Dark Matter Physics

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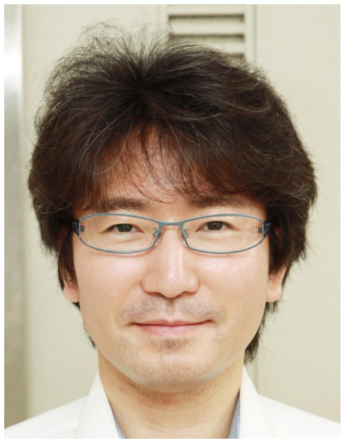
Self-Introduction



Name: Mitsuru KAKIZAKI

Affiliation: University of Toyama, Japan

Research fields:

Phenomenology, Particle cosmology:
- Higgs, Dark matter, Gravitational waves, etc.

History:

- Apr. 1995 – Mar. 2004: Tohoku University, Japan
- Apr. 2004 – Aug. 2005: ICRR, University of Tokyo, Japan
- Aug. 2005 – Sep. 2008: Bonn University, Germany
- Oct. 2008 – Sep. 2010: LAPTh, France
- Oct. 2010 – Mar. 2011: Hamburg University, Germany
- Apr. 2011 – Present: University of Toyama, Japan

Contents

D'où venons-nous? Que sommes-nous? Où allons-nous?

[Paul Gauguin]

i.e., at the most fundamental level

- How did the Universe begin?
- What is the Universe made of?
- What is the fate of the Universe?

The goal of particle physics is to answer these questions

How did the Universe begin?

Recombination (Cosmic microwave bg.)

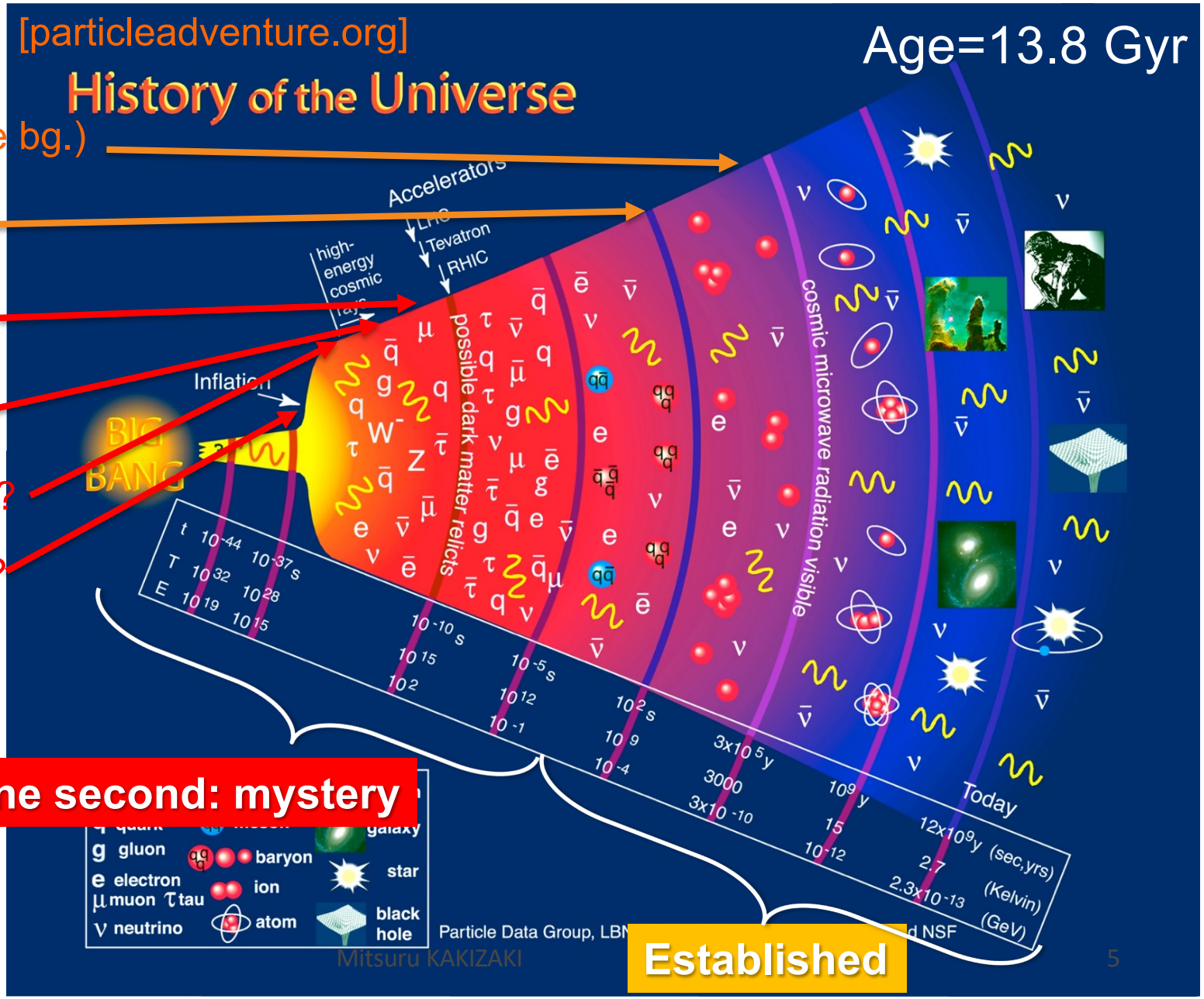
Big bang nucleosynthesis

Electroweak (EW) phase transition?

Dark matter?

Baryon asymmetry?

Cosmic inflation?



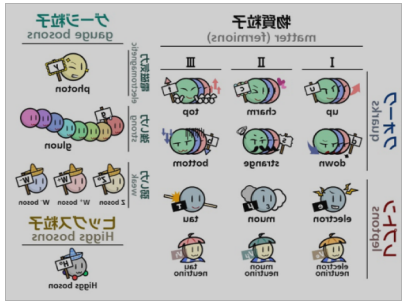
The first one second: mystery

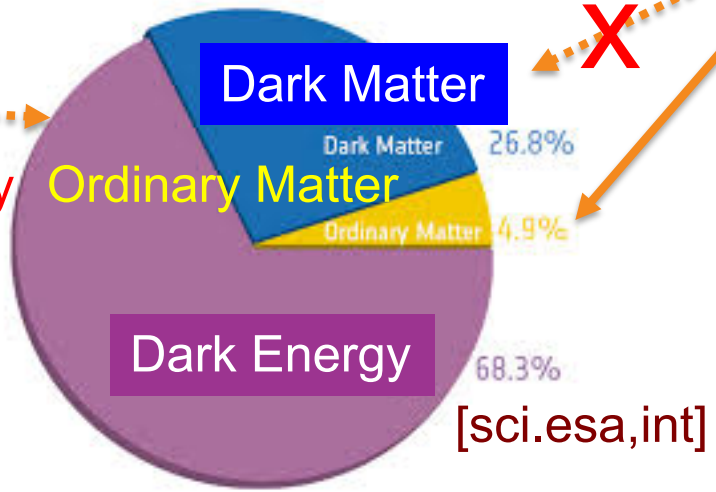
Established

What is the Universe made of?

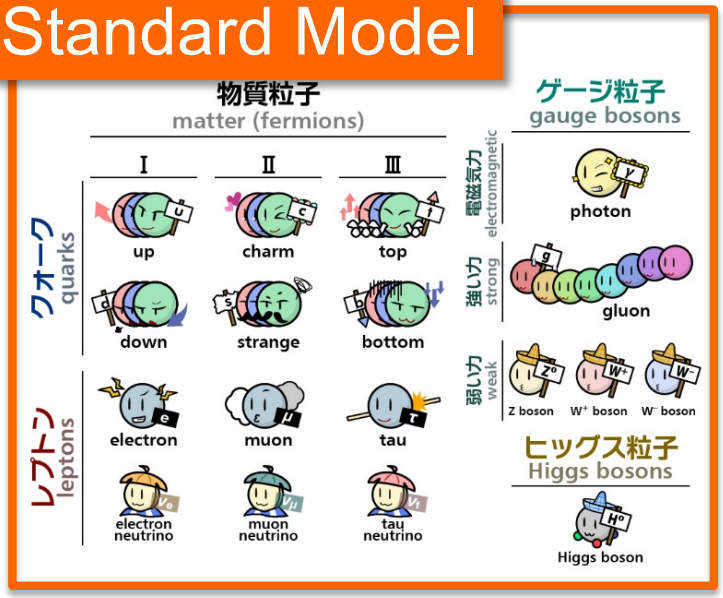
What is the Universe made of?

Anti-matter X Baryon asymmetry





X Standard Model



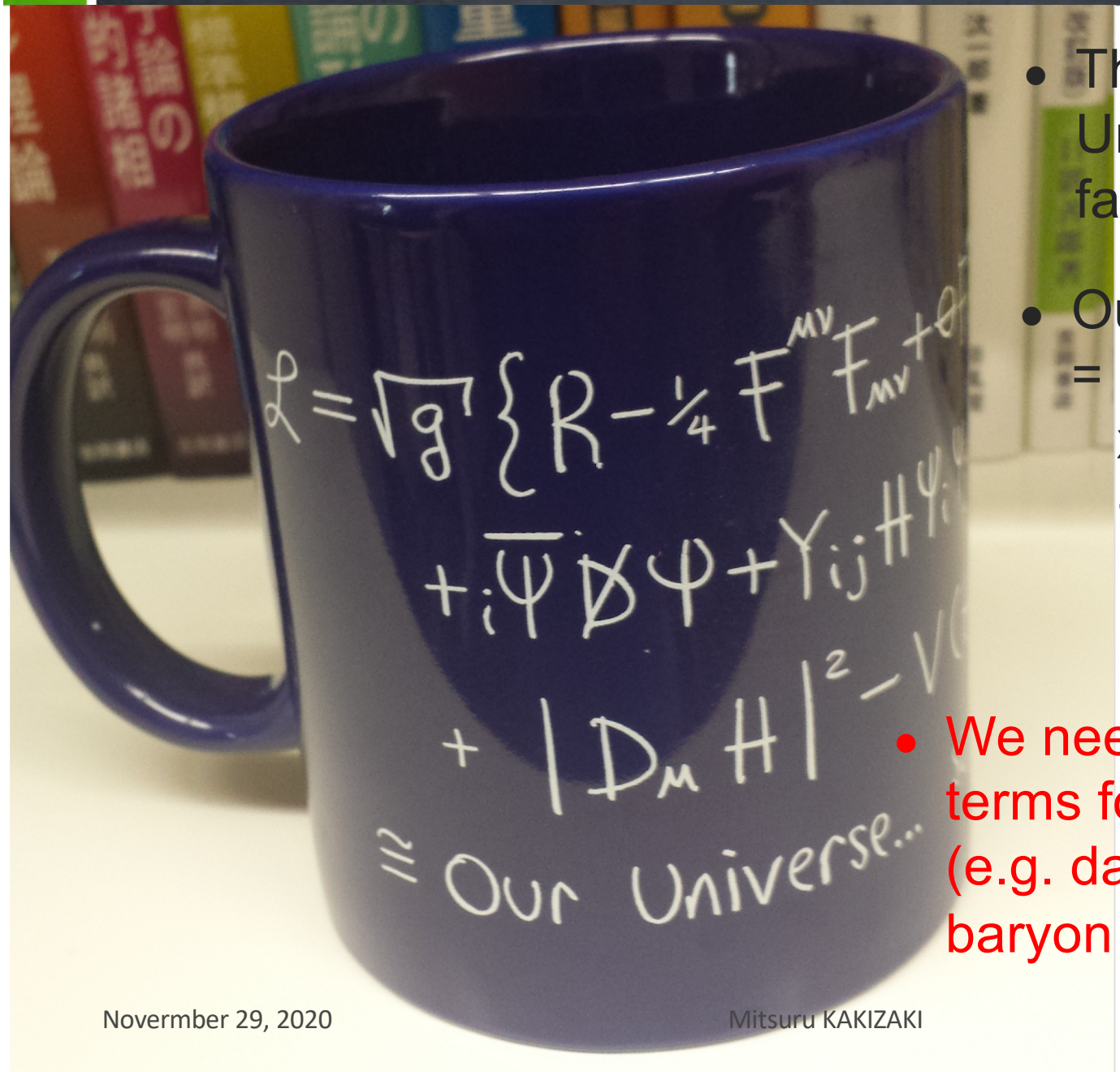
Discovery of the 125 GeV Higgs boson h at the CERN LHC

- The Standard Model (SM) has been established as a low-energy effective theory below $O(100)$ GeV

Phenomena beyond the Standard Model (SM)

- Existence of dark matter (DM)
- Baryon asymmetry of the Universe
- Cosmic inflation
- Neutrino oscillations

What is the fate of the Universe?

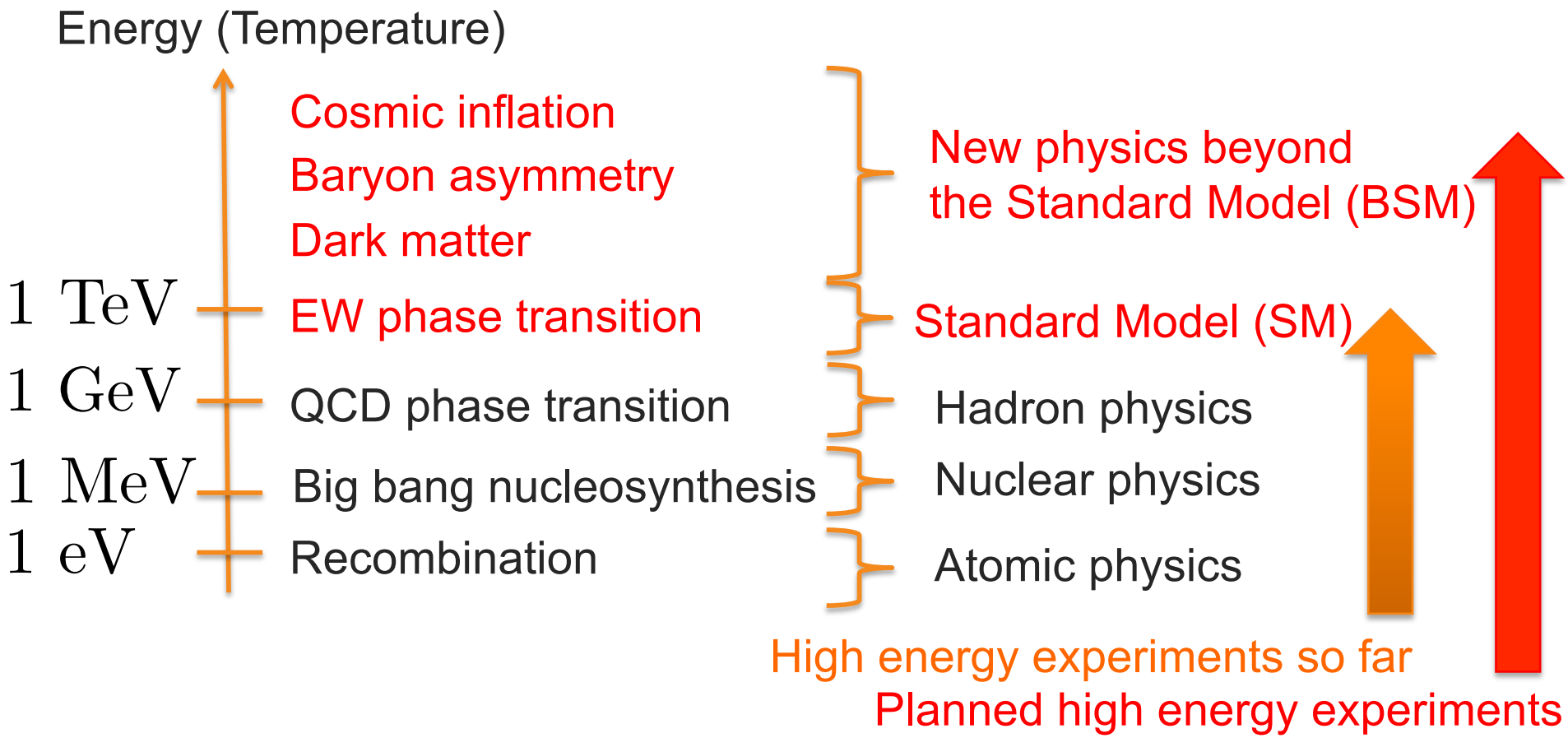


- The Lagrangian of the Universe encodes the fate of the Universe
- Our Universe
  = Standard Model
  x General Relativity
  + New Physics
- We need to reveal unknown terms for new physics (e.g. dark matter, baryon asymmetry, etc.)

Role of high energy experiments

History of the Universe

Theories in physics



High energy experiments approaches new physics and the early Universe

References

- G. Jungman, M. Kamionkowski and K. Griest, ``Supersymmetric dark matter,'' Phys. Rept. 267 (1996), 195-373 [arXiv:hep-ph/9506380 [hep-ph]
- G. Bertone, D. Hooper and J. Silk, ``Particle dark matter: Evidence, candidates and constraints,'' Phys. Rept. 405 (2005), 279-390 [arXiv:hep-ph/0404175 [hep-ph]]
- TASI 2018 lectures on dark matter
  - T. Lin, arXiv:1904.07915
  - D. Hooper, Lin, arXiv:1812.02029
  - J. M. Cline, arXiv:1807.08749

Note

- I will use the natural units:

$$c = \hbar = 1$$

[See Cao Hoang Nam's lecture]

- I will often use Hayakawa's formula:

$$10 = 1$$

for the purpose of estimation

- I will mainly use slides and the zoom whiteboard