# Overview on Thermal DM Models with emphasis on Electroweak Charges


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- ✓ Dark matter (DM) problem is one of the most important problems in many fields of physics!
- ✓ DM mass is, however, presently predicted to be in a range between $10^{-55}$g and $10^{+40}$g, namely uncertainty of a hundred orders of magnitude. Thus, we need diverse studies for the problem!
- ✓ Among various DM candidates, a weak-charged thermal DM attracts many attentions. I try to briefly outline the above story and present some basics of the weak-charged thermal DM!

# Dark Matter Candidates

Dark Matter
© Nintendo

**DM exists in form of halo associated w/ galaxy, etc.**

*I am (almost) stable, neutral, cold & weak interacting.*
*And, my weight must be in the following range!*

$10^{-22}$ eV — $2\pi/mv <$ Gal. size — $m <$ Gal. mass — $10^{40}$ g — m

## What is DM?

$10^{-22}\text{eV} < m < 10^{19}\text{GeV}$

$\lambda = 2\pi/m > 2m/M_{pl}^2$

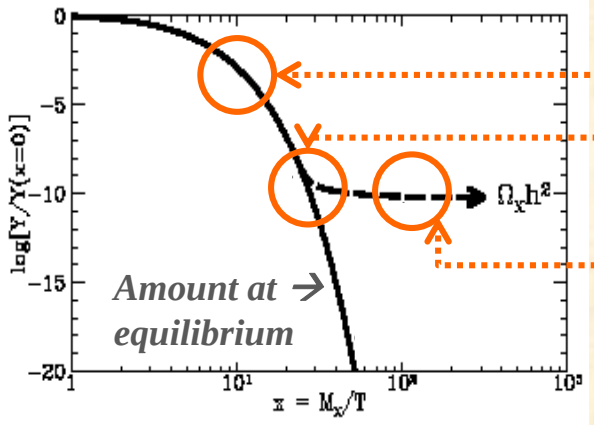
- **Particle**
  - $10^{-2}\text{GeV} < m < 10^{5}\text{GeV}$
    - **Thermal**
      - **Freeze-out**
      - **Asymmetric**
      - ●●●
    - **Non-thermal**
      - Eg. Axion, $\nu_R$, Fuzzy DM, …
- **Non-particle**
  - Eg. PBH

Motivation!

# (Freeze-out) Thermal DM candidates

DM abundance was fixed by the so-called thermal freeze-out process.

Freeze-out: Abundance of a species is determined by the competition between the expansion rate of the universe and the reaction rate to maintain equilibrium between the species and others in the universe.




DM is in equilibrium with SM particles.

DM decouples from thermal bath (SMs).

Amount of DM does not change anymore.

**Freeze-out mechanism is known to describe BBN and CMB phenomena very successfully!**

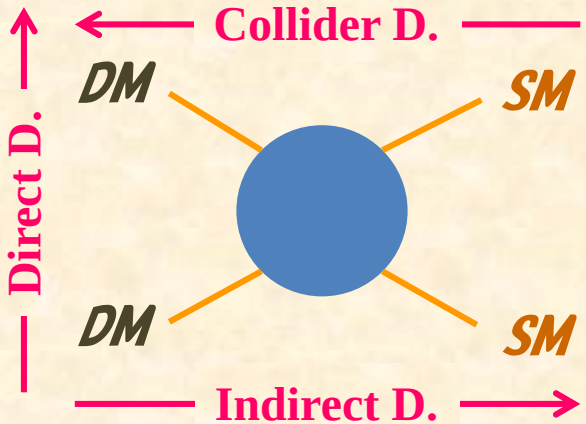
**Motivation!**

**Freeze-out**

How dark matter abundance observed today is determined?

- **WIMP-like**: DM DM ⇄ SM SM
- **SIMP-like**: 3DM ⇄ DM DM
- **Semi-ann.**: DM DM ⇄ DM SM
- • • •

# WIMP-like DM & its detection strategy



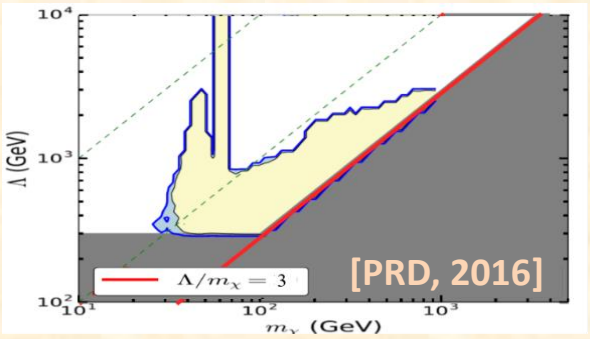

← The process maintaining chemical equilibrium. The same interaction offers the scattering between SM & DM, guaranteeing kinematical equilibrium during the freeze-out process.

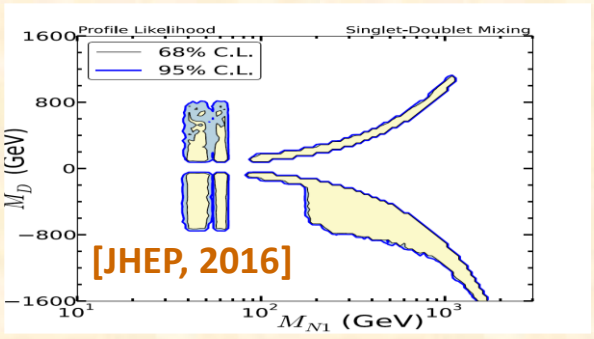
← The DM cand. most intensively studied so far. All interesting parameter region excluded?

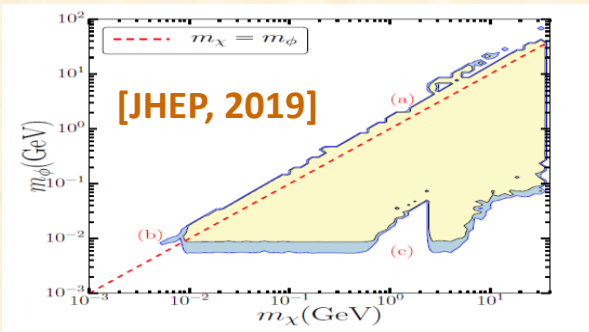
**Many types of WIMPy DM are uncharted yet because of its diversity!**

**Systematic & comprehensive studies tell us …** [S.M., Y. S. Tsai, et. al.]

1. Classifying WIMP based on its quantum numbers (spin, weak isospin).
2. Constructing a renormalizable Lagrangian with minimal contents.
3. Put all constraints obtained so far and relic abundance condition.




→ Light WIMP, Leptophilic WIMP, (CPV) H-portal, Weak-charged WIMP.

# Weak-charged WIMP and its properties

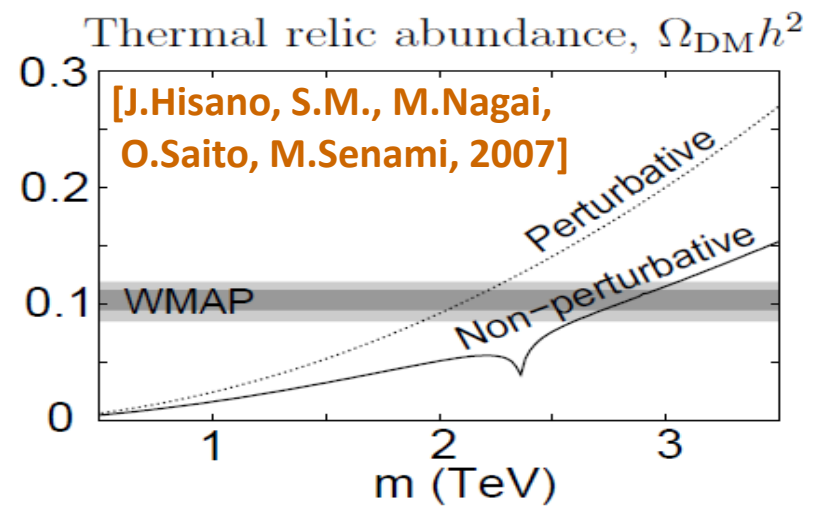
**Weak-charged WIMP dark matter**

= The one described by a field of a neutral component in a non-trivial SM $SU(2)_L$ multiplet!

- ✓ The state of DM is close to a gauge eigenstate of the weak interaction.
- ✓ A small mixing effect can be taken into account by higher-dim. Ops.

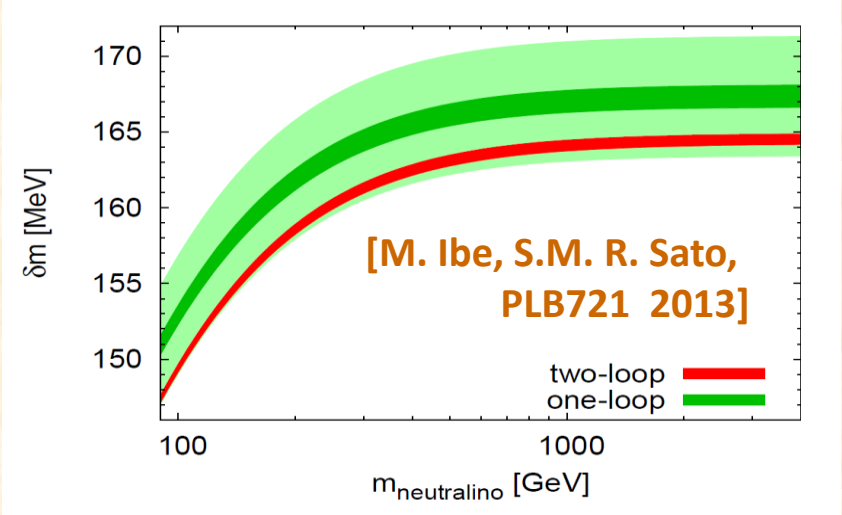
| U(1) \ SU(2) | 1 | 2 | 3 | 4 | 5 … |
|---|---|---|---|---|---|
| 0 | (OK) | | OK | | OK |
| ±1/2 | | OK | | OK | |
| ±1 | | | OK | | OK |
| ±3/2 | | | | OK | |
| ±2 | | | | | OK |
| ⋮ | | | | | |

**The mass is predicted to be O(1)TeV!**



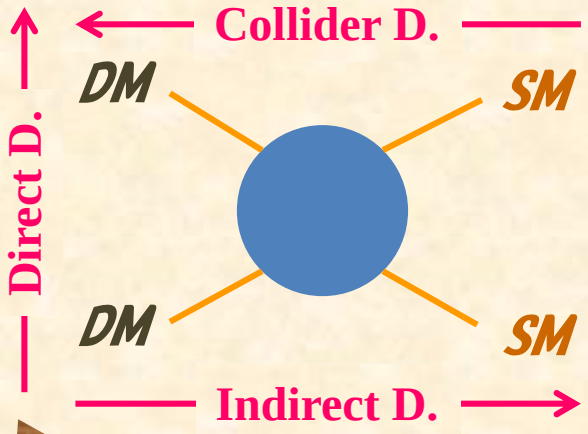

**NLO calculation needed. →Tobias's talk**

**Degeneracy among the component!**

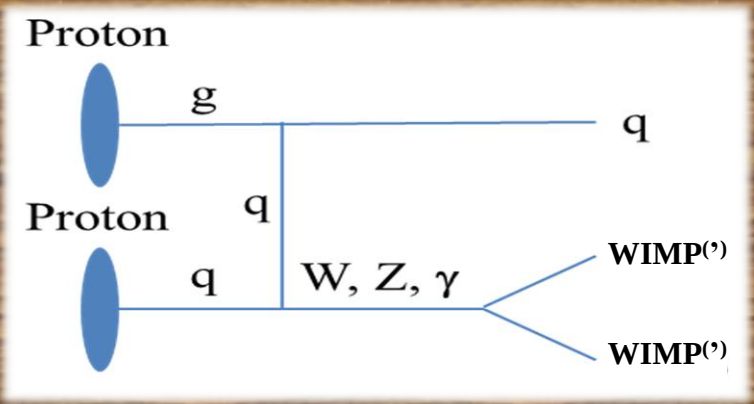



**Difference is O(100)MeV! → ∃LLP**

# Why they are not detected so far?

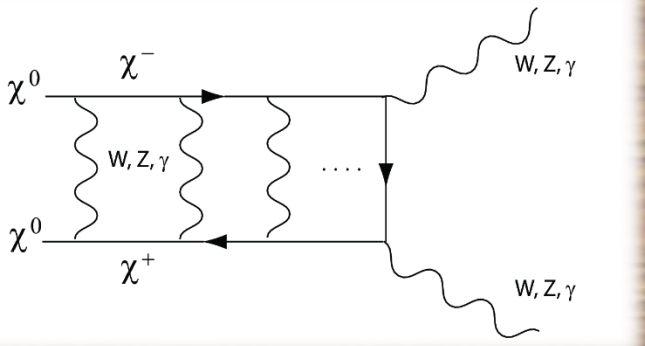



[S. Asai, T. Moroi, K. Nishihara, T. T. Yanagida, 2007]



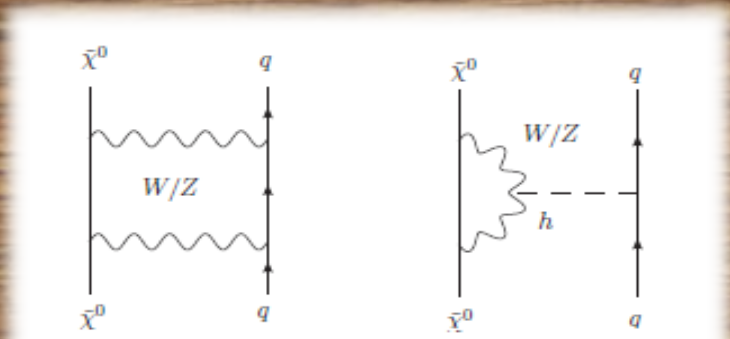

Too heavy & too degenerate @ LHC.
Use of LLP (charged one) required.

[J. Hisano, S. M., M. M. Nojiri, 2004]




Boosted by Sommerfeld effects.
Heavy and Uncertainty of astro.

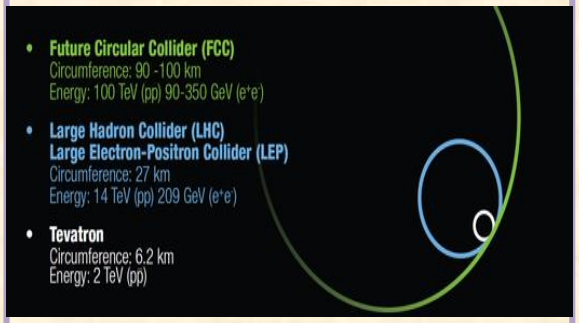
[J. Hisano, S. M., M. M. Nojiri, O. Saito, 2005]




LO contributions are suppressed.
Dedicated NLO calculation needed.

# Toward the detection of weak-charged DMs

## Colliders



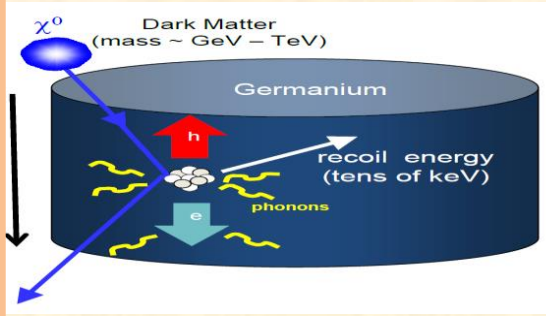

How large s needed?
What proc efficient?
Talks 12th morning!

## Theory

| U(1) \ SU(2) | 1 | 2 | 3 |
|---|---|---|---|
| 0 | (OK) | | OK |
| ±1/2 | | OK | |
| ±1 | | | OK |

What are Motivations?
Their phenomenology?
Takeo/Satoshi's talks!

## Direct D.




Future sensitivities?
Go beyond Nu floor?
Many Talks today!

## Indirect D.

What is the target?
Observation time?
Talks 13th morning!

## DM distributions

- ✓ Local DM distribution at ⊙,
- ✓ DM distribution @ Gal. Cent.
- ✓ DM distribution @ satellites.

Dr. Hiroshima talk
Shunichi's poster
Prof. Iocco's talk
Prof. Gelmini's talk
Prof. Salucci's talk

# Summary

- We know little about microscopic nature of dark matter, e.g. its mass is merely predicted to be within range of $10^{-55}$g to $10^{40}$g. So, many dark matter candidates (such as particle/non-particle, thermal/non-thermal, etc.) are now being studied intensively,

- Among various candidates, a thermal dark matter having a weak charge attracts attention, as it is well motivated from theories of EW symmetry breaking, and has an inherent feature making it difficult to be observed at current dark matter detections.

- I have briefly reviewed the dark matter focusing on a universal property that weak-charged dark matters have. More detailed property depending on each weak charge as well as theoretical motivation for each case will be discussed in following talks!