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Dependence of accessible DM annihilation cross-sections on the density profile of dSphs

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Contents:

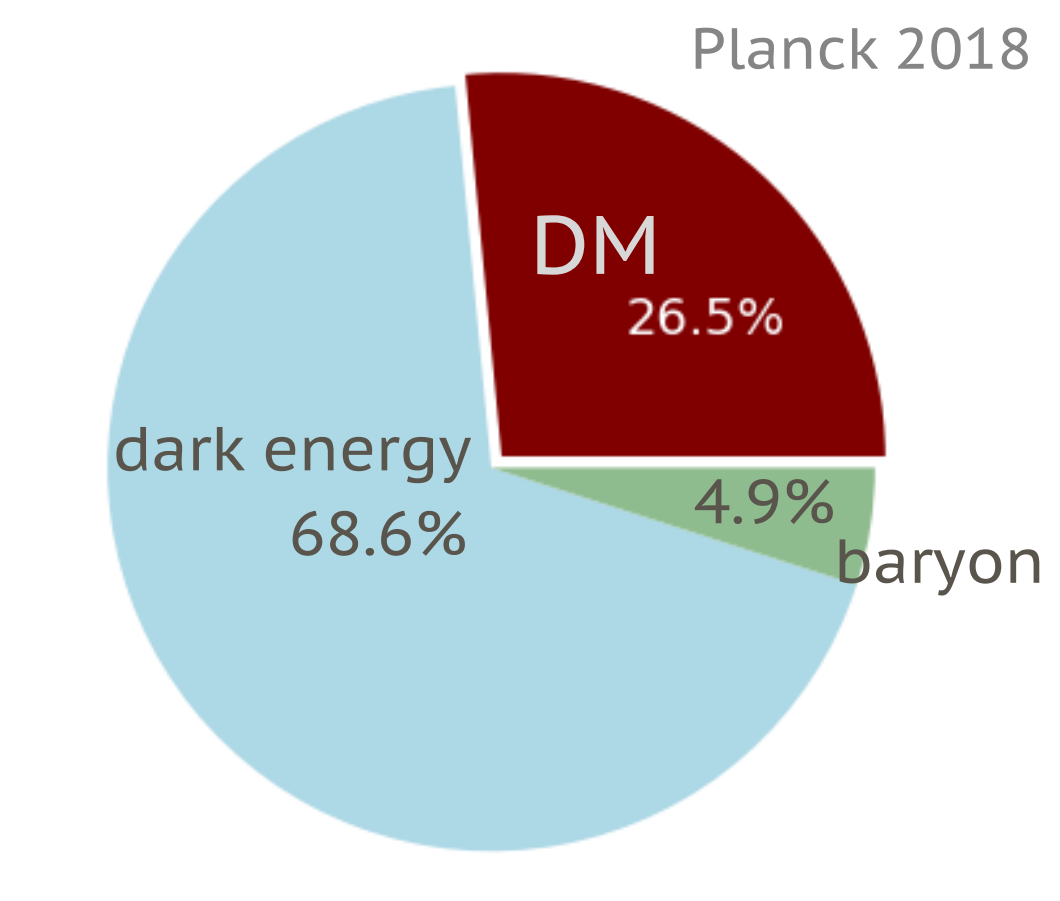
Introduction

Why is it important to consider DM distributions?

Dark Matter (DM):

Dark Matter (DM) is

- cold
- non-baryonic
- (almost) neutral
- (almost) invisible



matter components of the Universe occupying ~25% of its total energy density

WIMP:

- Weakly Interacting Massive Particle
- achieve the relic abundance via the thermal freeze-out mechanism
- the mass $m_{\mathrm{DM}} \sim \mathcal{O}(\mathrm{GeV}) - \mathcal{O}(\mathrm{TeV})$
- the annihilation cross-section

  $\langle \sigma v \rangle \sim \mathcal{O}(10^{-26} \mathrm{cm}^3 s^{-1})$

We do not see the annihilation signature yet.

γ-ray search:

DM + DM -> SM + SM

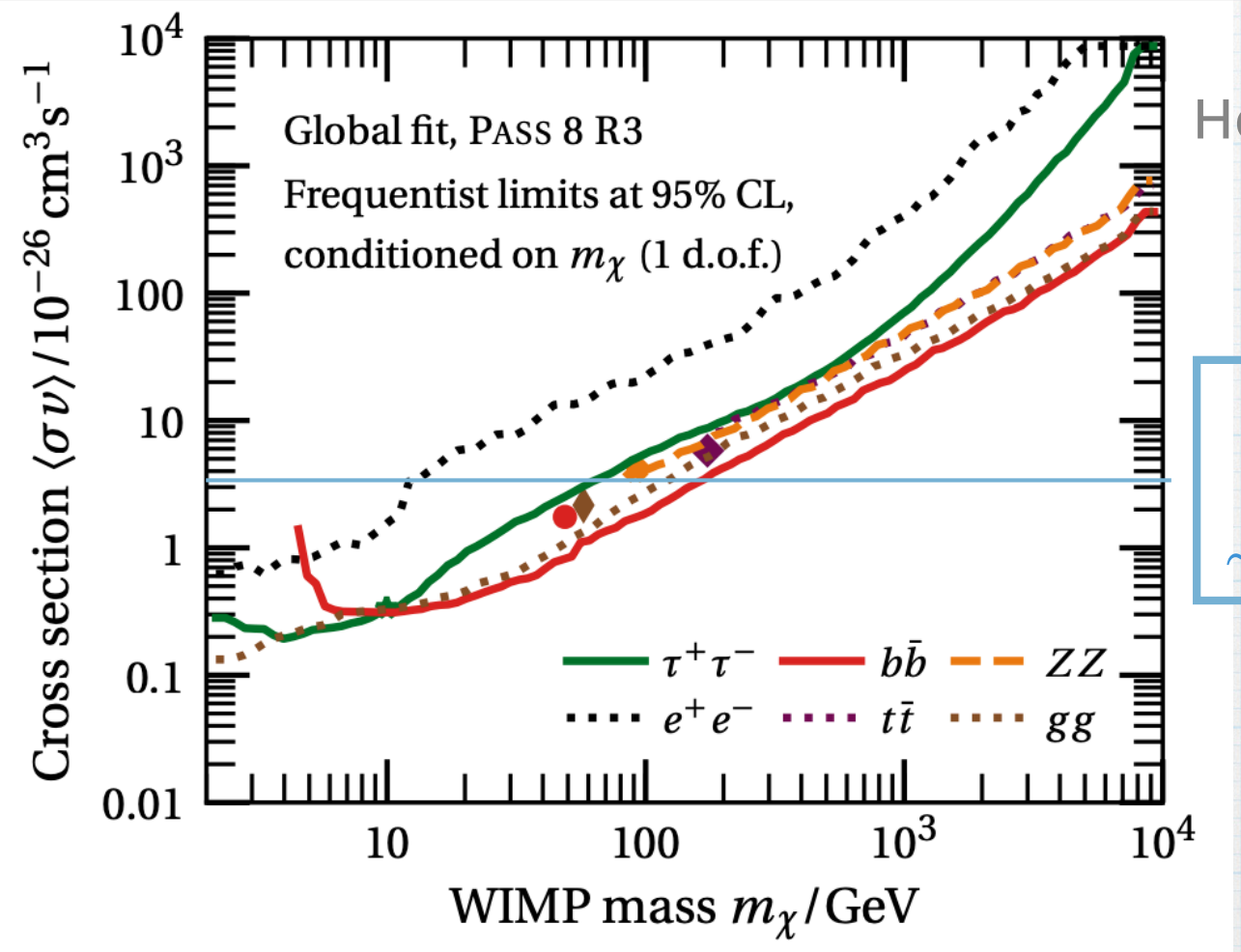
γ-rays
- are emitted in any of the annihilation channels.
- propagate straight from the source
- do not attenuate in z<<1 if $E < \mathcal{O}(\mathrm{PeV})$.

$$\phi_\gamma = \frac{1}{8\pi}\frac{\langle\sigma v\rangle}{m_{\mathrm{DM}}^2}\int_{E_{\mathrm{th}}}^{m_{\mathrm{DM}}} dE_\gamma \frac{dN_\gamma}{dE_\gamma} \boxed{\int_{\Delta\Omega} d\Omega \int_{l.o.s} ds \rho_{\mathrm{DM}}^2}$$

J-factor: $J_{\mathrm{tot}} = \int d\Omega \frac{dJ}{d\Omega} = \int d\Omega \int ds \rho_{\mathrm{DM}}^2$

Current constraints:

Fermi-LAT, 11y, 27 dwarf spheroidal galaxies (dSphs)



Hoof et al., 2020

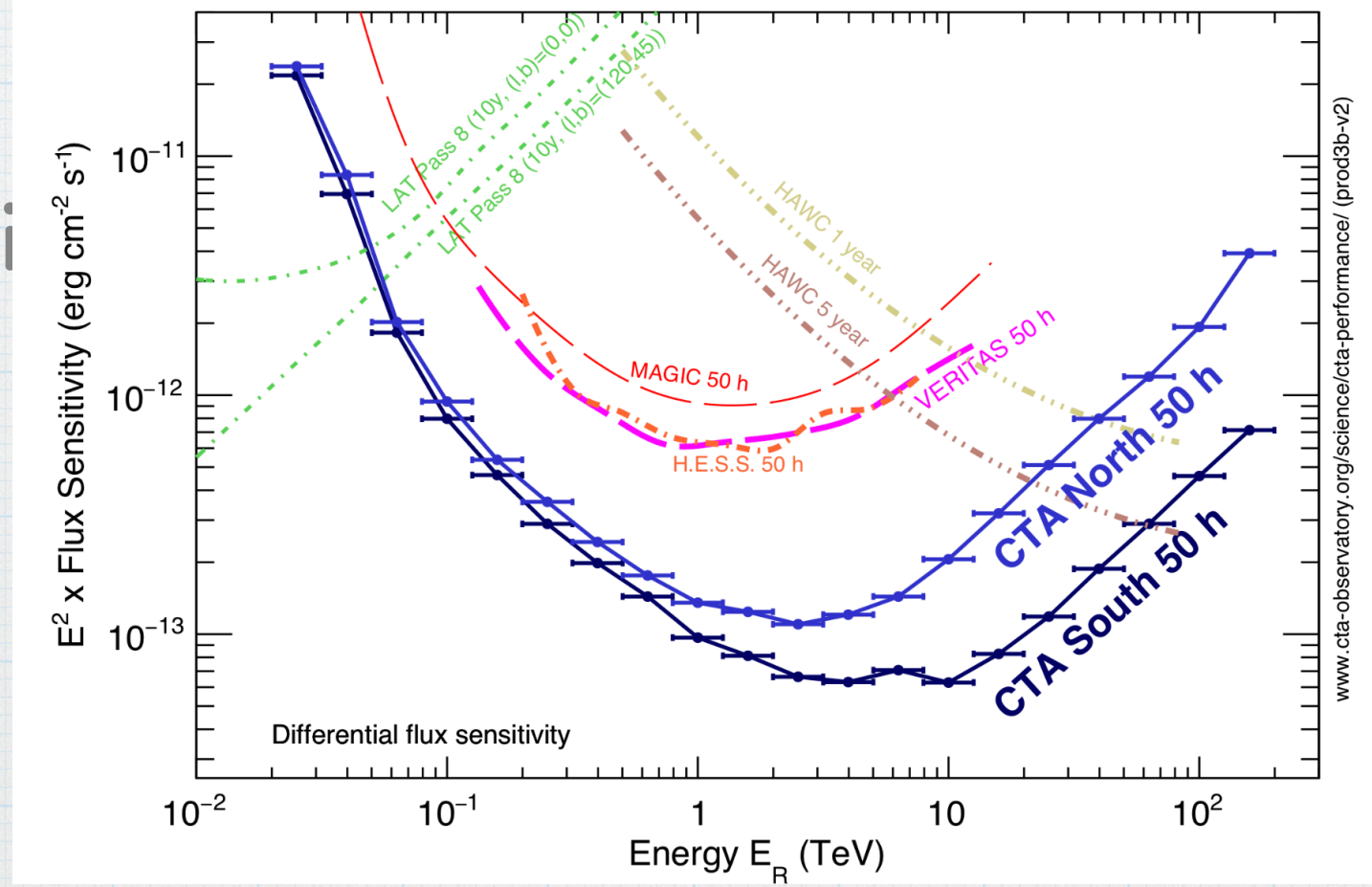
canonical

$\sim 3 \times 10^{-26}\mathrm{cm}^3/s$

We should consider TeV WIMP seriously.

TeV observation with CTA

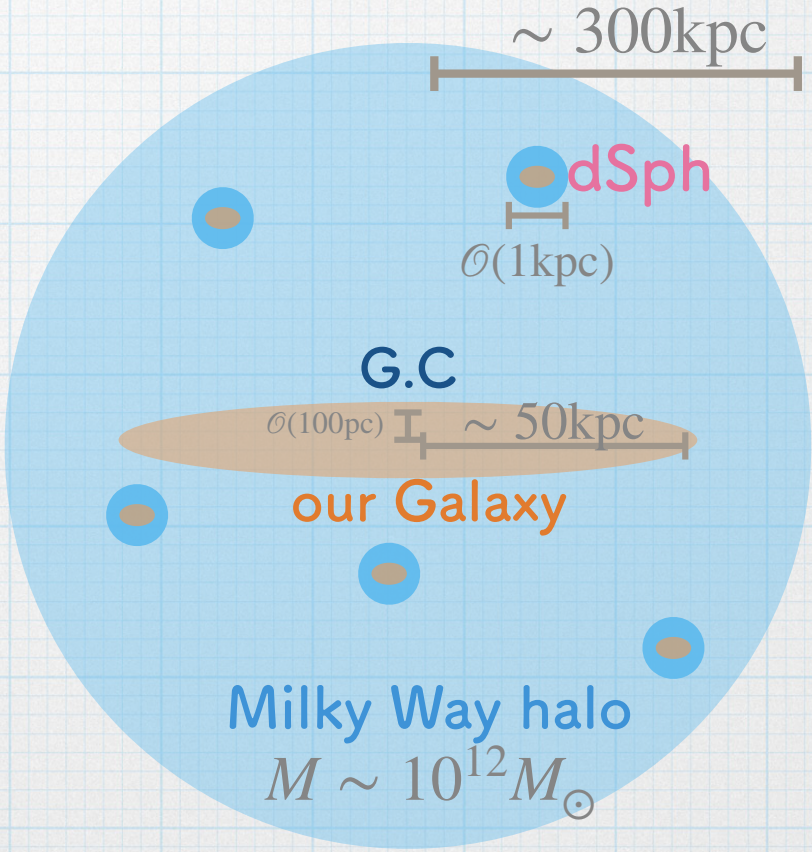
We could probe WIMP of $m_{\rm DM} \gtrsim \mathcal{O}(1)$ TeV



+improved angular resolution $\Delta\theta \sim 0.04^\circ$

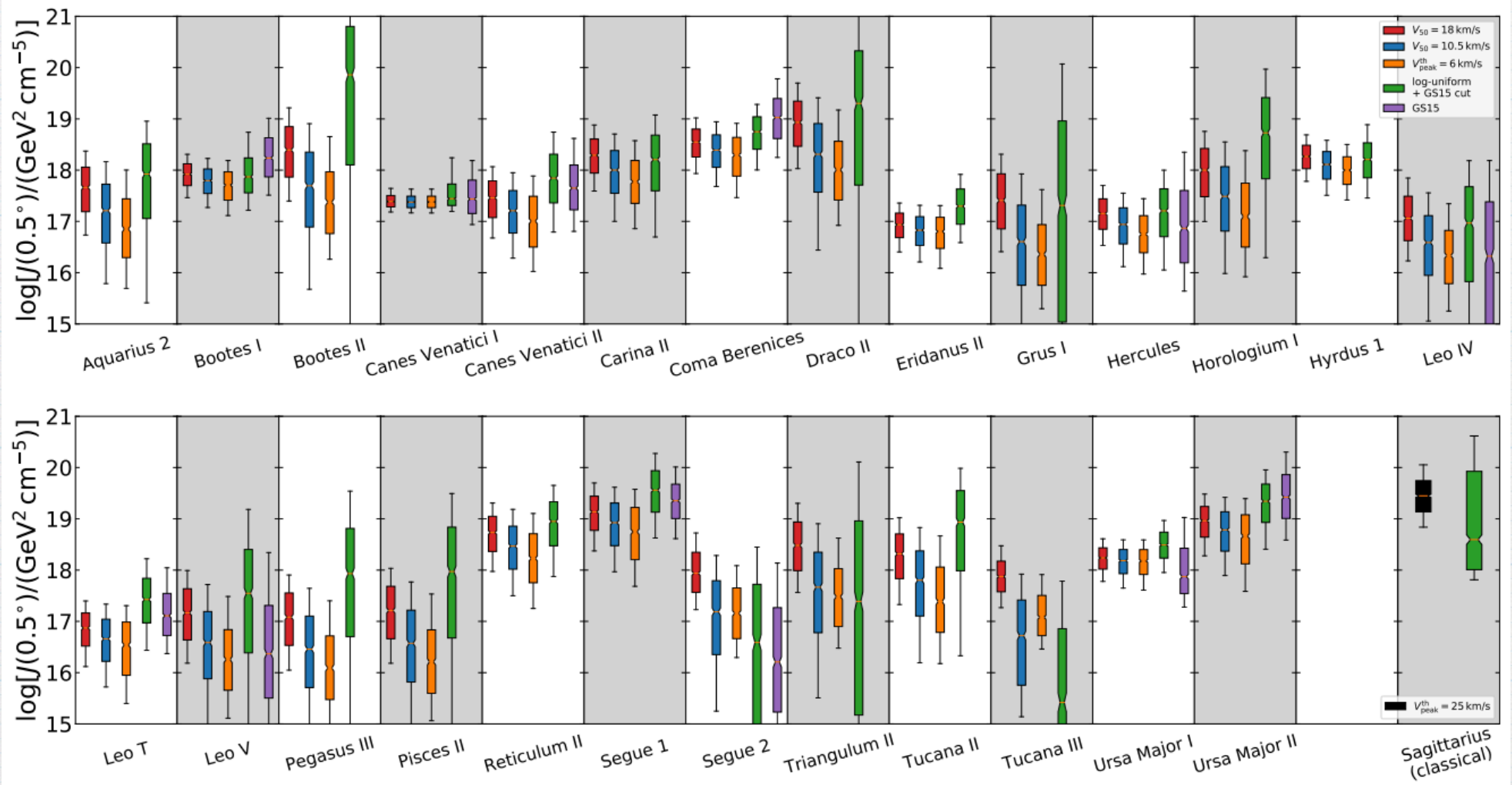
dSphs: Fermi's targets

- **satellite galaxies of the Milky Way**
- ~40 are confirmed
- $M \sim 10^{8-9} M_\odot$, $M/L \sim \mathcal{O}(10^3) M_\odot/L_\odot$
- do not show star formation activities
- dist $d \sim \mathcal{O}(100)$ kpc
- $\Delta\theta \lesssim \mathcal{O}(1\mathrm{deg})$



J-factor of dSphs

Ando et al., 2020



Motivation

- WIMP is a well-motivated DM model.
- γ-ray observations of dSphs are powerful in searching DM annihilation signature.
- TeV WIMPs are to be probed in future with future γ-ray observations.
- We have to quantify the effect of spatial structure of dSphs for CTA search.

Our analysis & Results

How does it affect our accessibility?

Procedure

Let's consider a realistic observation of dSph with CTA

1. collect models for DM distribution in dSphs

   test using Draco dSph

2. generate J-factor maps

3. generate model spectrum

   $\bar{b}b$, W^+W^-, $\tau^+\tau^-$ spectrum using `pythia8`

4. simulate γ-ray observation data

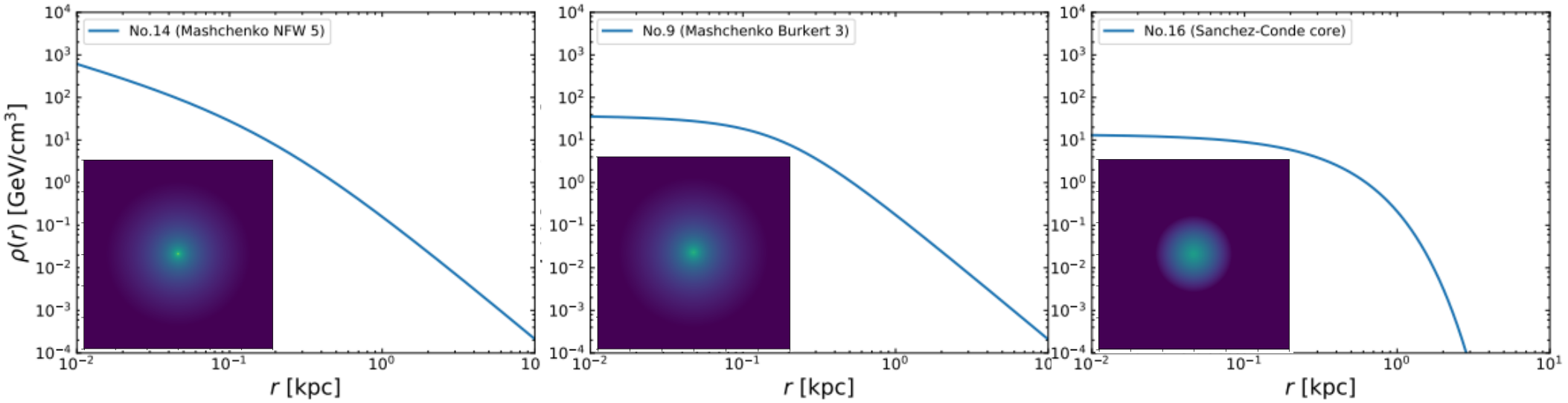
5. conduct likelihood analysis

   using `ctools`

1, profile & J-factor map

We test with 16 models for Draco

- (RA, DEC) = (260.052,57.915)
- d ~ 80kpc
- ~1000 member stars
- outermost member star @ $\theta_{\max} \sim 1.3^{\circ}$
- $J \sim \mathcal{O}(10^{19})$ GeV^{2}cm^{-5}



2, DM annihilation spectrum

$$\mathrm{DM} + \mathrm{DM} \to \bar{q}q \to \pi^0 + \ldots \to \gamma + \ldots$$

$$\to W^+W^- \to \bar{q}q + \ldots \to \gamma + \ldots$$

$$\to \bar{q}q + \ldots \to \gamma + \ldots$$

$$\to e^+\nu_e\bar{\nu}_e + \ldots \to e + \gamma + \ldots$$

$$\to l^+l^- \to l^+, l^-, \gamma + \ldots \to$$

$$\to W^\pm + \ldots$$

$$\to q + \ldots \to \gamma + \ldots$$

3, simulation & analysis

simulation using ctools (http://cta.irap.omp.eu/ctools/)

- CTA-North, full array

  IRF prod3b North, z20, average, 50h

- $4° \times 4°$ around Draco

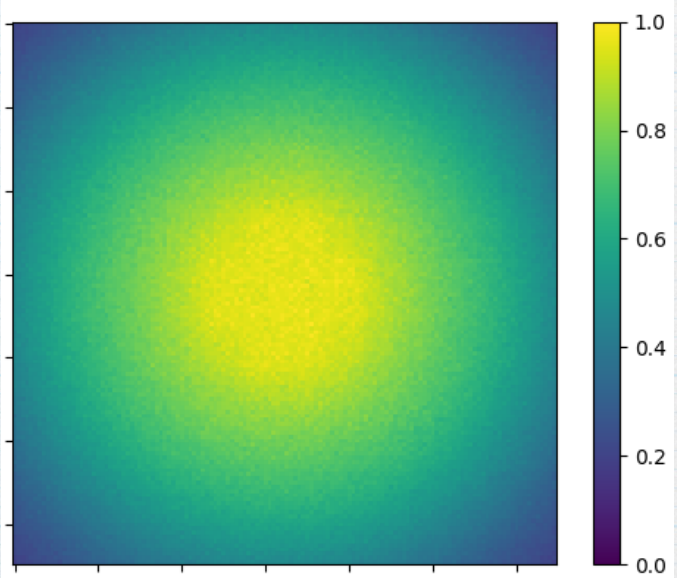
  $(0.03° \times 0.03°$ spatial bin)

- position center

  (RA, DEC)=(260.052, 57.915)

- 500 hour, c.r bkg only

- E=0.03-180TeV photon
  (5bins per decade)



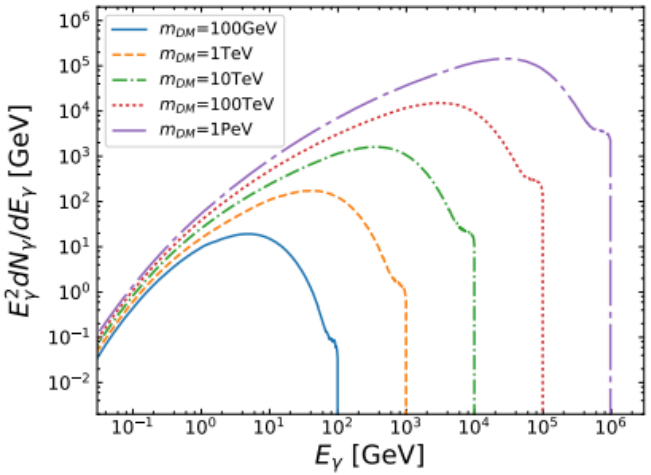
example: 92188344

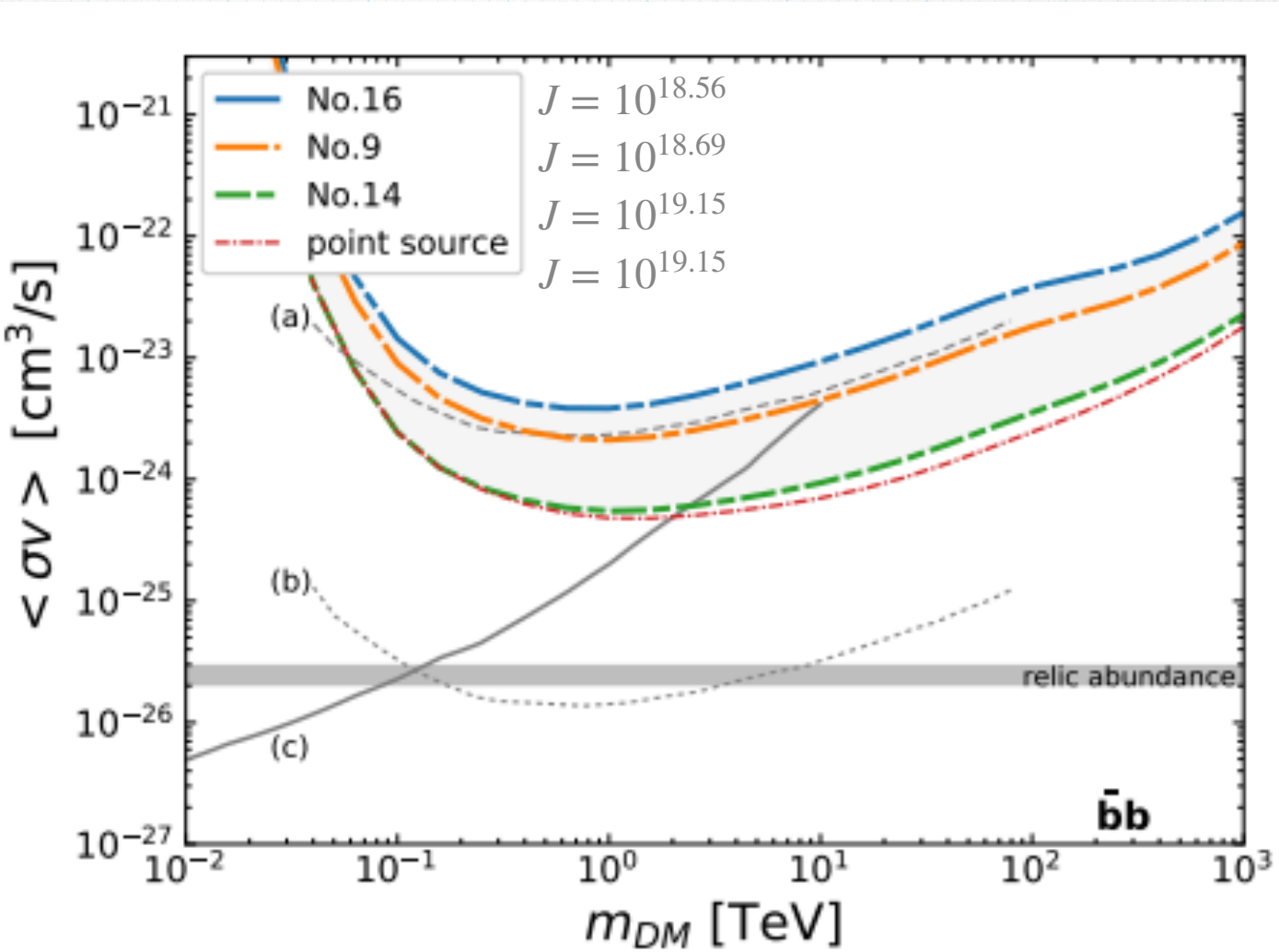
events in total

Our accessibility (1):

Hiroshima et al., 2019

95% C.L
sys. only





Our accessibility (2):

Hiroshima et al., 2019

95% C.L
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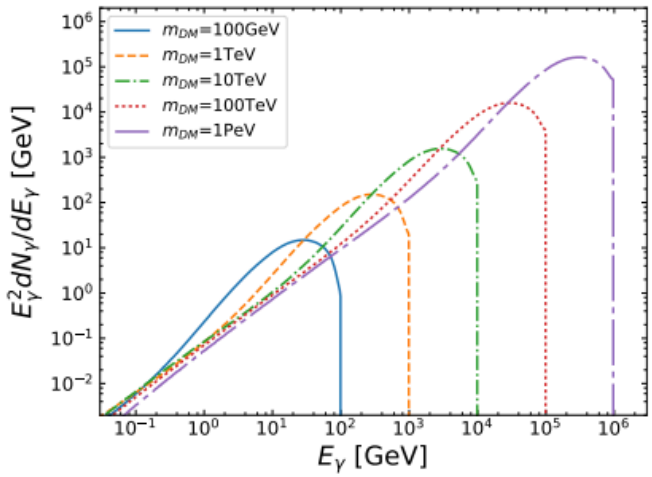

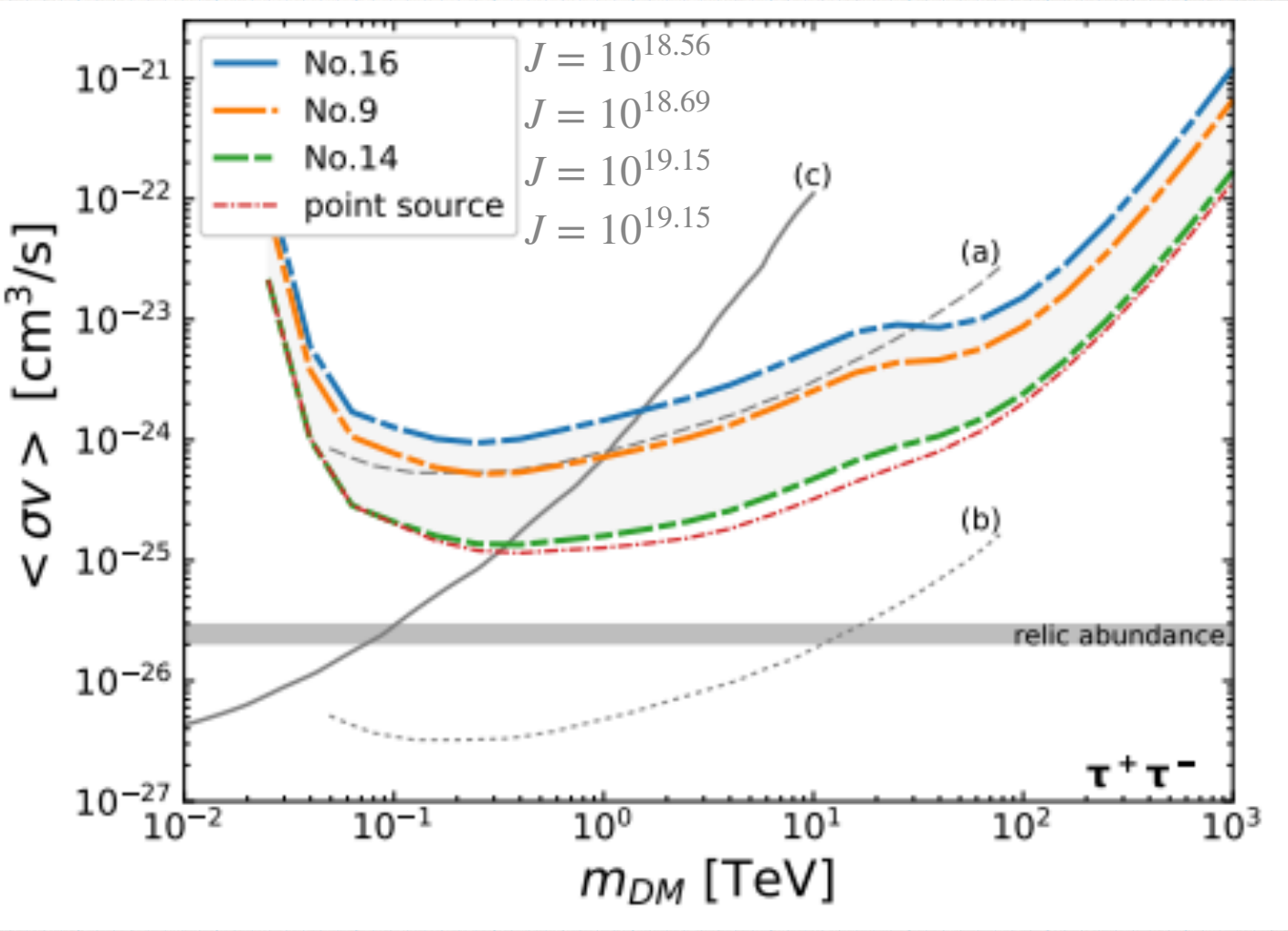

Conclusion

Conclusion

- We can access TeV WIMP with CTA.
- dSphs are good targets for γ-ray searches of DM with high J-factor and low background.
- The spatial distribution as well as the its integral of the J-factor is important especially for CTA.
- We can probe $\langle \sigma v \rangle \sim \mathcal{O}(10^{-23} - 10^{-24})\ \mathrm{cm}^3/s$ for $m_{\mathrm{DM}} \sim \mathcal{O}(1)$TeV, which could not be accessible with any other experiments.
- Precise determination of the density structure of dSphs are important for understanding DM nature.