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# Gamma-ray search of dark matter in spatially-extended dwarf spheroidal galaxies with CTA

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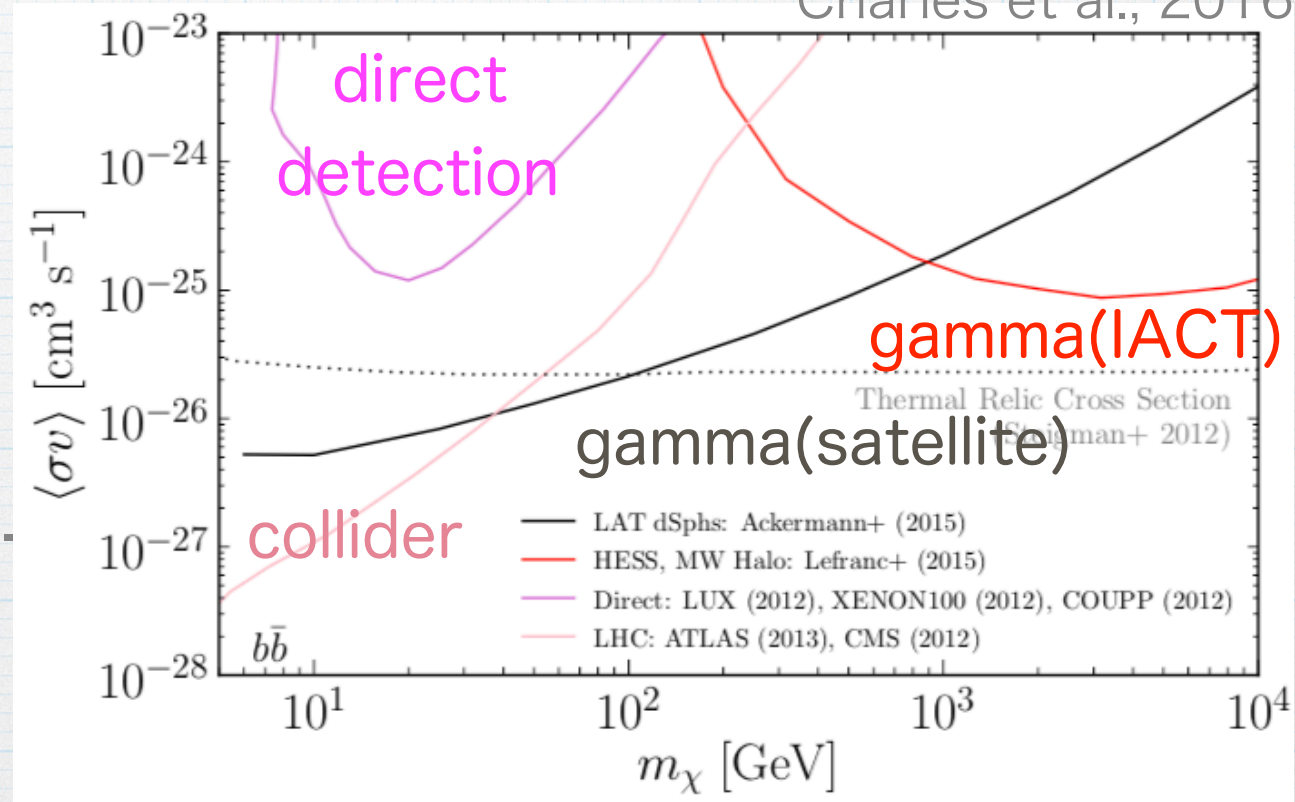
# Introduction

# Weakly Interacting Massive Particle (WIMP)

$$\frac{dn}{dt} + 3Hn = \langle \sigma v \rangle \left( n_{\rm eq}^2 - n^2 \right)$$

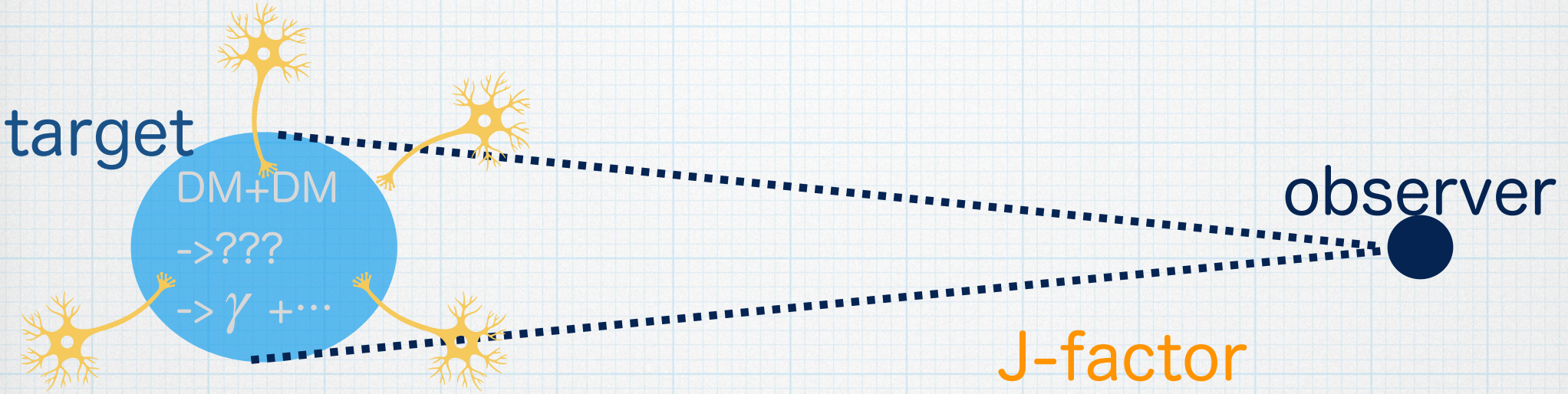
- two model parameters
- mass $m_{\rm DM}$
  $\mathcal{O}(1)$ GeV – $\mathcal{O}(1)$ TeV
- annihilation cross-section
  $\langle \sigma v \rangle \sim \mathcal{O}(10^{-26}) cm^3/s$

Charles et al., 2016




Gamma-ray observation is powerful

# Gamma-ray search of WIMP




J-factor

$$\phi = \frac{1}{4\pi}\frac{\langle\sigma v\rangle}{2m_{\mathrm{DM}}^2}\int_{E_{\mathrm{th}}}^{m_{\mathrm{DM}}} dE\frac{dN_\gamma}{dE}\cdot\int d\Omega\int ds\,\rho_{\mathrm{DM}}^2.$$

Requirements

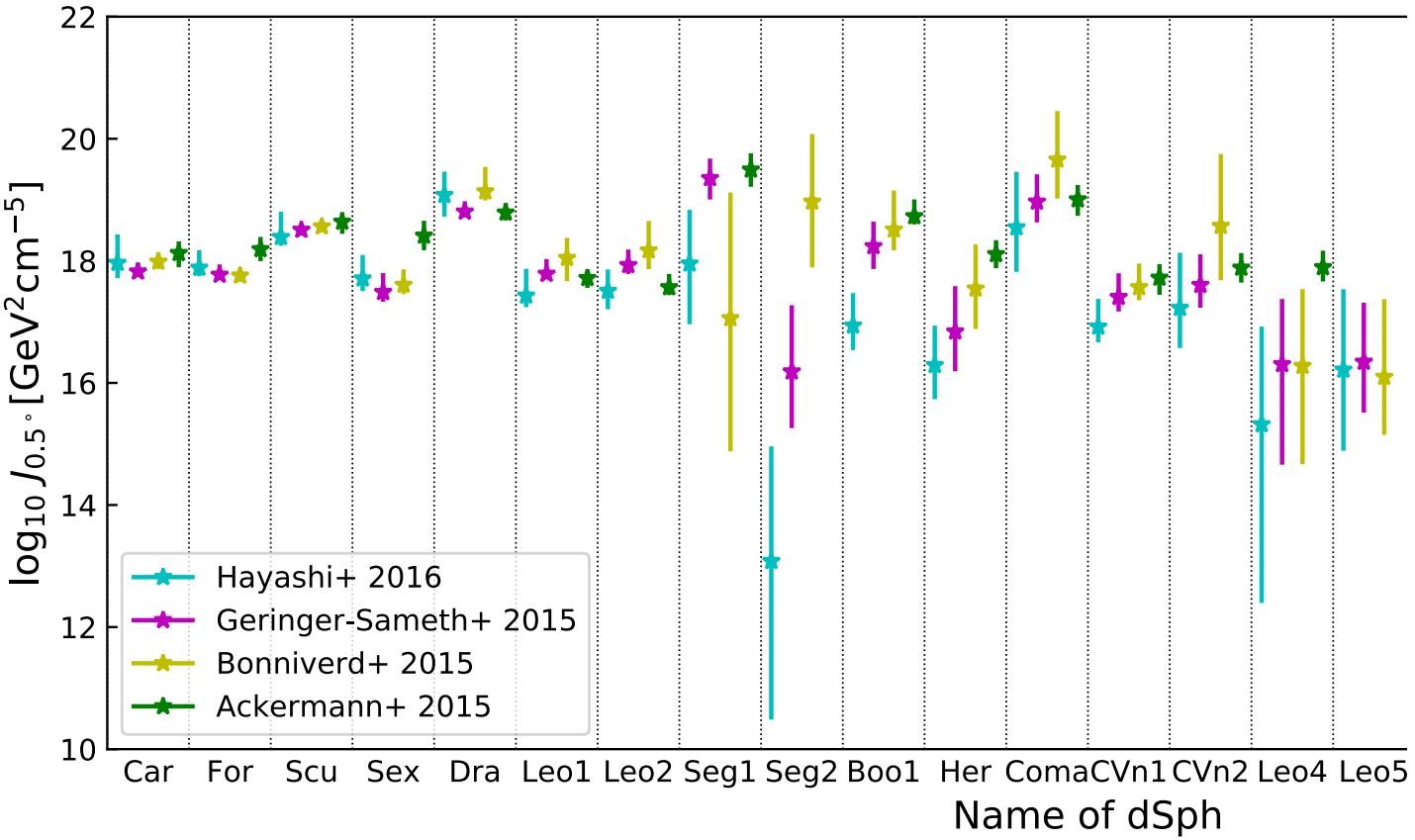
- high J-factor
- low astrophysical background

**dwarf spheroidal galaxies (dSphs)**

# dwarf spheroidal galaxies (dSphs)

- satellite galaxy of the Milky Way
- $M/L$ $\sim 10^3 M_\odot/L_\odot$
- angular size $\Delta\theta \lesssim \mathcal{O}(1^\circ)$
- ~40 are identified

Hayashi et al.,2016

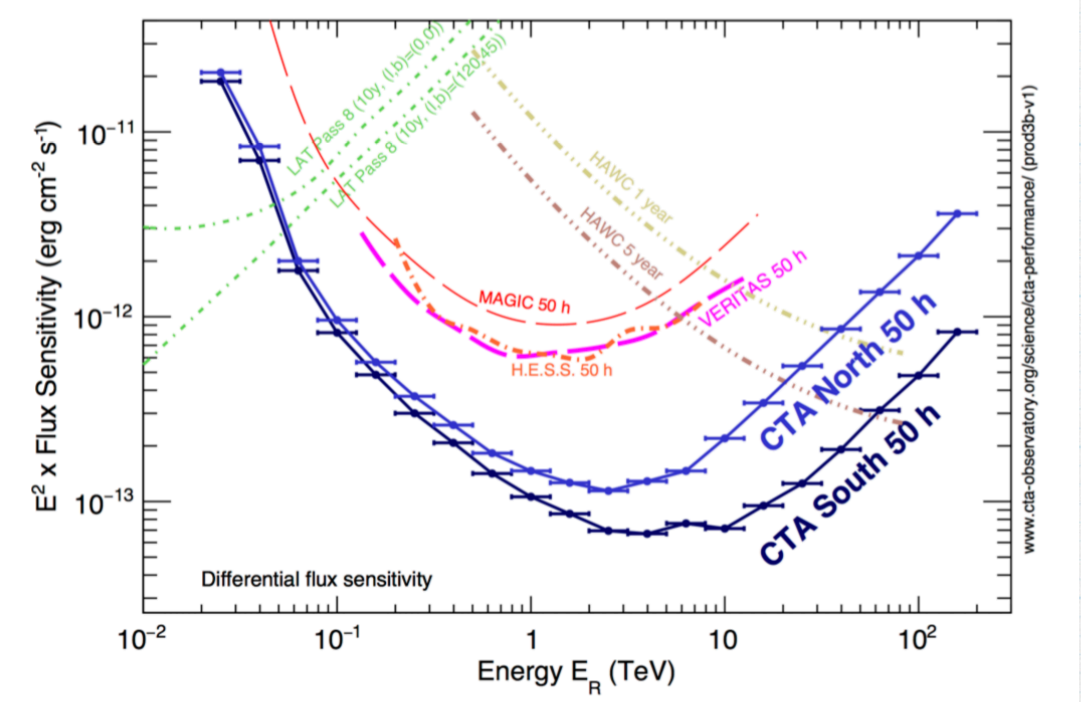


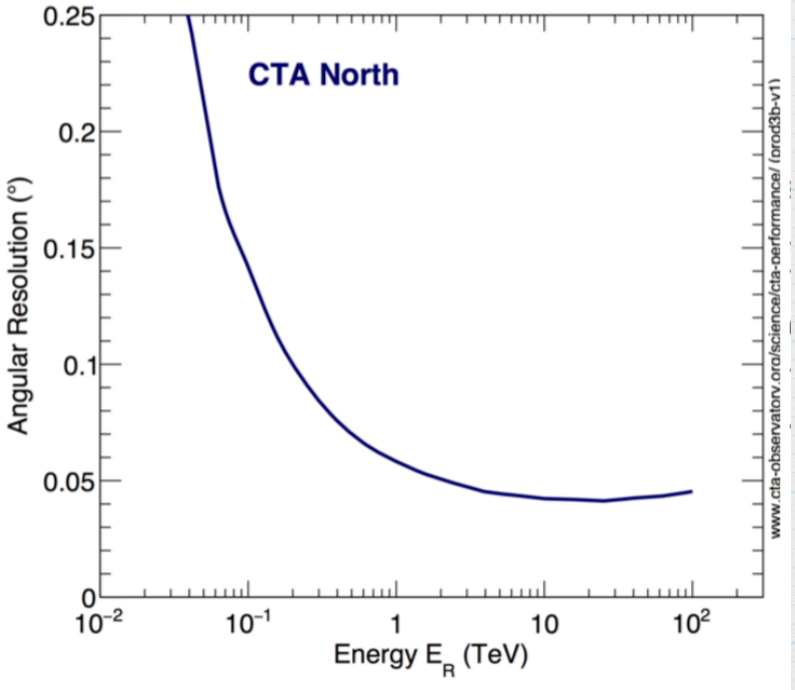

J-factor changes with models.

# CTA for WIMP

- great TeV sensitivity
- ability to resolve DM distributions in the center of dSphs

↔ previous analyses assuming dSphs as point sources




**How the DM distribution in dSphs affect the sensitivity?**

# Motivations

- Observation of dSph with CTA should enhance our accessibility to WIMP of $M_{\mathrm{DM}} \gtrsim \mathcal{O}(1)\ \mathrm{TeV}$
- dSphs are good targets of low astrophysical background and high J-factor
- Previous analyses usually neglect the spatial extension of dSphs
- The importance of the profile should increases with the angular resolution of CTA and it must be quantified.

# Method

# analyses of simulated data

1. Simulate observations of Draco dSph

   500-hour, CTA-North full-array

2. Select and bin the data

   energy: 0.03-180TeV, 5bin/decade

   space: $4^\circ \times 4^\circ$, bin in $0.03^\circ \times 0.03^\circ$

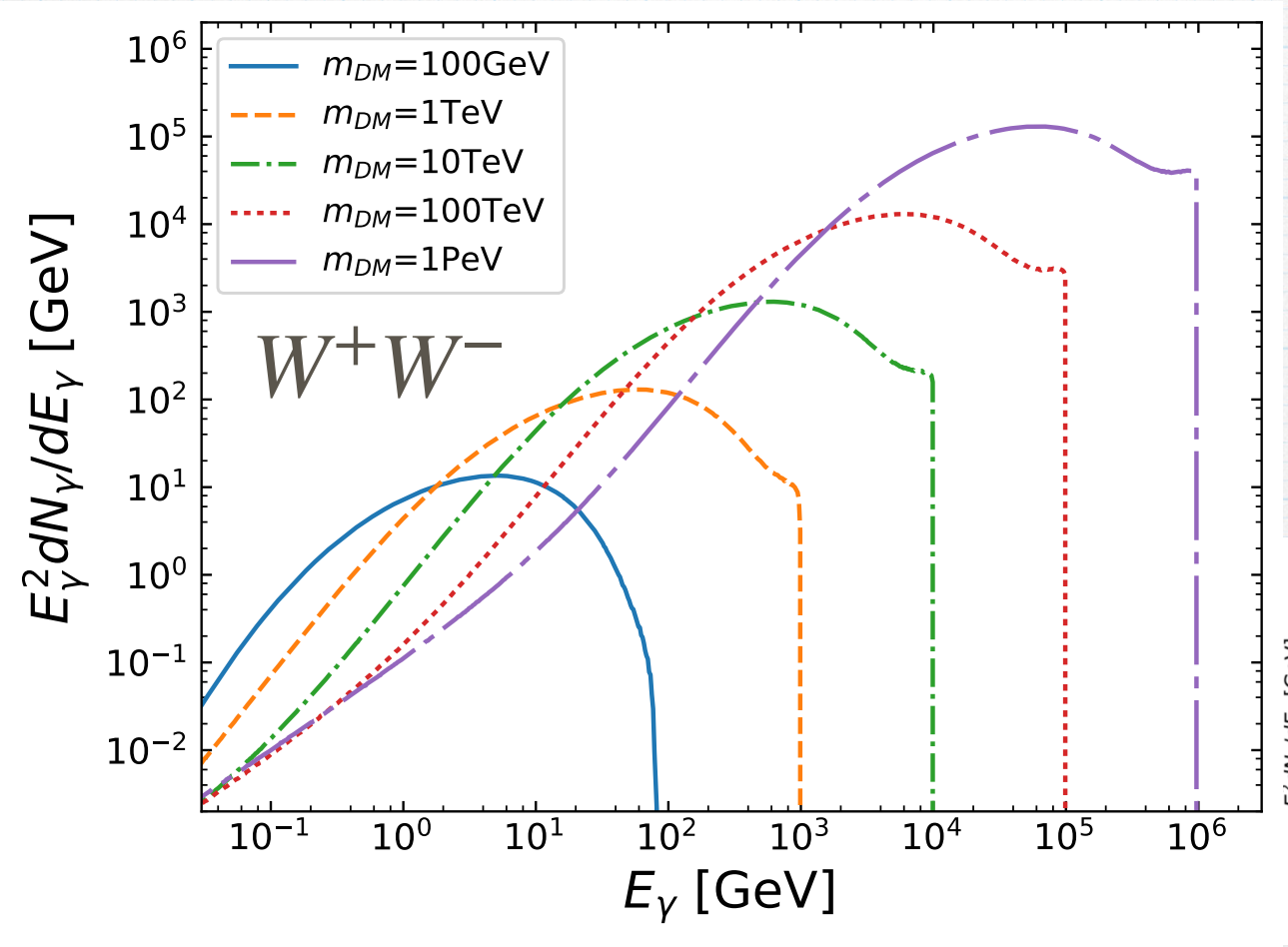
3. Derive 95% confidence level upper limits of gamma-ray flux

3 channel ($\bar{b}b, W^+W^-, \tau^+\tau^-$), 16 profile for Draco

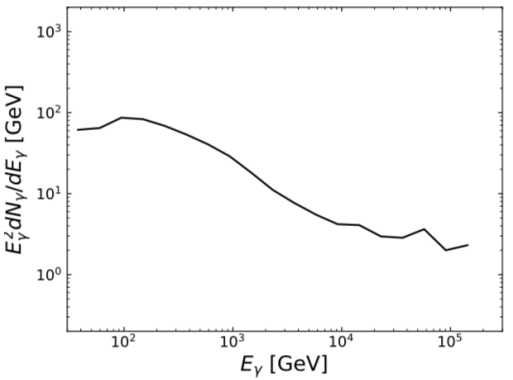
**using ctools**

# Flux from DM annihilation

Hiroshima, Hayashida, Kohri in prep




background

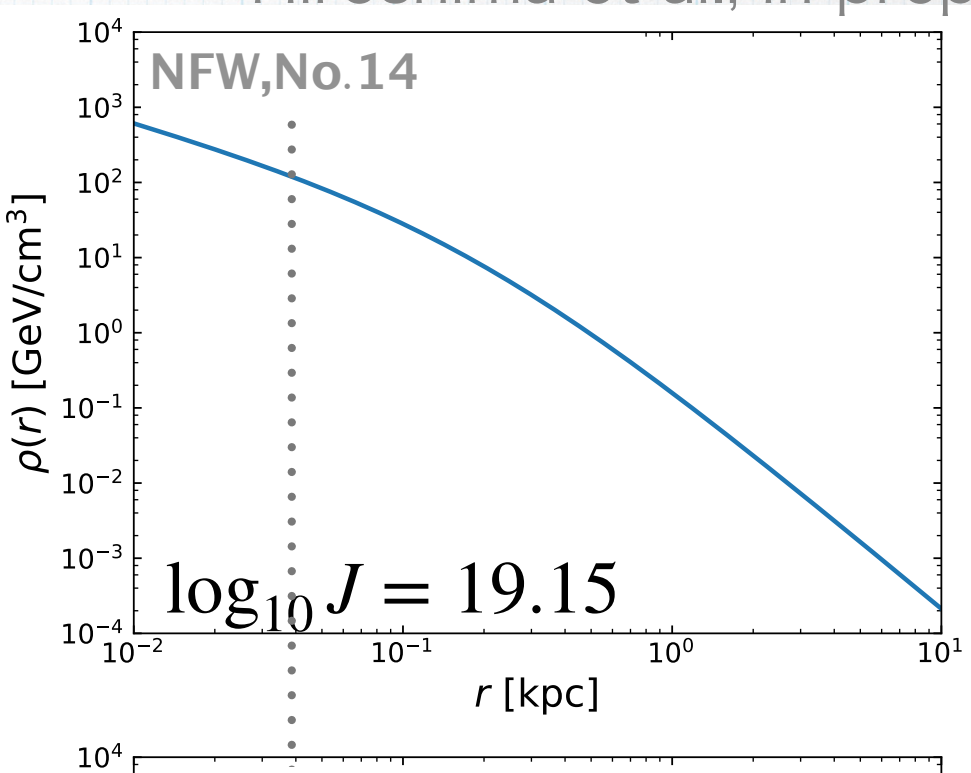


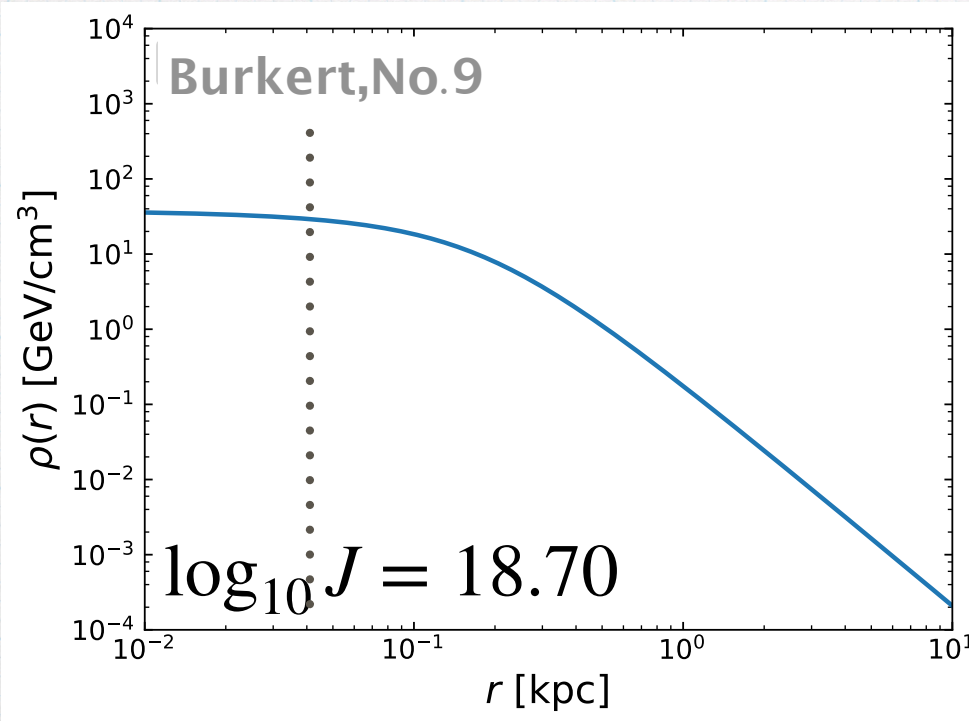

$$\mathrm{DM} + \mathrm{DM} \rightarrow W^+W^- \rightarrow \pi^0 + \ldots \rightarrow 2\gamma + \ldots$$
$$\rightarrow \mu + \bar{\nu}_\mu + \ldots \rightarrow \gamma + \ldots$$

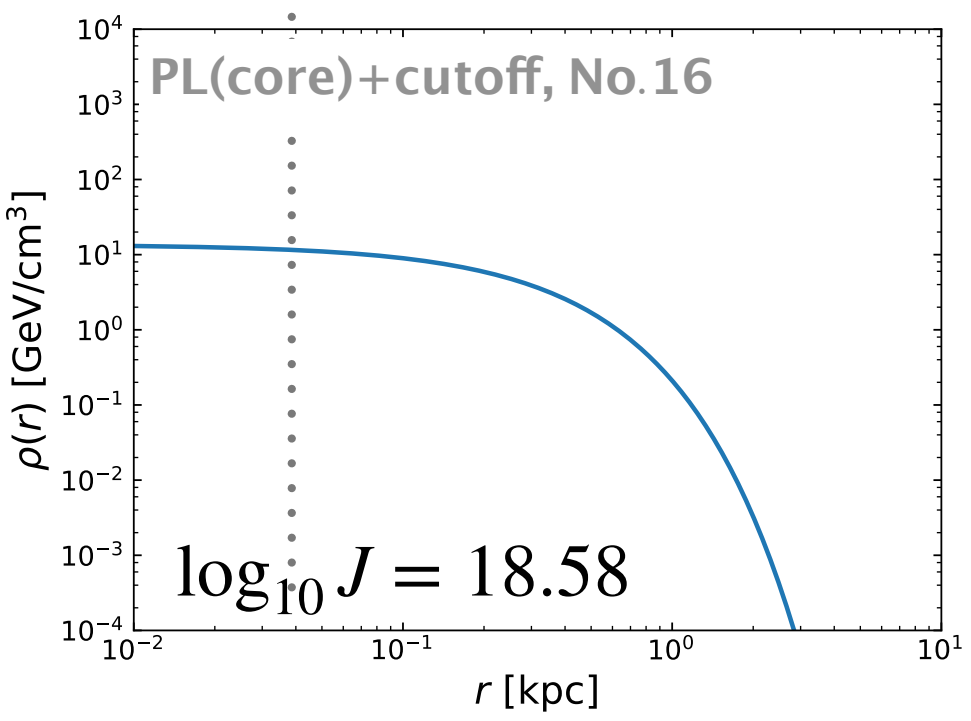
# profiles

Hiroshima et al., in prep

- 16 spherical profiles for Draco in the literature
- fitted or compared to stellar data



# Results

# Conclusion

# Conclusion

- We can probe WIMPs of $m_{\mathrm{DM}} \gtrsim \mathcal{O}(1)$ TeV with CTA.
- dSphs are resolved as extended sources.
- Analyses assuming a point-like dSph should overly constrain the annihilation cross-section.
- We can derive the particle parameter within a factor of ~10 uncertainty in profile models.
- We can probe unexplored regions smaller than $\langle \sigma v \rangle = 10^{-23} - 10^{-24} \mathrm{cm}^3/s$ for $m_{\mathrm{DM}} \gtrsim \mathcal{O}(1)\mathrm{TeV}$ WIMPs.
- This is sufficient to test some well-motivated models expecting resonant annihilations.