

From Particle Physics to Cosmology

Michel GONIN, ILANCE

Tomotake MATSUMURA, IPMU

LHC Programs, Masaya Ishino, ICEPP

Neutrinos Programs, Benjamin Quilain, ILANCE

Cosmology Programs - Cosmic Microwave Background,

Guillaume Patanchon, ILANCE

Astrophysics Programs, Kotaro Kohno, IoA

Telescope Array, Hitoshi Oshima, ICRR

Cherenkov Telescope Array Observatory, Shotaro Abe, ICRR

Machine Learning, Christine Quach, ILANCE

BELLE II, Fumiaki Otani, IPMU

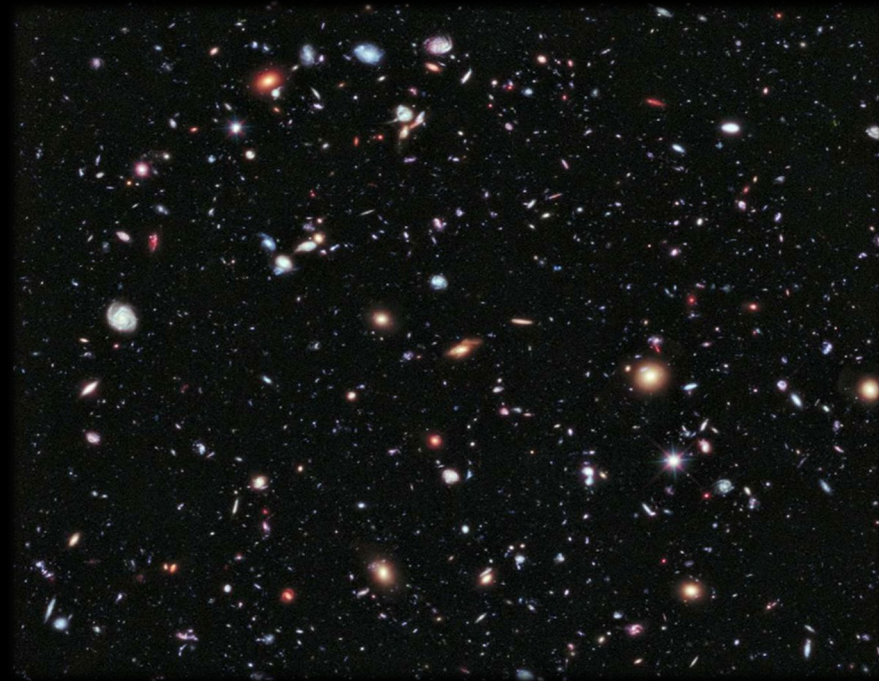
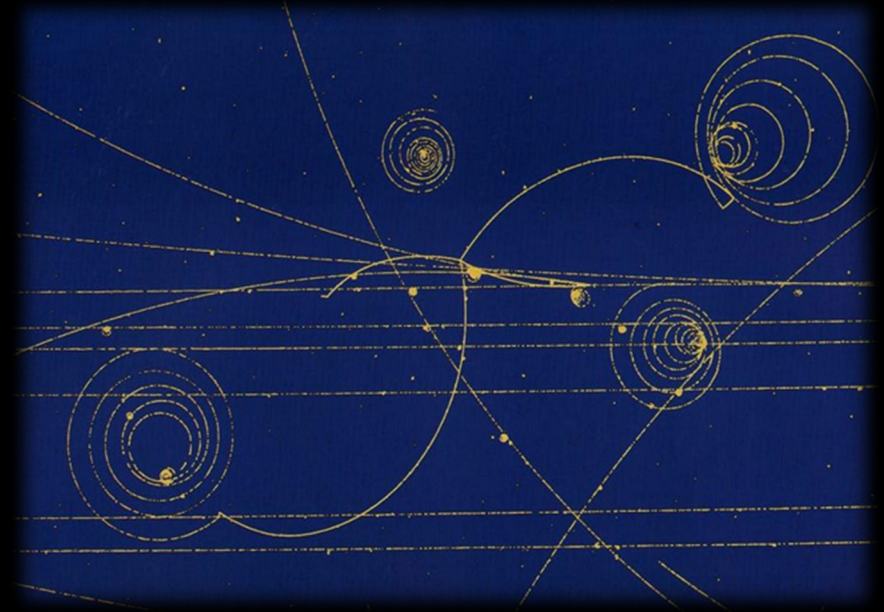
LiteBird, Clement Leloup, IPMU

Cosmology from HSC, Jessica Cowell, IPMU

Super-Kamiokande, Lorenzo Périssé, ILANCE

TIFUUN, Kanako Narita, IoA

CNRS-JSPS-JST
Celebration Event for the
50th
Anniversary
of France-Japan
Scientific Cooperation



The Physics of the Two Infinities

Big Bang

10^{-32} seconds

Inflation

Initial expansion

1 microsecond

First Particles

Neutrons, protons, and electrons form

3 minutes

First Nuclei

Helium and hydrogen form

380,000 years

First Light

The first atoms form

200 million years

First Stars

Gas and dust condense into stars

400 million years

Galaxies & Dark Matter

Galaxies form in dark matter cradles

10 billion years

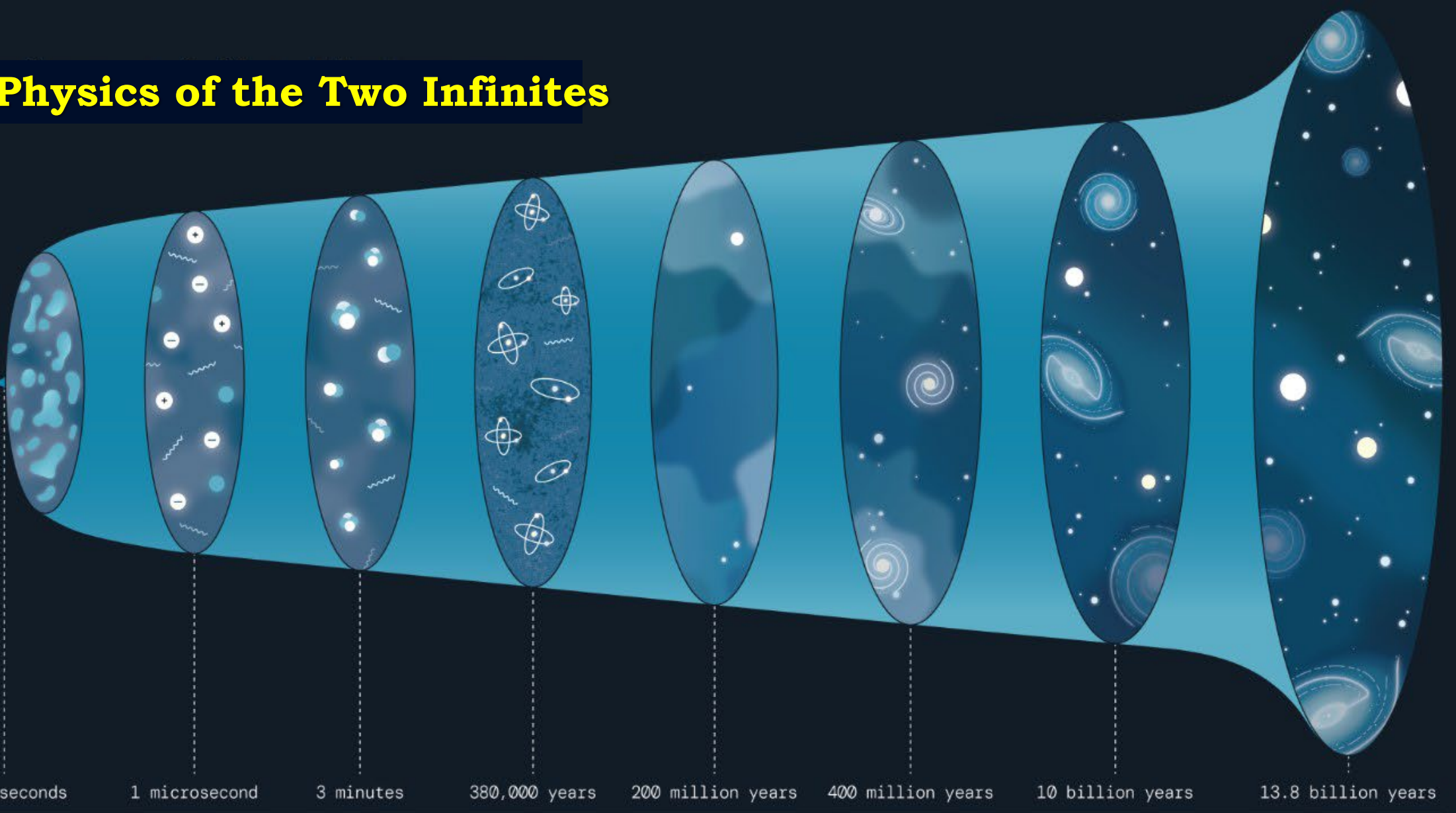
Dark Energy

Expansion accelerates

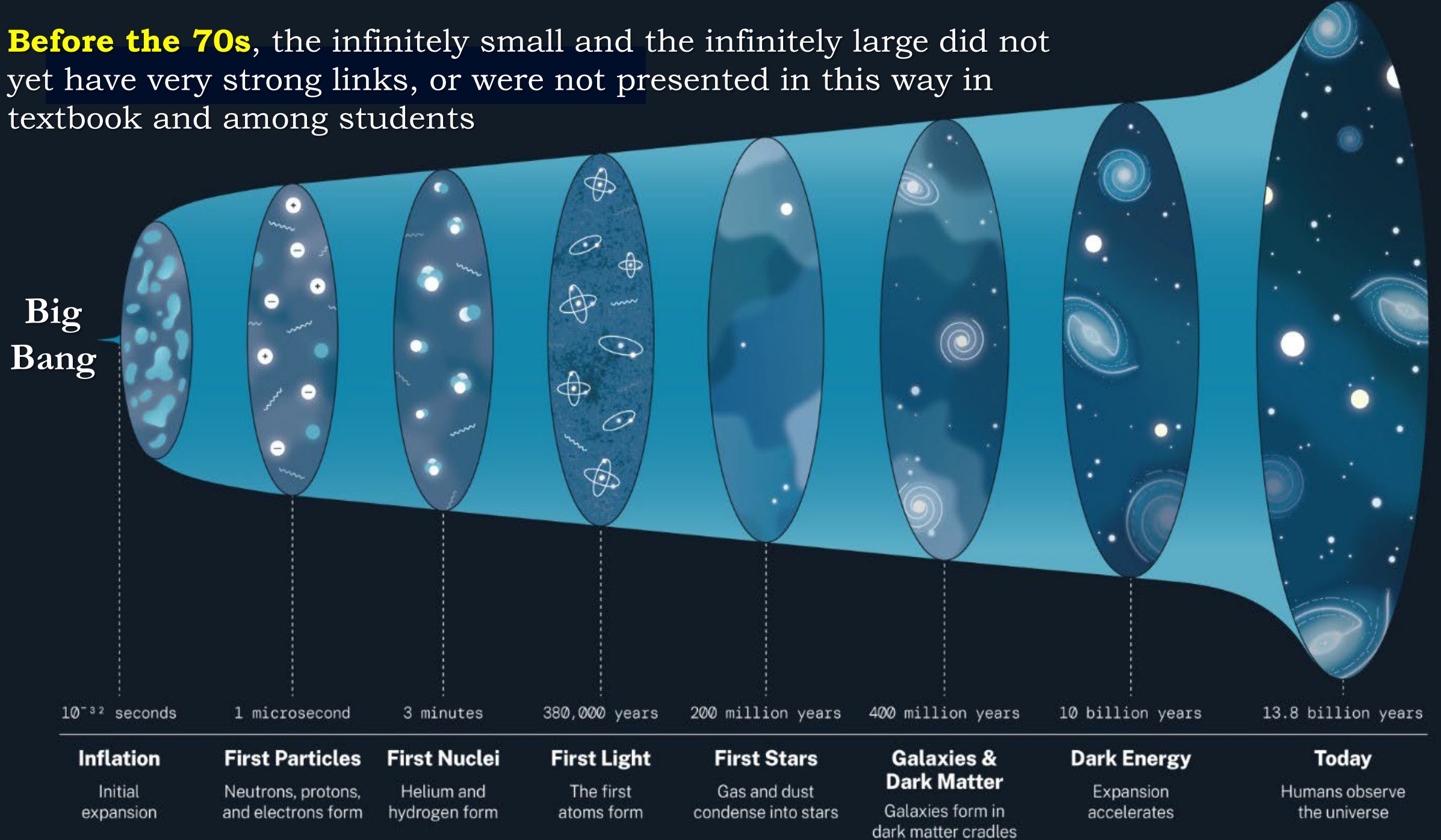
13.8 billion years

Today

Humans observe the universe



Before the 70s, the infinitely small and the infinitely large did not yet have very strong links, or were not presented in this way in textbook and among students



Particle Physics 50 years ago

three generations of matter
(fermions)

interactions / force carriers
(bosons)

QUARKS

$\approx 2.2 \text{ MeV}/c^2$
 $\frac{2}{3}$
 $\frac{1}{2}$
u
up

$\approx 4.7 \text{ MeV}/c^2$
 $-\frac{1}{3}$
 $\frac{1}{2}$
d
down

$\approx 96 \text{ MeV}/c^2$
 $-\frac{1}{3}$
 $\frac{1}{2}$
s
strange

0
0
1
 γ
photon

LEPTONS

$\approx 0.511 \text{ MeV}/c^2$
-1
 $\frac{1}{2}$
e
electron

$\approx 105.66 \text{ MeV}/c^2$
-1
 $\frac{1}{2}$
 μ
muon

$< 2.2 \text{ eV}/c^2$
0
 $\frac{1}{2}$
 ν_e
electron
neutrino

$< 0.17 \text{ MeV}/c^2$
0
 $\frac{1}{2}$
 ν_μ
muon
neutrino

Particle Physics Today

three generations of matter
(fermions)

interactions / force carriers
(bosons)

QUARKS

LEPTONS

$\approx 2.2 \text{ MeV}c^2$
 $\frac{2}{3}$
 $\frac{1}{2}$
u
 up

$\approx 1.28 \text{ GeV}c^2$
 $\frac{2}{3}$
 $\frac{1}{2}$
c
 charm

$\approx 173.1 \text{ GeV}c^2$
 $\frac{2}{3}$
 $\frac{1}{2}$
t
 top

$\approx 4.7 \text{ MeV}c^2$
 $-\frac{1}{3}$
 $\frac{1}{2}$
d
 down

$\approx 96 \text{ MeV}c^2$
 $-\frac{1}{3}$
 $\frac{1}{2}$
s
 strange

$\approx 4.18 \text{ GeV}c^2$
 $-\frac{1}{3}$
 $\frac{1}{2}$
b
 bottom

$\approx 0.511 \text{ MeV}c^2$
 -1
 $\frac{1}{2}$
e
 electron

$\approx 105.66 \text{ MeV}c^2$
 -1
 $\frac{1}{2}$
 μ
 muon

$\approx 1.7768 \text{ GeV}c^2$
 -1
 $\frac{1}{2}$
 τ
 tau

$< 2.2 \text{ eV}c^2$
 0
 $\frac{1}{2}$
 ν_e
 electron neutrino

$< 0.17 \text{ MeV}c^2$
 0
 $\frac{1}{2}$
 ν_μ
 muon neutrino

$< 18.2 \text{ MeV}c^2$
 0
 $\frac{1}{2}$
 ν_τ
 tau neutrino

0
 0
 1
g
 gluon

$\approx 124.97 \text{ GeV}c^2$
 0
 0
H
 higgs

0
 0
 1
 γ
 photon

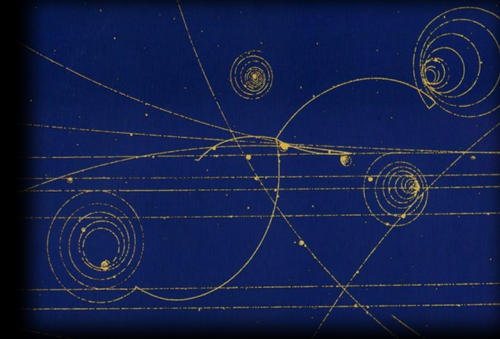
$\approx 91.19 \text{ GeV}c^2$
 0
 1
Z
 Z boson

$\approx 80.39 \text{ GeV}c^2$
 ± 1
 1
W
 W boson

GAUGE BOSONS
VECTOR BOSONS

SCALAR BOSONS

The Standard Model in Particle Physics Today



three generations of matter (fermions)			interactions / force carriers (bosons)		
	I	II	III		
QUARKS	$\approx 2.2 \text{ MeV}c^2$ $\frac{2}{3}$ $\frac{1}{2}$ u up	$\approx 1.28 \text{ GeV}c^2$ $\frac{2}{3}$ $\frac{1}{2}$ c charm	$\approx 173.1 \text{ GeV}c^2$ $\frac{2}{3}$ $\frac{1}{2}$ t top	0 0 1 g gluon	$\approx 124.97 \text{ GeV}c^2$ 0 0 H higgs
	$\approx 4.7 \text{ MeV}c^2$ $-\frac{2}{3}$ $\frac{1}{2}$ d down	$\approx 96 \text{ MeV}c^2$ $-\frac{2}{3}$ $\frac{1}{2}$ s strange	$\approx 4.18 \text{ GeV}c^2$ $-\frac{2}{3}$ $\frac{1}{2}$ b bottom	0 0 1 γ photon	SCALAR BOSONS
	$\approx 0.511 \text{ MeV}c^2$ -1 $\frac{1}{2}$ e electron	$\approx 105.66 \text{ MeV}c^2$ -1 $\frac{1}{2}$ μ muon	$\approx 1.7768 \text{ GeV}c^2$ -1 $\frac{1}{2}$ τ tau	$\approx 91.19 \text{ GeV}c^2$ 0 1 Z Z boson	
$< 2.2 \text{ eV}c^2$ 0 $\frac{1}{2}$ ν_e electron neutrino	$< 0.17 \text{ MeV}c^2$ 0 $\frac{1}{2}$ ν_μ muon neutrino	$< 18.2 \text{ MeV}c^2$ 0 $\frac{1}{2}$ ν_τ tau neutrino	$\approx 80.39 \text{ GeV}c^2$ ± 1 1 W W boson		

- **Dark Matter (Wimps, Machos, ...)**
- **Higgs boson and Cosmology (Inflation, Dark Matter,)**
- **Neutrinos and Cosmology (Nucleosynthesis, Leptogenesis, ...)**
- **Antimatter in our Universe (CP Symmetry)**

Cosmology and Astrophysics 50 years ago

Before 1920s The Universe was static, without any “history”

1927-1929 Discovery of the expansion of the Universe, Galaxies

1930s First Big Bang models

1930s Cosmic rays

1950s Stellar nucleosynthesis

1950s The abundance of the elements in the Universe

1960s Cosmic Microwave Background CMB radiation

1970s Dark Matter

Progress in Cosmology and Astrophysics over the last 50th years

- **CMB measurements**
- **Supernovae**
- **Neutron stars**
- **Standard model of cosmology**
- **Black Holes**
- **Dark Energy**
- **Inflation theory**
- **Large-scale structure of the cosmos**
- **Galaxy formation**
- **High energy gamma ray sources**
- **Gravitational waves**

Progress in Cosmology and Astrophysics over the last 50th years

- **CMB measurements**
- **Supernovae**
- **Neutron stars**
- **Standard model of cosmology**
- **Black Holes**
- **Dark Energy**
- **Inflation theory**
- **Large-scale structure of the cosmos**
- **Galaxy formation**
- **High energy gamma ray sources**
- **Gravitational waves**

CNRS-JSPS-JST
Celebration Event for the
50th
Anniversary
of France-Japan
Scientific Cooperation

Many France-Japan collaborations have contributed to the physics of the two infinities over the last 50 years

And this will continue with new projects !