Weak-charged WIMP

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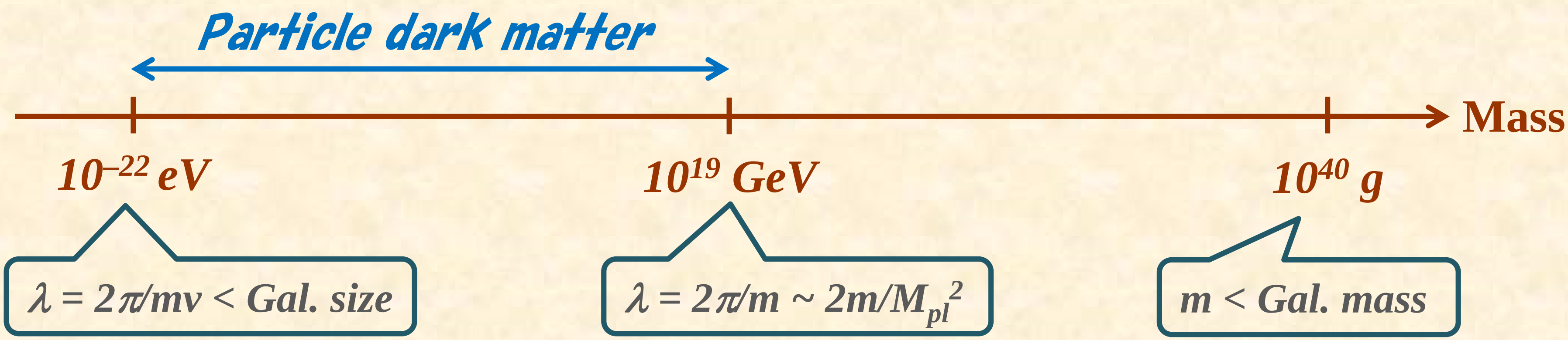
Collaborators: Members in IPMU WIMP PROJECT

Weak-charged WIMP recently attracts many attentions.
We introduce the WIMP focusing on following questions:
Why it is attractive and how it can be tested in future.

Dark matter hypotheses



Experimental/Observational anomalies

Dark matter hypotheses

Sterile ν, SIMP, ADM, FIMP, Axion, Fuzzy DM, WIMP, pBH

Motivations from new physics models

Phenomenological test of each ansatz. (Present S. & Future P)

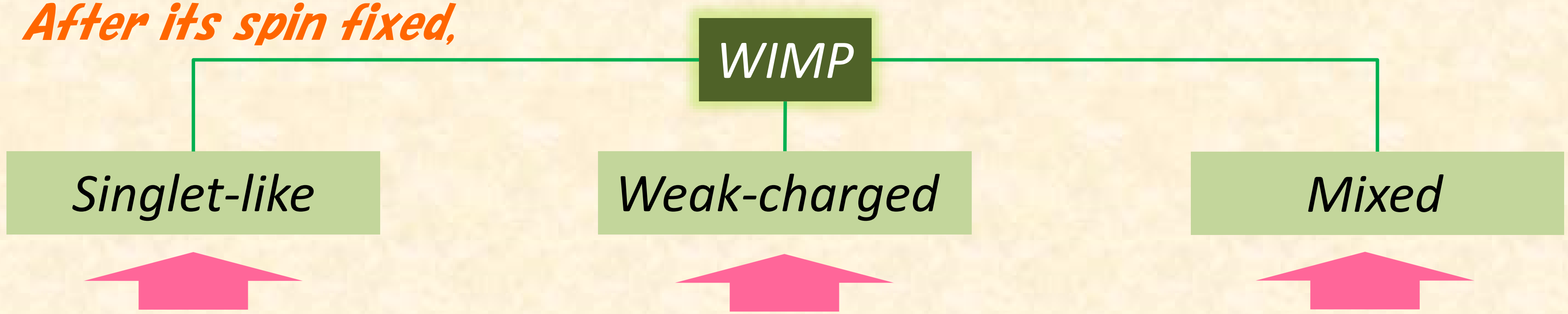
WIMP hypothesis

"Dark matter is a massive, stable and electrically neutral particle, and was in a thermal equilibrium with SM particles in the early universe."

There are many types of WIMP, depending on those quantum numbers.

→ Classification of WIMP in terms of its spin and isospin!

After its spin fixed,



Unexplored well.
Good motivation?

Vert attractive!!!

being excluded by
direct detections.

Weak-charged WIMP (Triplet WIMP)

$$\mathcal{L} = \mathcal{L}_{\rm SM} + \frac{1}{2}\bar{T}\,(\not{D} - M_T)\,T$$

[Z_2 symmetry imposed]

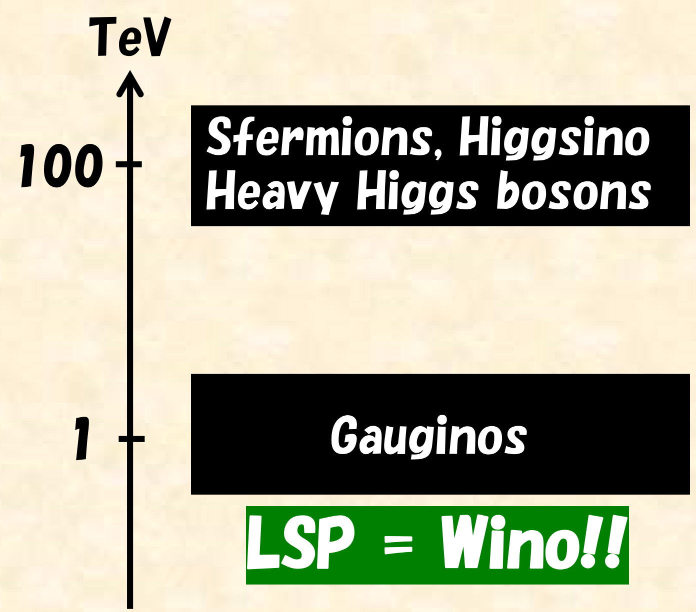
DM physics governed by $SU(2)_L$
One new physics parameter M_T

Theoretical motivation … Anomaly mediated SUSY breaking scenario

It is know to be the simplest SUSY breaking model consistent with cosmology!

MSSM --- Simplest mediation / w/o singlet → ~~SUSY~~

- ✓ Split SUSY spectrum predicted.
- ✓ Wino (Triplet WIMP) is the LSP.
- ✓ Its mass is predicted to be 3TeV!
- ✓ m_{LSP} is O(1)TeV → M_{SUSY} is O(100)TeV.
- ✓ Hiss mass is predicted to be 125GeV.
- ✓ Avoid serious SUSY flavor problems.
- ✓ Free from any cosmological problems.



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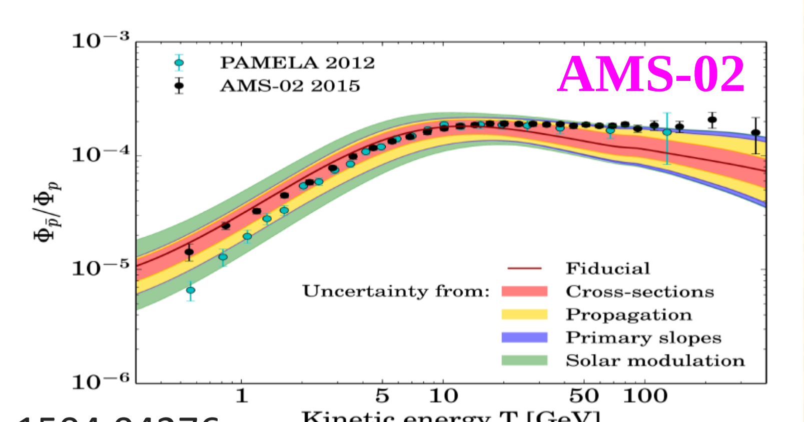
Phenomenological motivation ··· Anti-proton flux observed at AMS-02.

It is consistent with BG, but there is a trend of the deviation at E > 100GeV.



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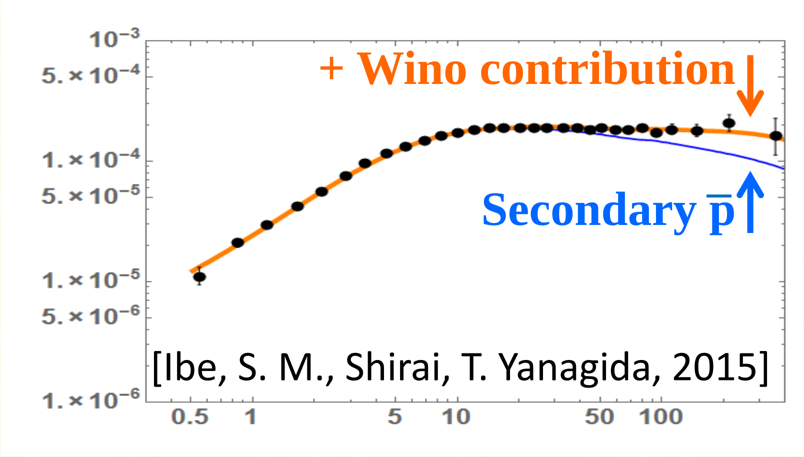
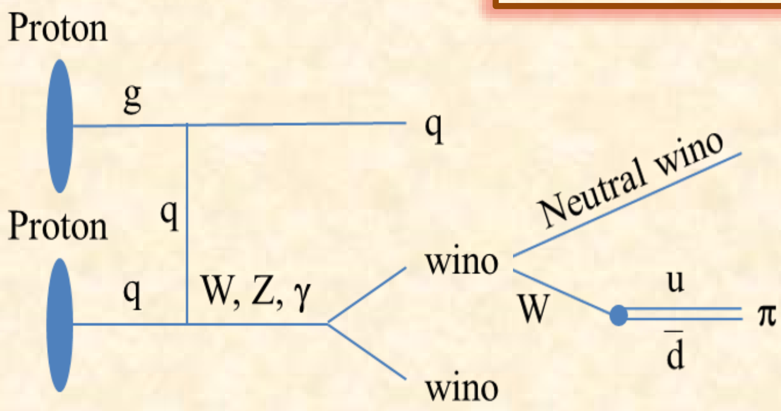
⇔



If we include the Triplet WIMP contribution, the fitting becomes better.
(There is no new physics parameters we can vary, for m_T = 3TeV.)

How we can test the triplet WIMP?

Search @ Collider experiments



Disappearing charged track search

Current limit (13TeV LHC)

→ m_T < 460GeV

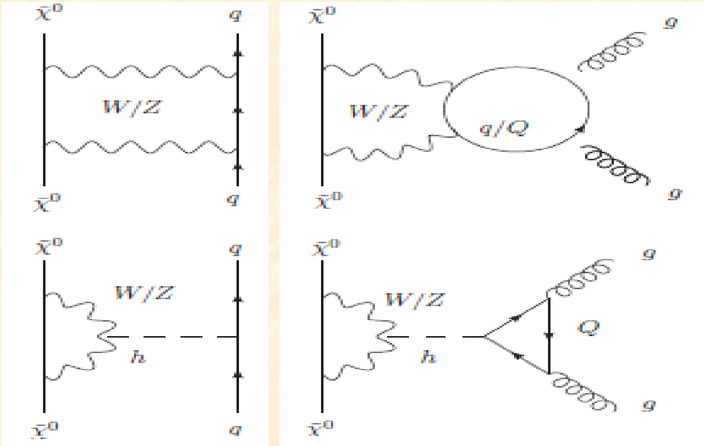
Future-expected limit (HL-LHC)

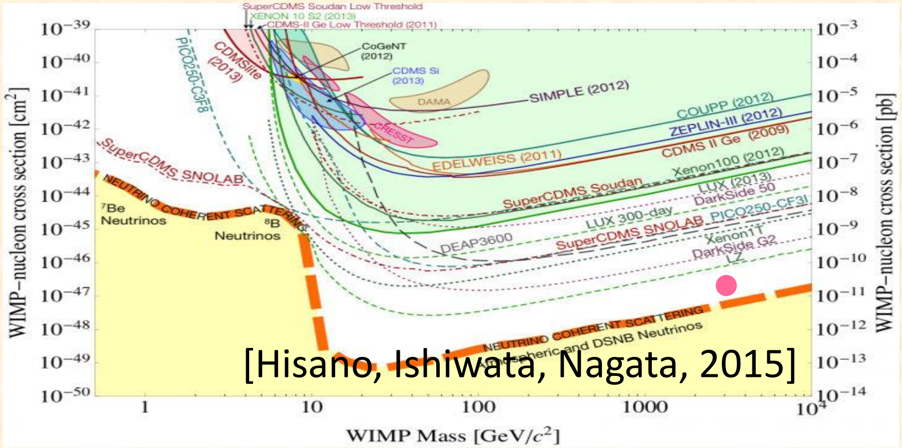
→ m_T < 1TeV

Future-expected limit (100TeV pp)

→ m_T < 3TeV

Search @ Direct detections





[Hisano, Ishiwata, Nagata, 2015]

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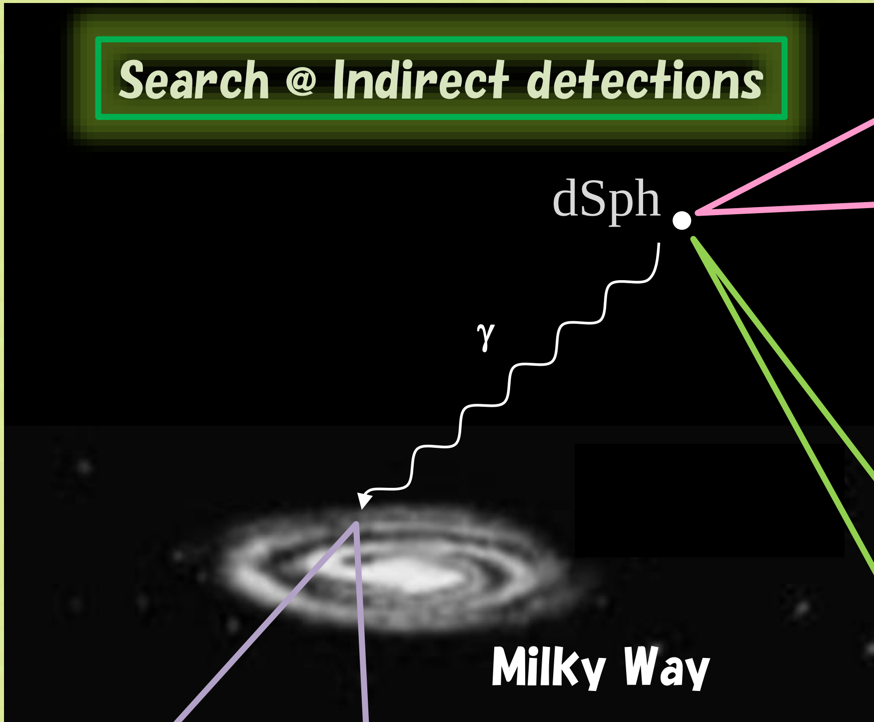

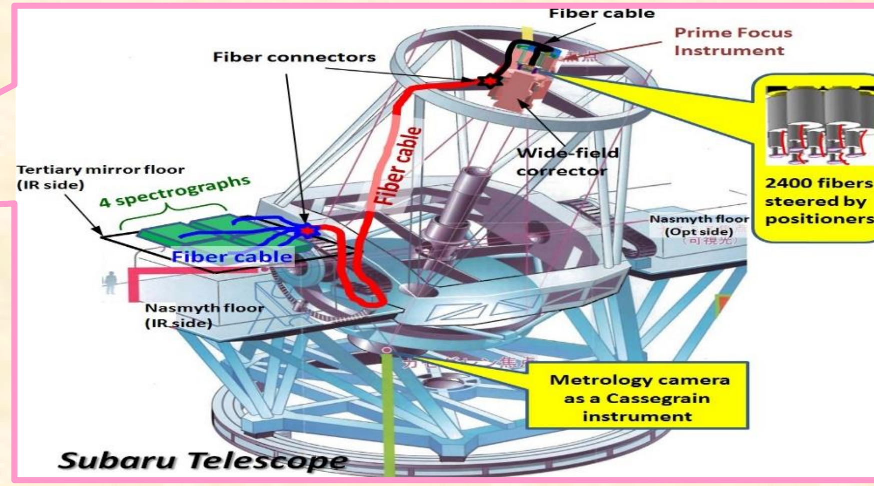

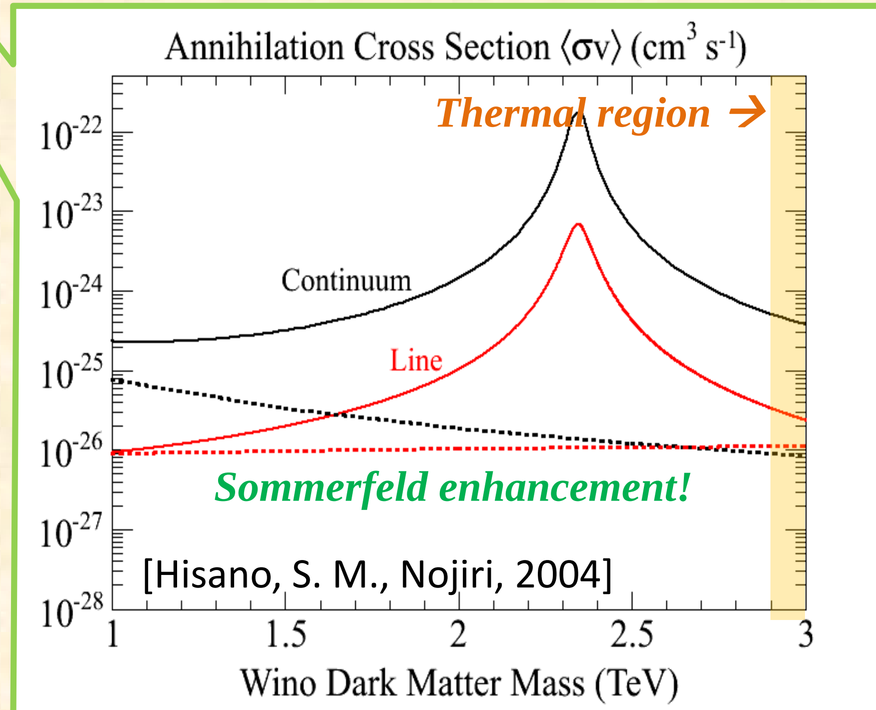

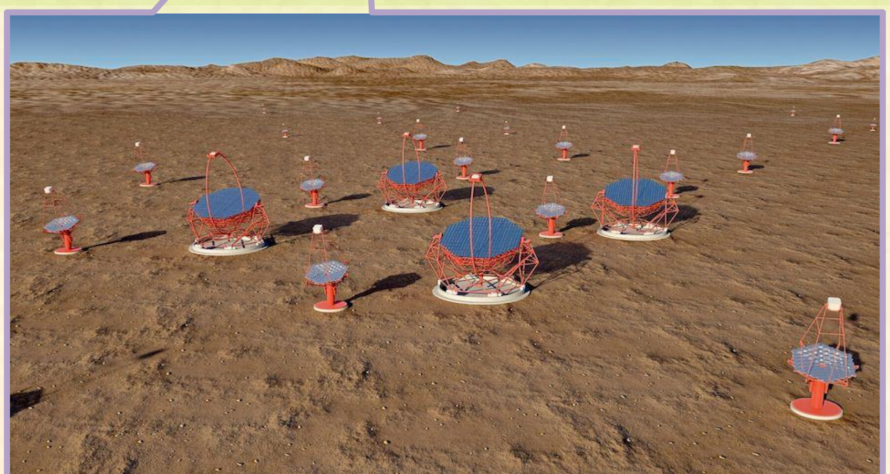

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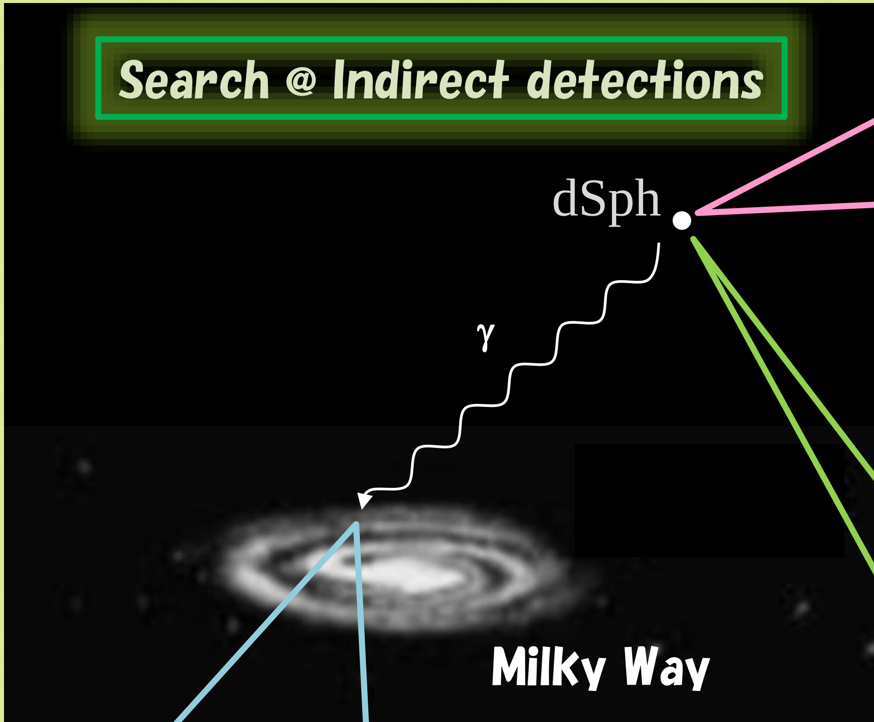

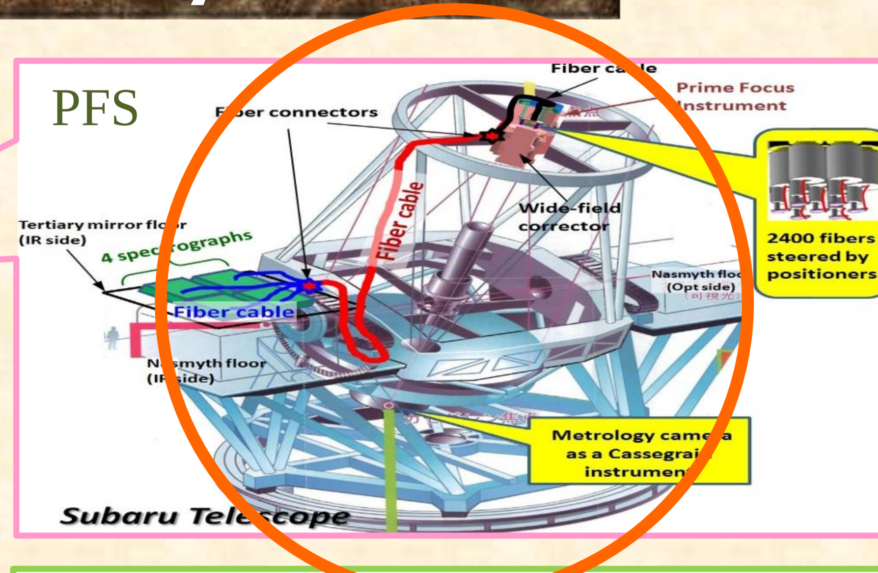

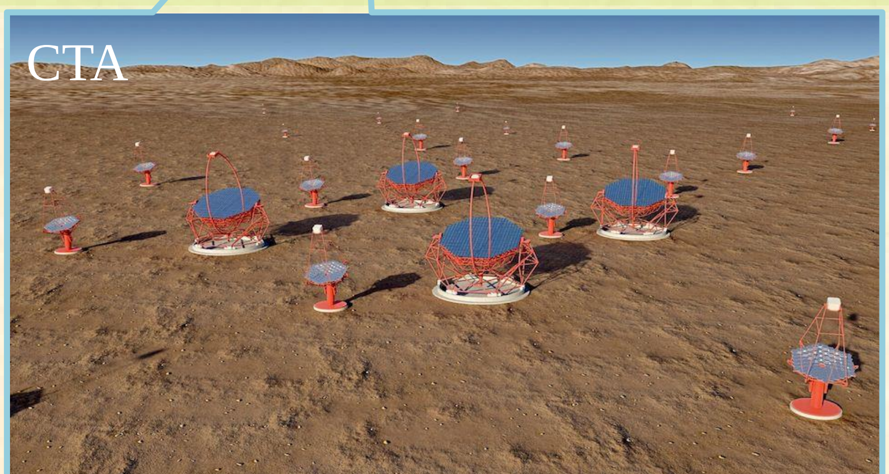

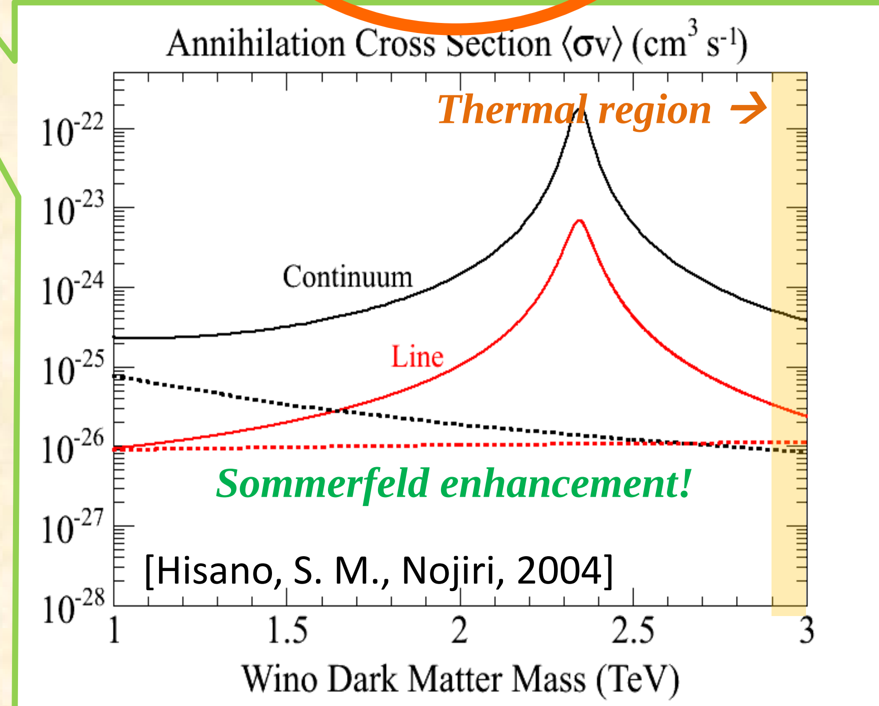

How we can test the triplet WIMP?

Theory side

Collisionless Boltzmann eq.

⇓

Jean's equation derived.

Distribution of member stars [f(x, v) of the member stars]

↕

DM mass distribution [ρ(x)]

Bayesian analysis ↔

Observation side

Astrophysical observations

Photometric data:
Locations of the member stars, etc. are obtained.

Spectroscopy data:
Velocity of the member stars, etc. are obtained.

DM profile ρ(x) obtained. → J-factor is evaluated as the pdf of the analysis.

Systematic errors associated with the J-factor determination

- ✔ The systematic error coming from the non-spherical nature of dSphs.
- ✔ The systematic error coming from the contamination of foreground stars.
- ✔ The systematic error coming from binaries composed of member stars.
- ✔ The systematic error coming from asymmetry of velocity dissipations.

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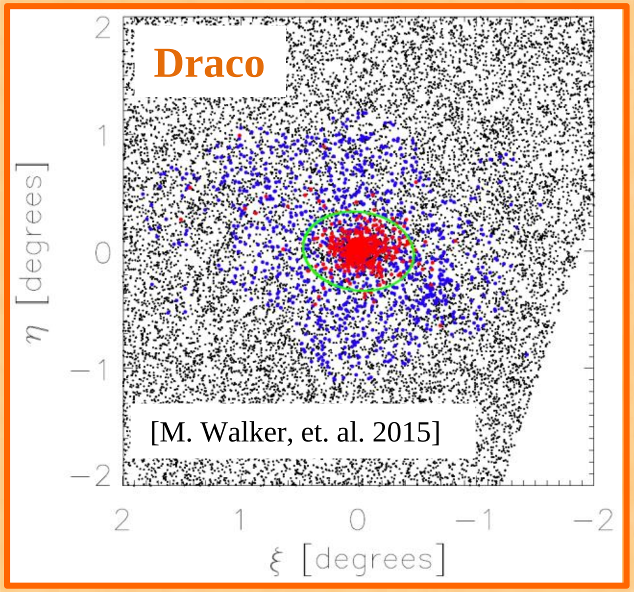

[M. Walker, et. al. 2015]

Several ways to deal with the contamination:

1. Cut-based identification of member stars, which is used for the most of UF dSphs.
2. EM method to put a membership probability, which is currently used for CL dSphs.
3. KI method (that we have recently proposed.), which is based on the one LHC is adopting.

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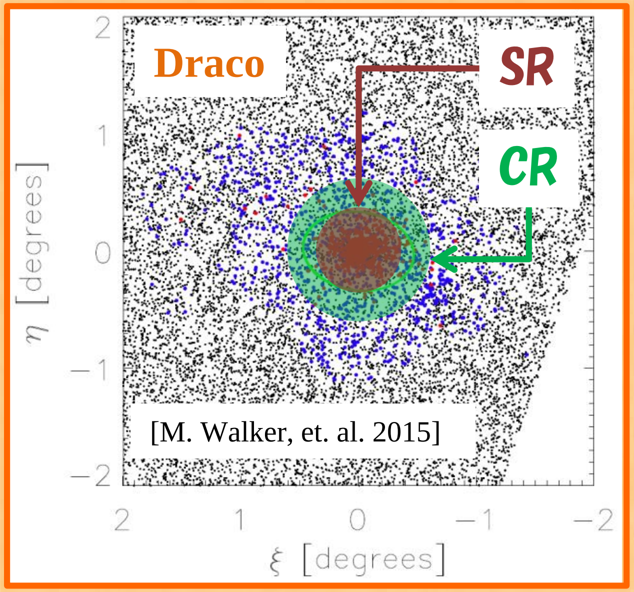

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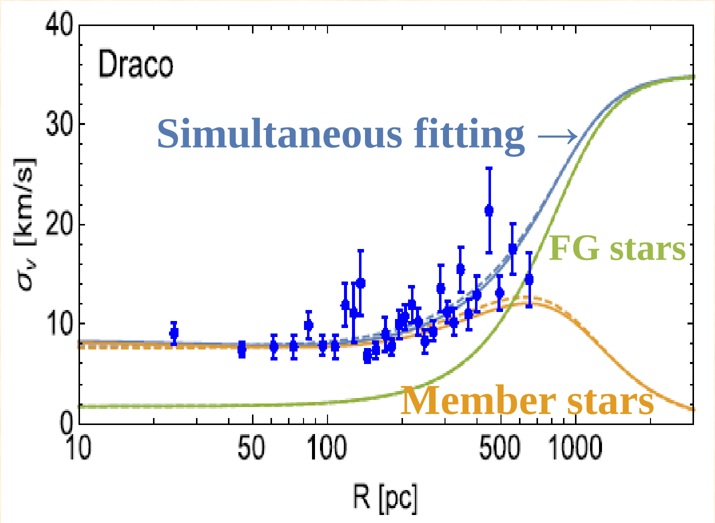

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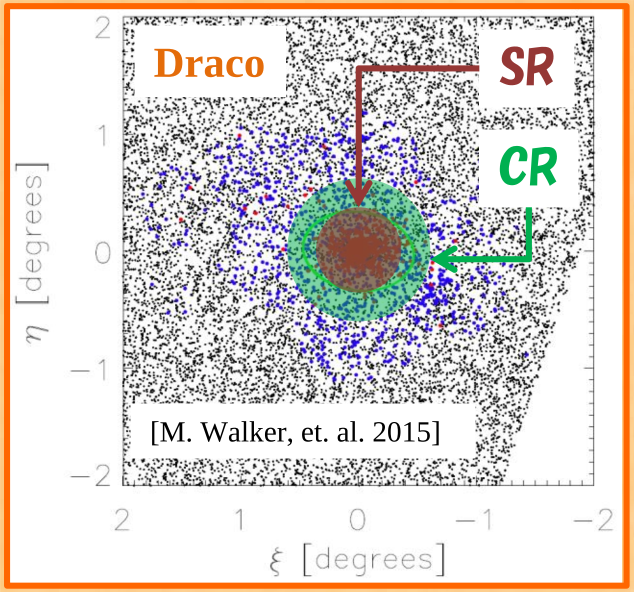

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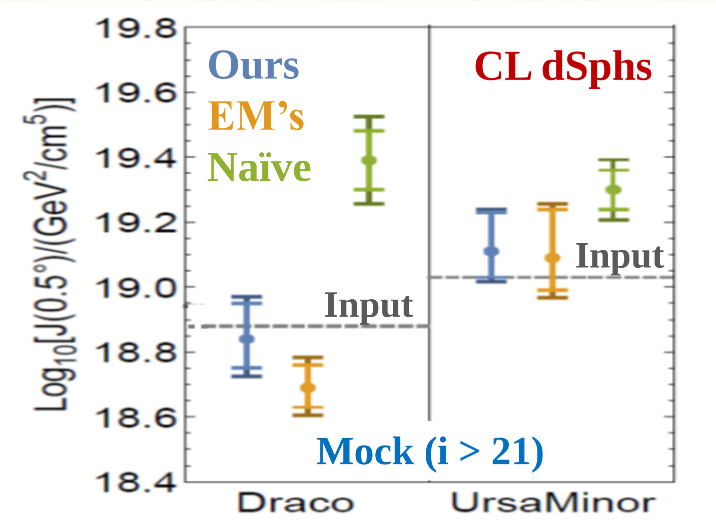

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- ✓ EM method also reproduces the input, though some systematic errors remain.
- ✓ Cut-based one always overestimates the input. The trend becomes more sizable for fainter dSphs UF dSphs). Remember the nightmare of Segue 1!

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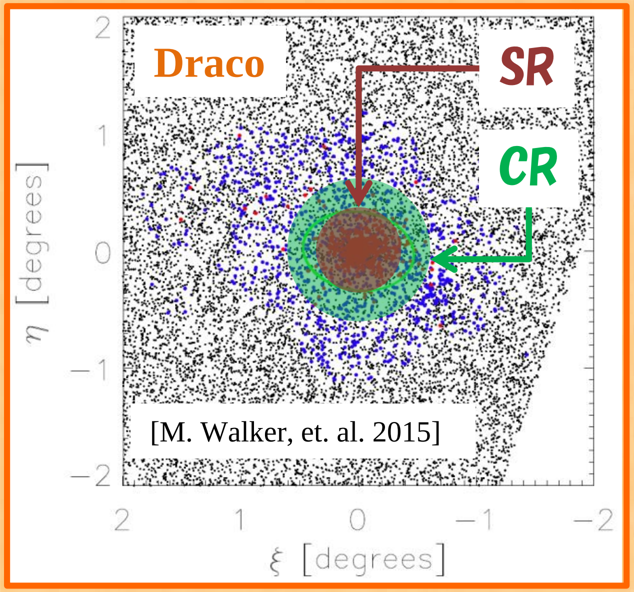

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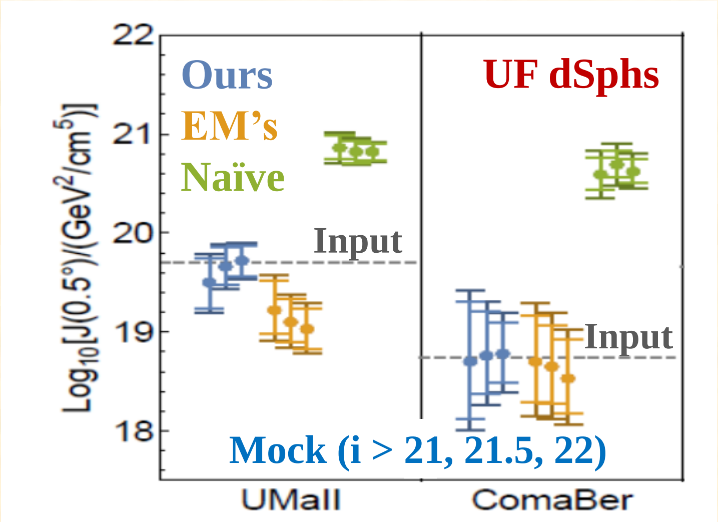

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Summary

- WIMP which has a weak charge attracts many attentions after the Higgs discovery. Only indirect dark matter detections allow us to detect the WIMP in near future, for it has O(1)TeV mass.
- Among various indirect dark matter detections, the observation of gamma-rays from dSphs are the most robust one to detect the signal of, or to put a constraint on the TeV scale WIMP.
- It is important to predict the signal flux for this purpose, and it requires the careful estimation of J-factors involving the treatment of FG star contamination and the DM & stellar non-sphericity, etc. Future spectroscopic measurements such as the PFS in the SuMIRe project will play a very important role!

Backup (Triplet-like Fermion WIMP)

Field Theory Lagrangian of WIMP

$$\mathcal{L} = \mathcal{L}_{SM} + \bar{T}\left(i\gamma^{\mu}D_{\mu} - \mathrm{M_T}\right)T$$

↓

Non-relativistic expansion and introducing a 'composite' field describing WIMP 2-body states.

↓

The Schrodinger eq. is obtained as EOM of the composite field.

$$[-\nabla^2/m + V(r)]\psi(r) = 0$$

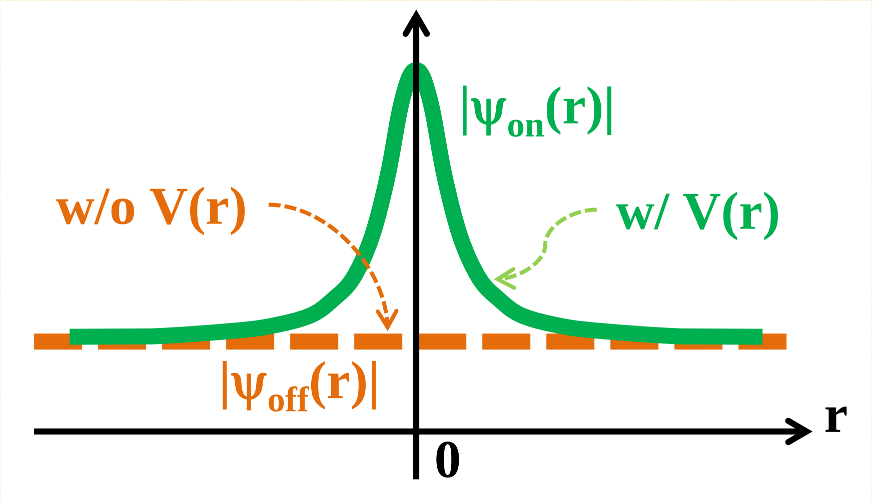
↓

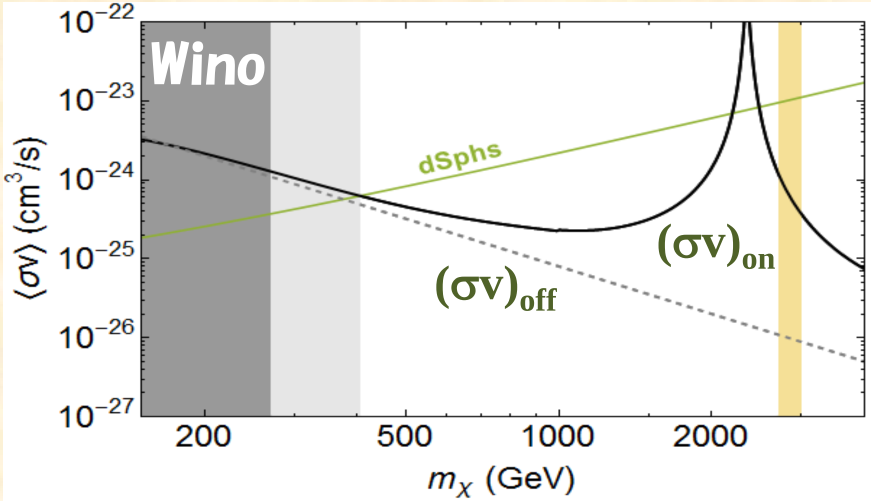
WIMP Annihilation cross section is obtained by the formula:

$$(\sigma v)_{on} = (|\psi_{on}(0)|^2/|\psi_{off}(0)|^2)\ (\sigma v)_{off}$$

↓

Weak long-range force increase the wave function at origin, for it acts as a attractive force!!!





[J. Hisano, S. M., M. Nagai, M. Nojiri, O. Saito, M. Senami, 2004-2007.]