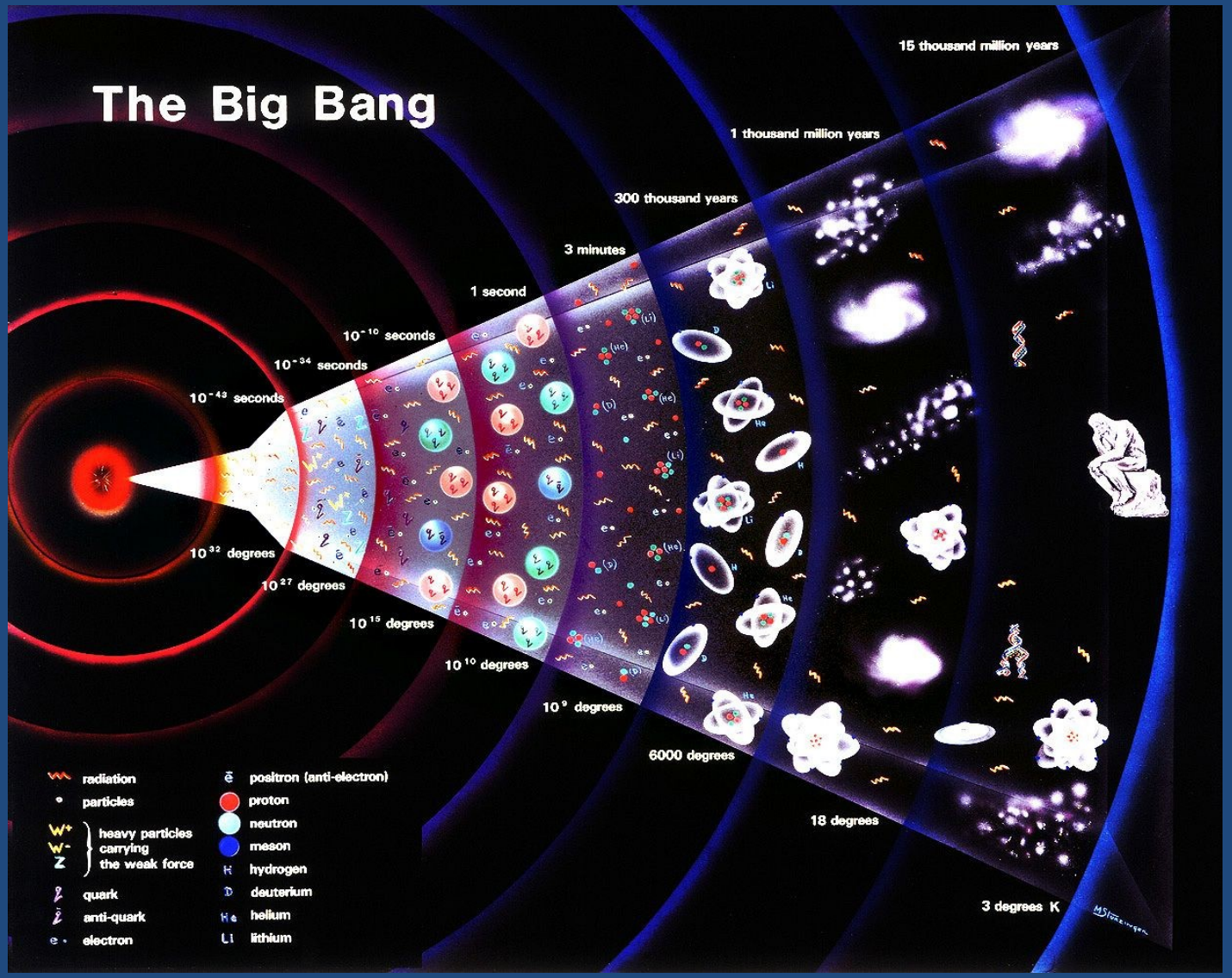
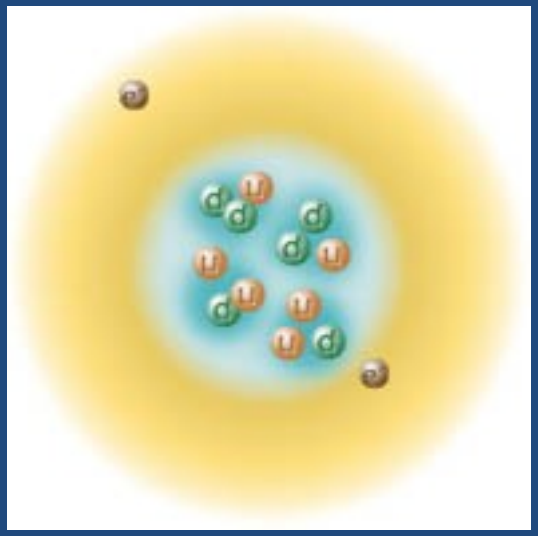
ERASMUS+ KA2
STARS IN EUROPE

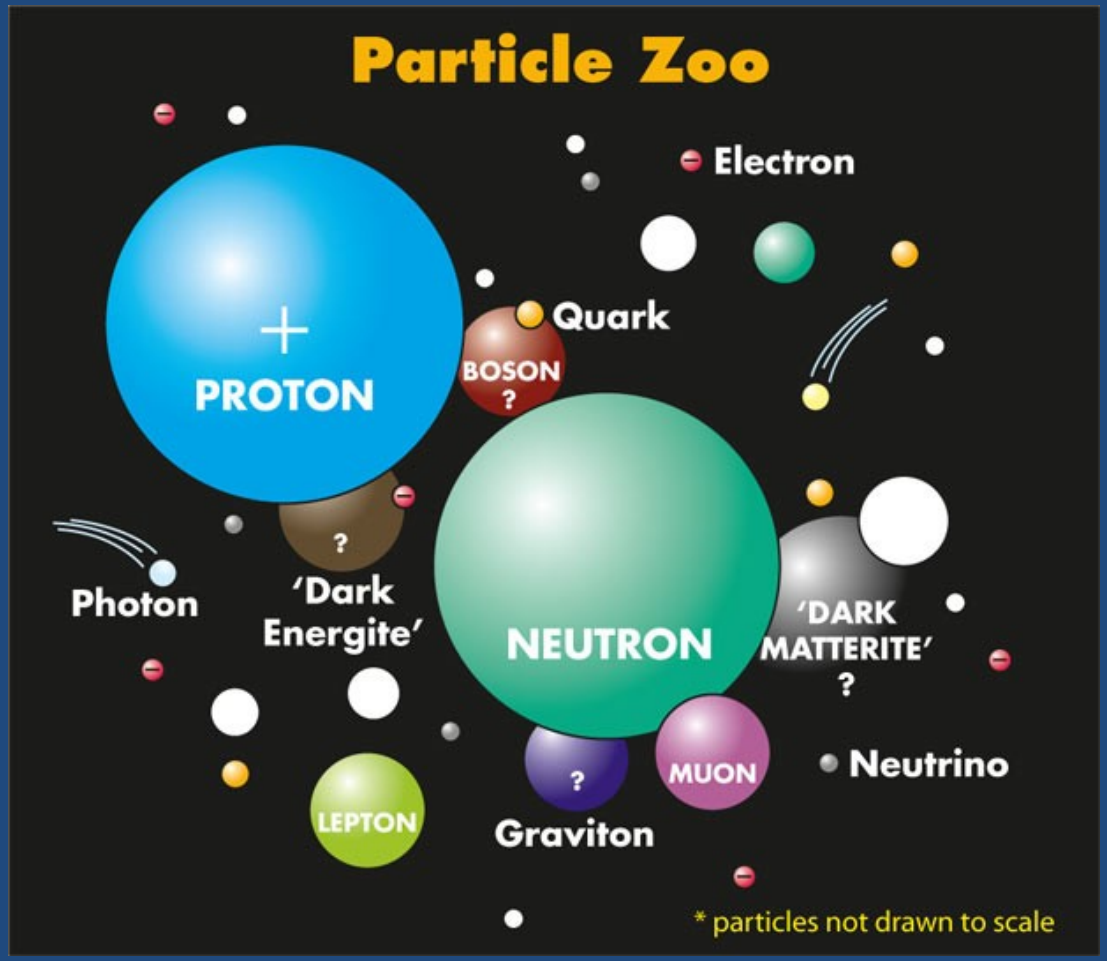
The Standard Model of Particle Physics


The Big Bang
15 thousand million years
1 thousand million years
300 thousand years
3 minutes
1 second
10⁻¹⁰ seconds
10⁻³⁴ seconds
10⁻⁴³ seconds
10³² degrees
10²⁷ degrees
10¹⁵ degrees
10¹⁰ degrees
10⁹ degrees
6000 degrees
18 degrees
3 degrees K
radiation
particles
W+ W- Z heavy particles carrying the weak force
quark
anti-quark
electron
positron (anti-electron)
proton
neutron
meson
H hydrogen
D deuterium
He helium
Li lithium

THE ATOM



- A cloud of electrons in constant motion around the nucleus
- And protons and neutrons in motion in the nucleus
- And quarks in motion within the protons and neutrons


Particle Zoo
Electron
PROTON
Quark
BOSON
?
Photon
?
'Dark
Energite'
NEUTRON
'DARK
MATTERITE'
?
Neutrino
MUON
?
Graviton
LEPTON
* particles not drawn to scale

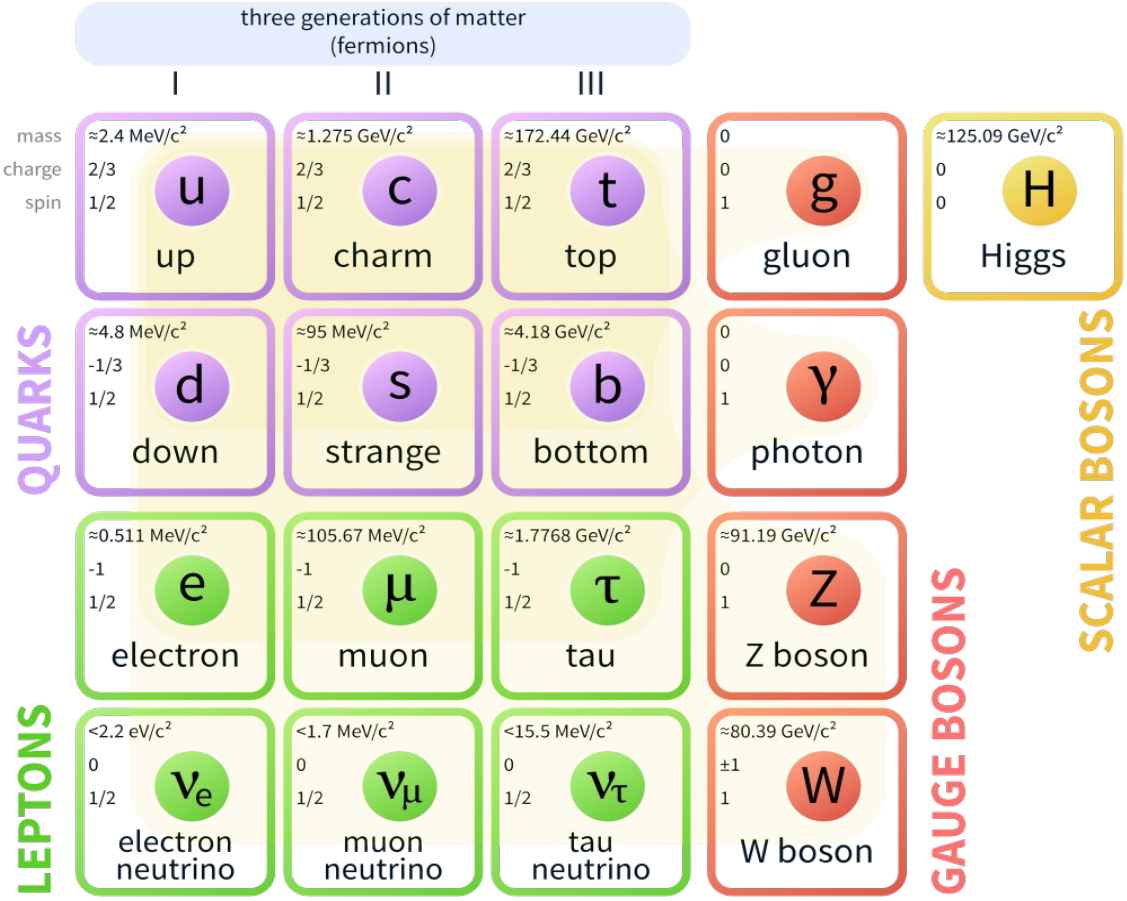
The Standard Model of Particle Physics is a **theory**, not a law, that is used to explain the existence of all the **particles** that have been observed and the **forces** that hold atoms together or lead to their decay.

The particles are classified according to the types of interactions they have with other particles.

Physicists now believe that all particles can be grouped into three families:

quarks, leptons and **force carriers**

Standard Model of Elementary Particles



QUARKS

- **quark** is a type of elementary particle and a fundamental constituent of matter. Quarks combine to form composite particles called hadrons, the most stable of which are protons and neutrons, the components of atomic nuclei.
- quarks are never directly observed or found in isolation

LEPTONS

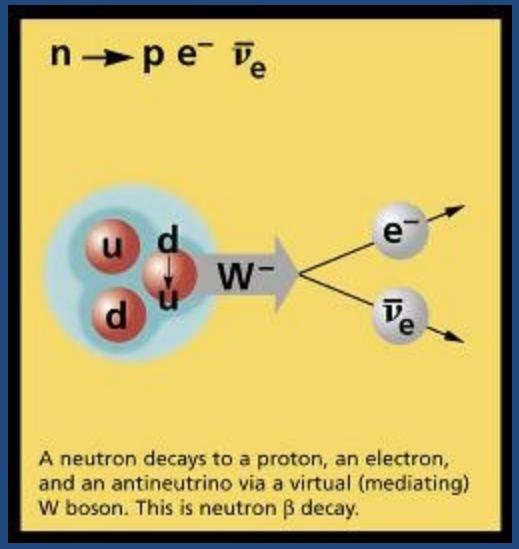
- There are six leptons, three charged and three neutral
- They appear to be point-like particles with no internal structure
- Electrons are the most common and are the only ones found in ordinary matter
- Muons (μ) and taus (τ) are heavier and charged like the electron
- Neutrinos have no charge and very little mass

THE 4 FUNDAMENTAL FORCES

The four fundamental forces of nature:

1. The “strong interaction” that’s responsible for holding the nuclei of atoms together.
2. The “weak force” that’s responsible for radioactive decay and neutrino interactions.
3. The electromagnetic force that causes effects such as the interaction of magnetic and electrical charges.
4. The gravitational force that attracts matter to other matter that has a mass.

β decay



A neutron decays to a proton, an electron, and an antineutrino via a virtual (mediating) W boson. This is neutron β decay.

Antimatter

Antimatter is material consisting of atoms that are composed of **antiparticles**.

Each particle has an antiparticle, which has the same mass, lifetime, and spin but with charge of opposite sign and magnetic moment reversed in sign.

- What is it? The best theoretical framework we have for particle physics today

- It has been a remarkable success BUT we know it is incomplete

- So, what does the phrase "STANDARD MODEL" mean?
  - A unification of all matter into two types of particles
  - A unification of the Electromagnetic and Weak Nuclear forces
  - A description of the interaction between fundamental particles in terms of the exchange of fundamental force particles

- Some things it does not do:
  - It does not unify the Strong and Electro-Weak forces
  - It ignores Gravity, so does not tell us anything about how it might be unified with the other forces
  - It does not explain why there are so many generations of particles
  - It does not explain the disappearance of anti-matter in the Universe