Estimating J-factors of dSphs for indirect dark matter detections

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[arXiv:1603.08046 (Mon. Not. Roy. Astron. Soc.)]

The purpose of this study is to accurately estimate the so-called 'J-factors' (astrophysical factors) of the gamma-ray fluxes from WIMP annihilation in dSphs.

Motivation

Various WIMP possibilities → Limits from LHC & direct detections →

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

Among the remaining parameter regions, WIMP having a weak charge (WIMP which is 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).

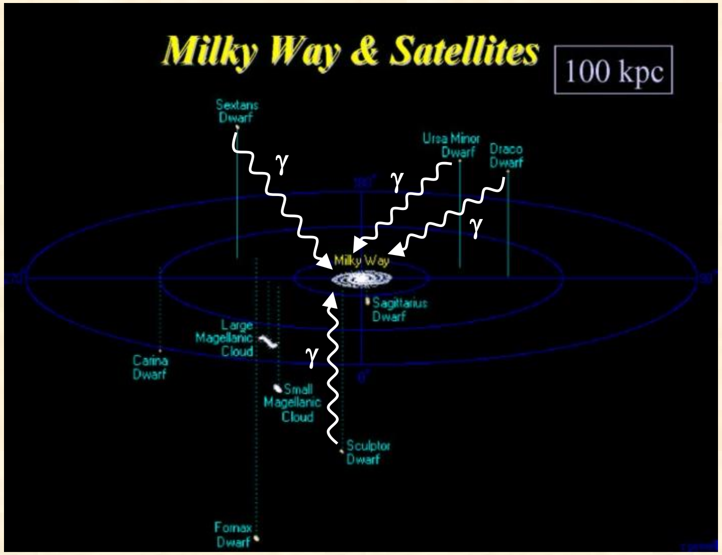
Generic property of such a WIMP ($SU(2)_L$ charged WIMP) is as follows:

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.

Motivation

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

- 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.

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

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

Estimation of the J-factor, which is from the WIMP mass distribution squared inside each dSph, has a large uncertainty.

In order to detect or put a robust constraint on the WIMP, it is important to estimate the gamma-ray flux (in particular, the J-factor) accurately!

Estimating J-factors

Theory side

- ✓ DM distribution
- ✓ Stellar distribution
- ✓ FG star distribution

→

Bayesian analysis of velocity distribution along the line of sight.

←

Observation side

- ✓ Photometric data
- ✓ Spectroscopy data
- ✓ FG star rejection

↓

Posterior distribution of the J-factor

However, several intrinsic systematic errors are currently ignored!!!

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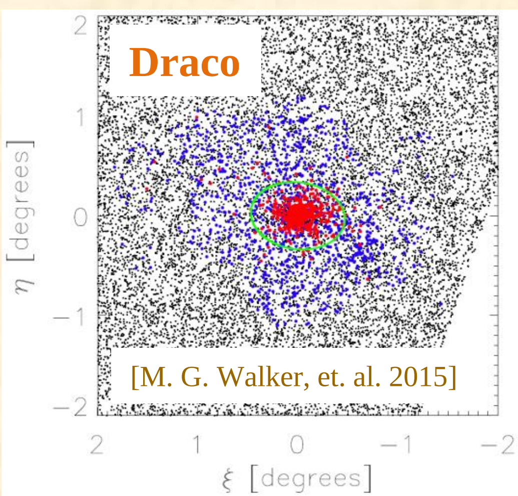
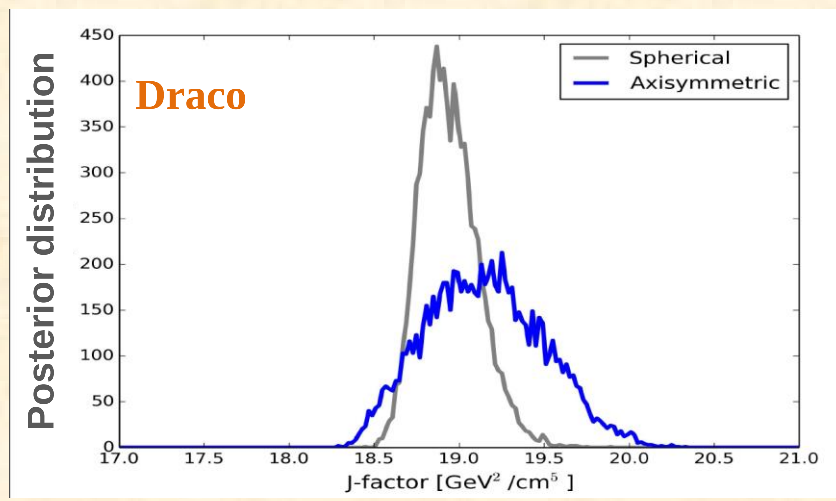
Spherical dark matter and stellar distributions are assumed so far. Is this OK?



Axisymmetric → fitting
(Real data used.)



Does it look spherical?

Better fit is from the axisymmetric one.

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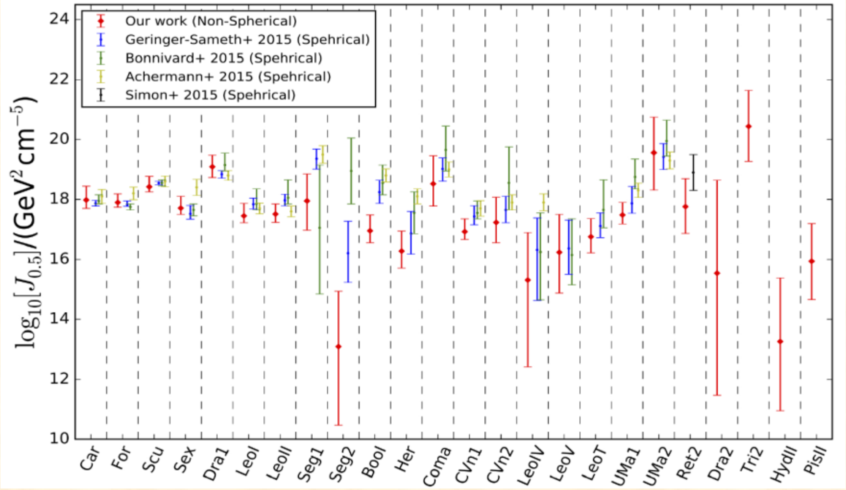

J-factors for various dSphs

- ✓ The axisymmetric model always gives better fitting than symmetric one.
- ✓ The axisymmetric model gives smaller J-factors than symmetric one.
- ✓ Uncertainties of the J-factors are increased in the axisymmetric model.

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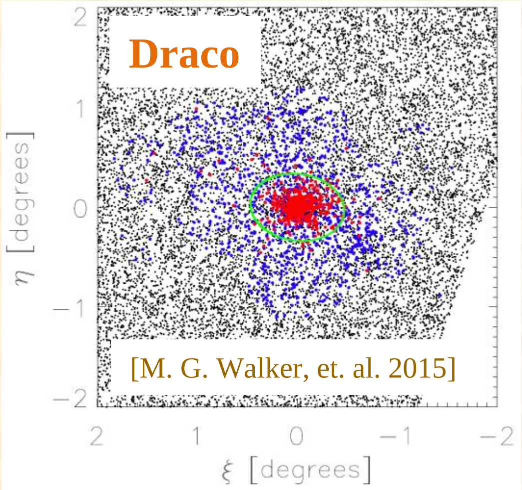
Posterior distribution of the J-factor

However, several intrinsic systematic errors are currently ignored!!!

There is the contamination of FG stars in the analysis so far. Is this OK?



At least, 5% contamination.

Estimating J-factors

Theory side

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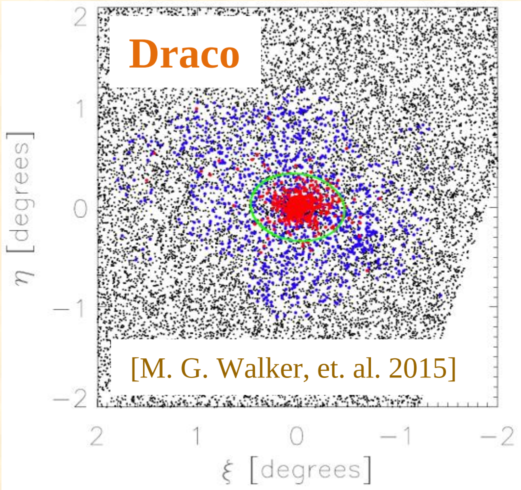
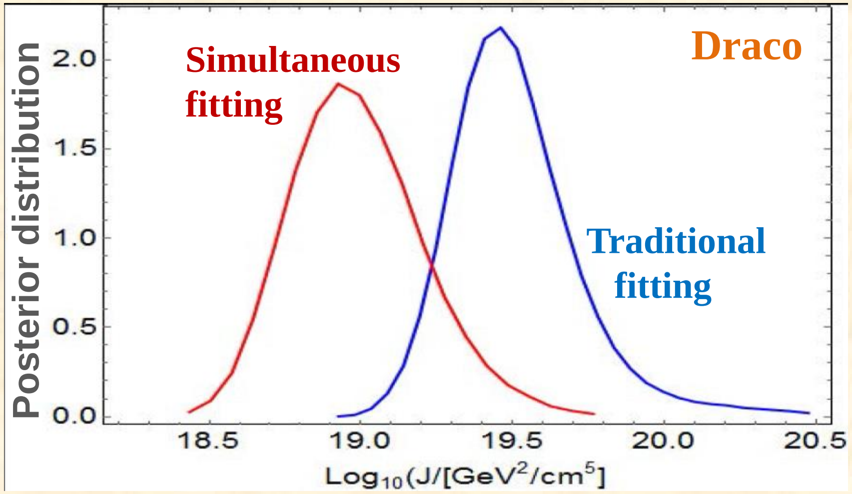


Simultaneous → fitting
(Mock data used.)



At least, 5% contamination.

Small contamination gives a strong bias.

Estimating J-factors

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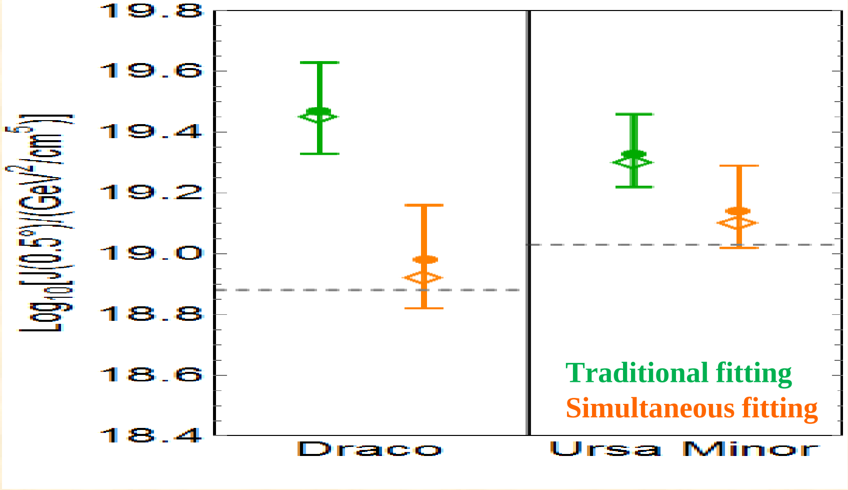

J-factors for Draco & Ursa minor

- ✓ Traditional fitting overestimates the value of the J-factor. Horizontal line is the input value of the J-factor.
- ✓ The simultaneous fitting gives the J-factor consistent with the input.
- ✓ The problem of the traditional one is more serious for ultra faint dSphs.

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 if 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 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 dark matter/stellar elasticity and FG stars.