TeV scale WIMP and Astrophysics

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The purpose of this study is to accurately estimate the so-called 'J-factors' (astrophysical factors) of dSphs for indirect detections (γ-ray) of the TeV scale WIMP.

TeV scale WIMP

Various WIMP possibilities → Limits from LHC & direct detections →

- ✓ $SU(2)_L$ (weak) charged WIMP
- ✓ WIMP with a light mediator
- ✓ Leptophilic WIMP, etc.

Among the remaining parameter regions, a fermionic WIMP having a weak charge (close to a non-singlet $SU(2)_L$ gauge eigenstate) is well-motivated from the new physics viewpoint (e.g. Higgsino or Wino WIMP in MSSM).

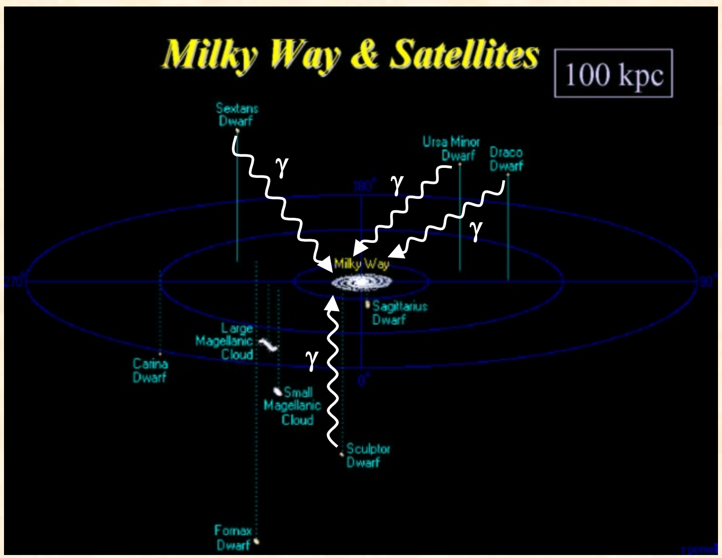
Generic property of such a WIMP ($SU(2)_L$ charged WIMP) is as follows:

1. Its mass is predicted from WIMP miracle mechanism to be around the TeV scale due to the weak interaction. It degenerates with its $SU(2)_L$ partner.
   → The WIMP is hard to be detected at collider experiments in near future.
2. The WIMP has a very suppressed WIMP-WIMP-Higgs coupling (and also a WIMP-WIMP-Z coupling), for it is close to a $SU(2)_L$ gauge eigenstate.
   → The WIMP is hard to be detected at direct detections in near future.
3. Annihilation between the WIMPs is boosted very much thanks to the so-called Sommerfeld enhancement effect [J. Hisano, S. M., M. Nojiri, 2004].
   → The WIMP is efficiently detected at indirect detections in near future.

Indirect detection

Among various indirect dark matter detections, observing gamma-rays from the WIMP annihilation in dSphs is the most robust and efficient detection:

- We can expect enough strong signals, for dSphs are located very close to us and they are also known to be dark matter rich astrophysics objects.
- BGs against the signals are suppressed, for there are few astrophysical activities in dSphs. Main BG is from cosmic-ray induced γs in our galaxy.



Gamma-ray flux formula from each dSph.

$$\Phi(E,\Delta\Omega) = \left[\frac{\langle\sigma v\rangle}{8\pi m_{DM}^2}\sum_f b_f \frac{dN_\gamma}{dE}\right] \times J_{\Delta\Omega}$$

$$J_{\Delta\Omega} = \int_{\Delta\Omega}\int_{\rm l.o.s} d\ell d\Omega\ \rho^2(\ell,\Omega)$$

To detect or put a robust limit on the WIMP, it's mandatory to have the flux accurately!

However, the estimation of the J-factor, which is obtained by the WIMP mass distribution squared inside each dSph galaxy, has a large uncertainty!!!

Estimating the J-factors

Theory side

Collisionless Boltzmann eq.

⇓

Jean's equation derived.

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

↕

DM mass distribution [$\rho(x)$]

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 $\rho(x)$ obtained. → J-factor is evaluated as the pdf of the analysis.

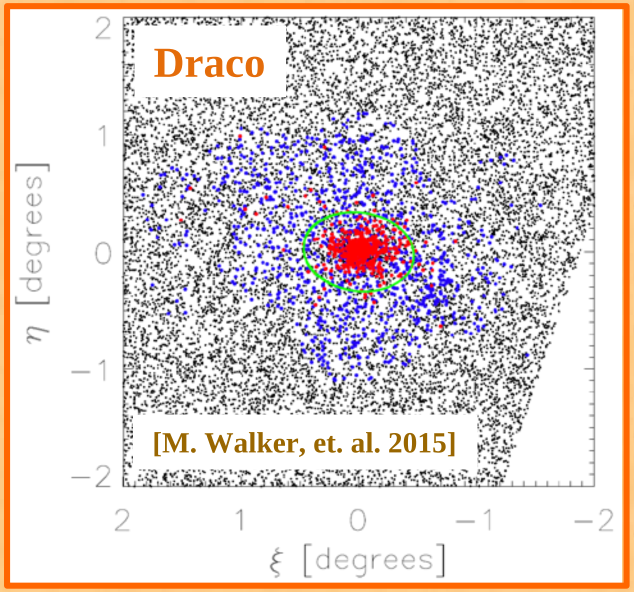
Current analysis does not include several systematic errors!!!

Most of the errors will be negligibly small when data is accumulated enough.

However, there are some intrinsic errors not improved:

- ✔ The intrinsic error from the subtraction of foreground stars.
- ✔ The intrinsic error from the spherical assumption of dSphs.

Subtracting FG stars

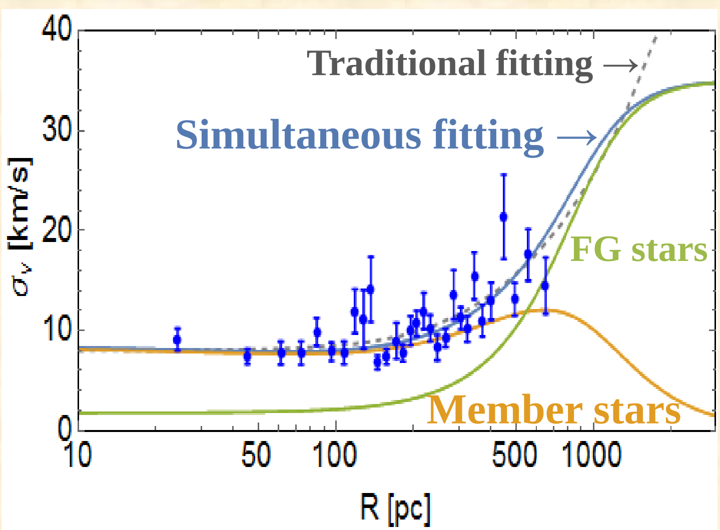


← Stars by photometric color-magnitude criteria.
Stars selected by spectroscopic observation.
Probable member stars by stronger criteria.

The contamination of the foreground (FG) stars increases more at the outer region of the dSph.

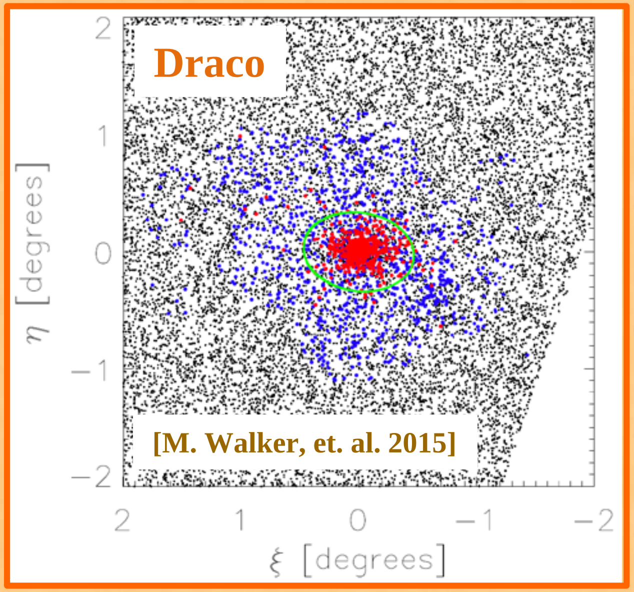
The contamination makes the dSph mass heavier, leading to the overestimation of the J-factor.

We have developed a method to solve it based on simultaneous fitting of the member & FG stars!!



✓ The simultaneous fitting method works well for both member and FG stars.

Subtracting FG stars



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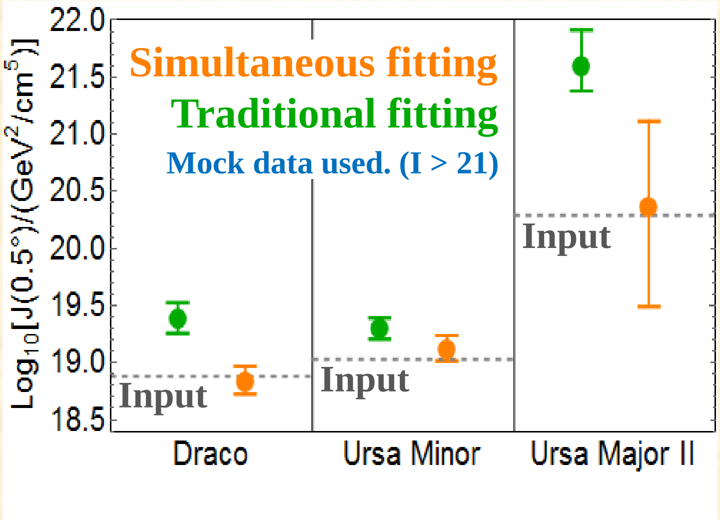


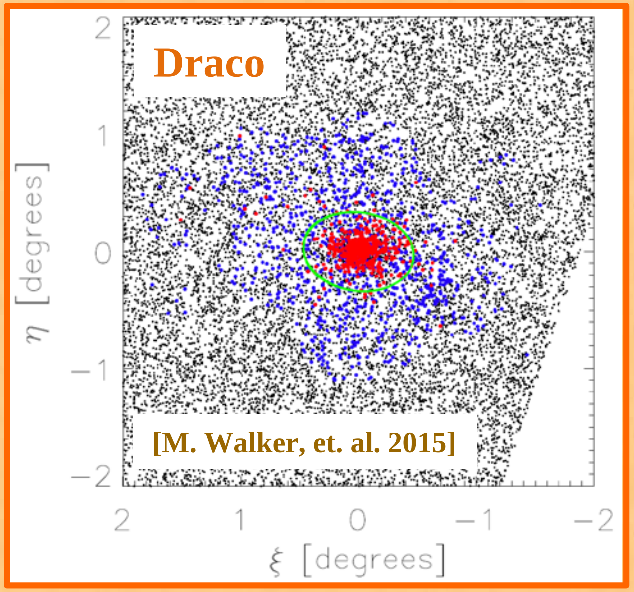
✓ The simultaneous fitting method works well for both member and FG stars.

✓ The traditional fitting method tends to overestimate the J-factors of dSphs.

✓ The simultaneous fitting method gives the J-factors of dSphs correctly.

✓ The contamination of FG stars becomes more & more serious for fainter dSphs.

Non-sphericity of dSphs



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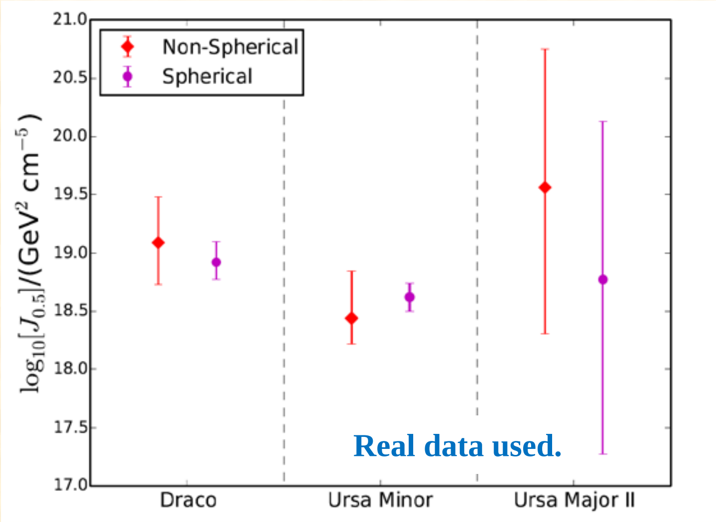
Another notable systematic error is from the shape of dSphs: the non-sphericity of dSphs.

In the most of studies performed so far, dSphs are assume to have a complete spherical from.

We have studied the effect of non-sphericity by using axisymmetric DM/Star distributions.



- ✓ The axisymmetric model always gives better fitting than the symmetric one.
- ✓ Central values of the J-factors does not seem to be altered significantly.
- ✓ Errors of the J-factors are increased for the CL dSphs (2-3 times larger).
- ✓ Errors of J-factors for the UF dSph seems to be governed by statistics.

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, observation of gamma-rays from dSphs are the most robust one to detect 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 the J-factor involving the treatment of the DM/stellar non-sphelicity and FG stars.