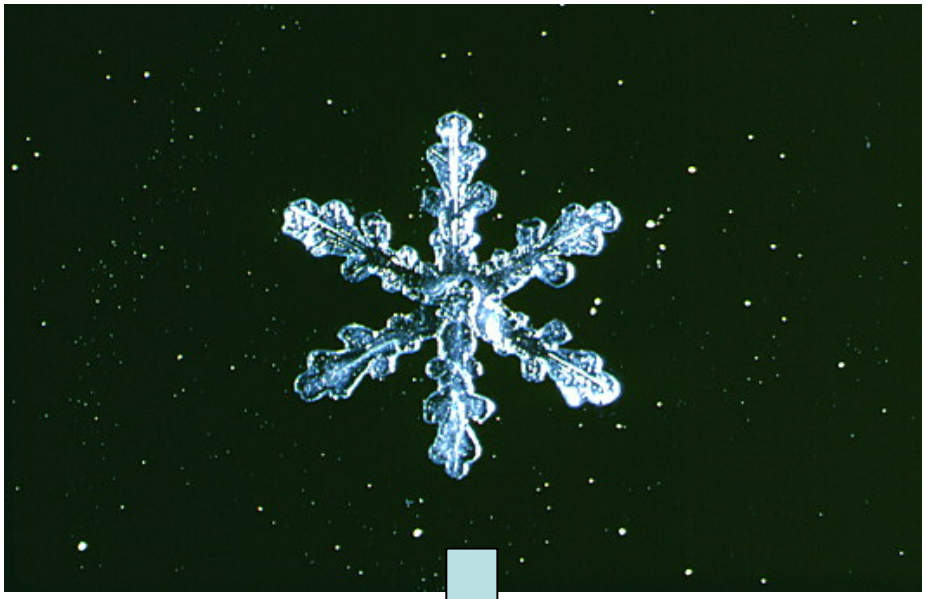
United electrowek/QCD

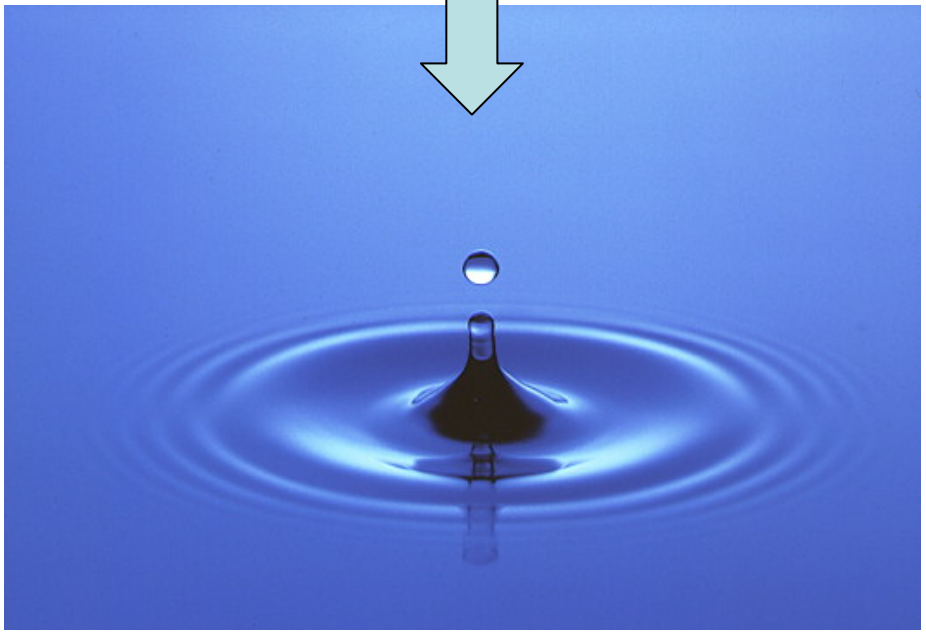
ELECTROweak force binds electrons



electroWEAK force = radioactivity

Colour QCD force binds quarks





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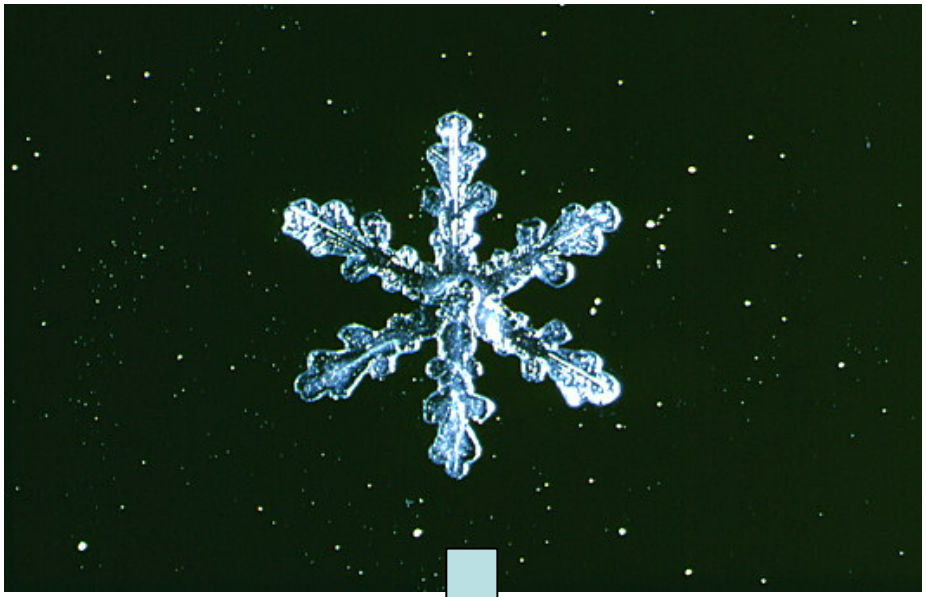
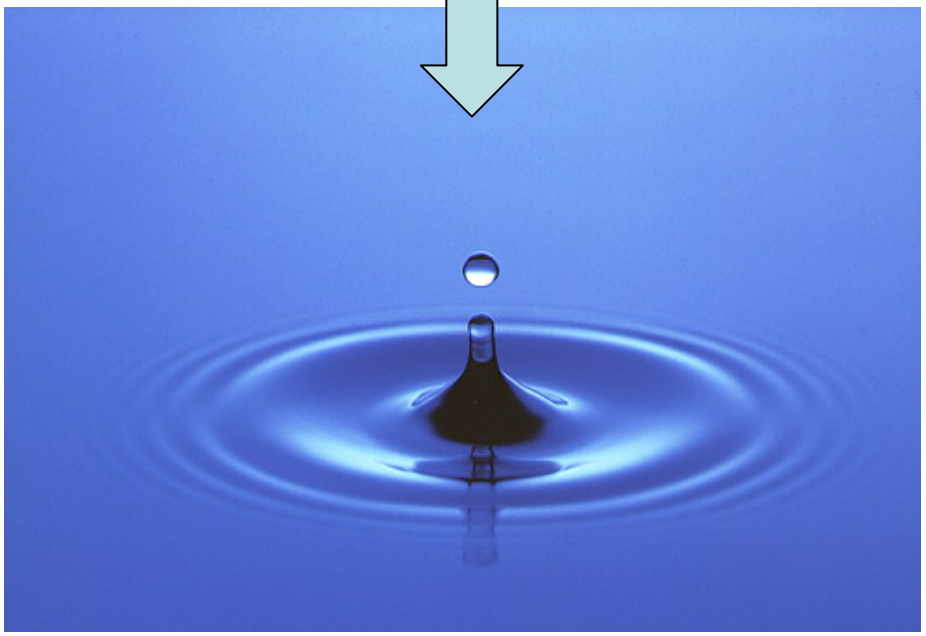
Symmetry when warm (high energy)





FORCES 1955-2005

COLD

Electromagnetic
Weak
Strong

WARM

ElectroWeak
Strong (QCD)

HOT

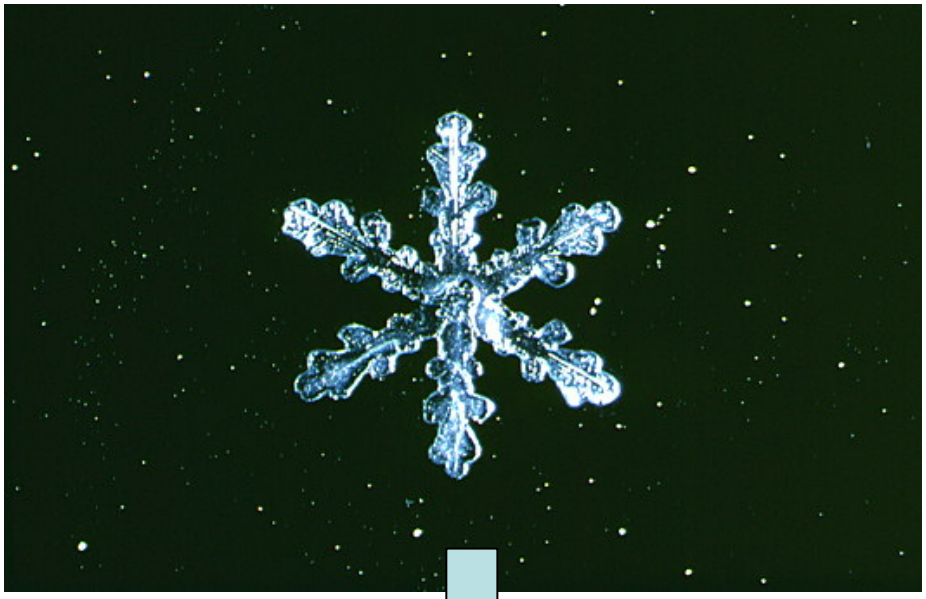
GrandUnified
Force

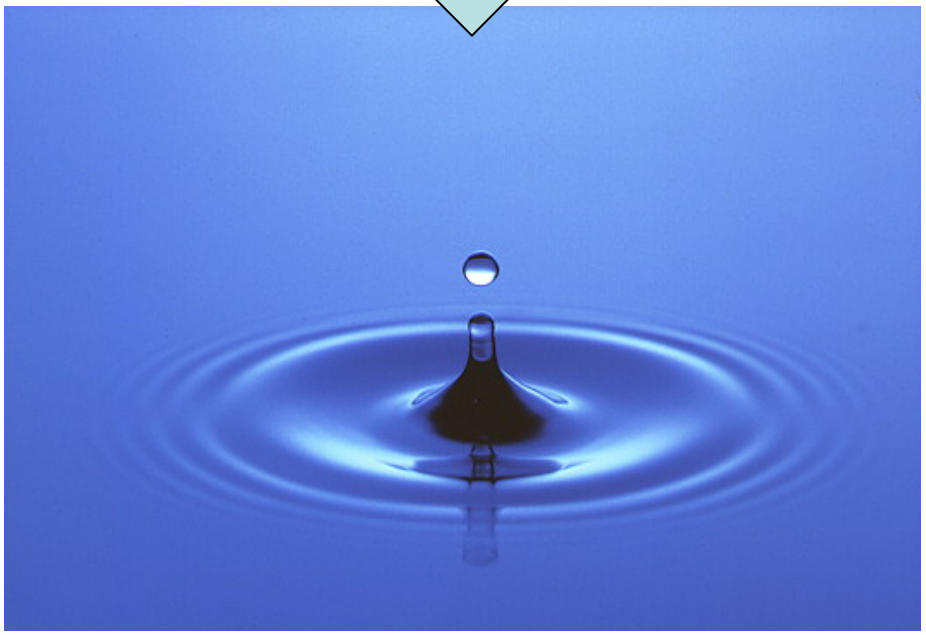
Standard Model of **Quarks Leptons and forces**

= pattern based on **mass**

“cold” =“low” energy

= **below 1 TeV**





Standard Model of **Quarks Leptons and forces**

= pattern based on **mass**

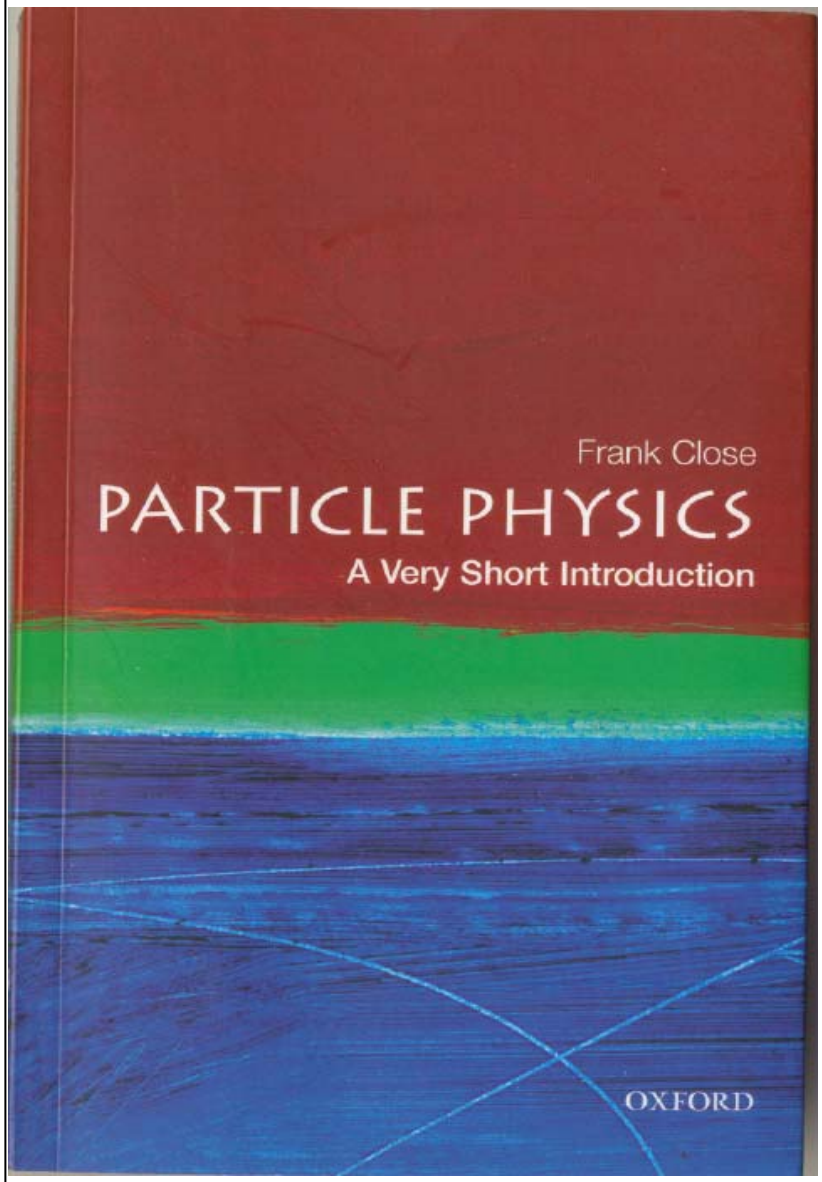
“cold” =“low” energy

= **below 1 TeV**

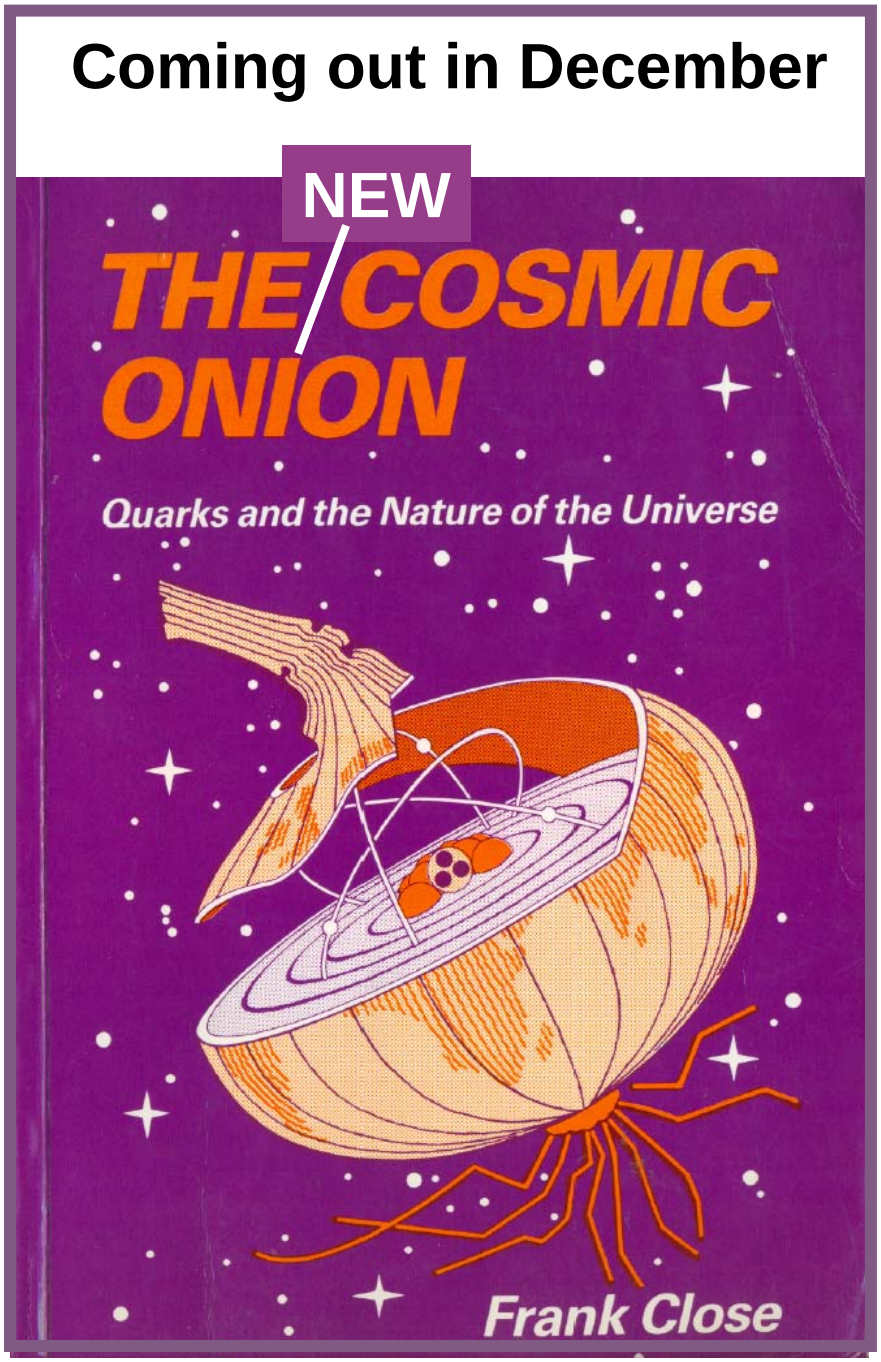
super**Symmetry**
when **“warm”**
(= high energy **> 1TeV)**

Higgs Boson
Supersymmetry
Nature of Reality

A Very Short Introduction



Coming out in December



…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	γ_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	γ_g

Nuclear Isotopes

Mendeleev

Snowflake pattern