CTA-Japan workshop 2017

Dark Matter Search in dwarf Spheroidal galaxies

work in progress (2017)

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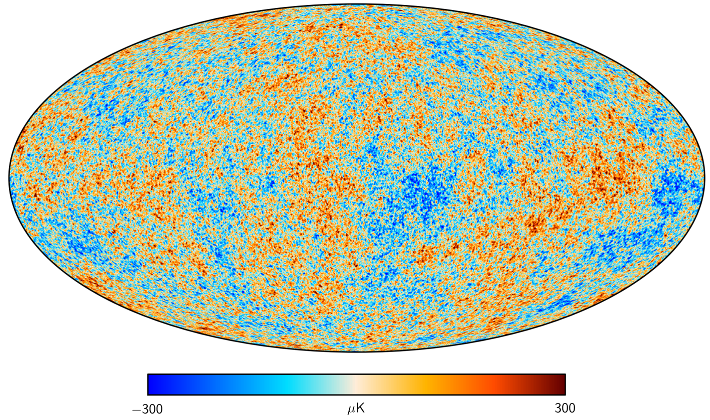
Introduction

Dark Matter search in dwarf spheroidal galaxies

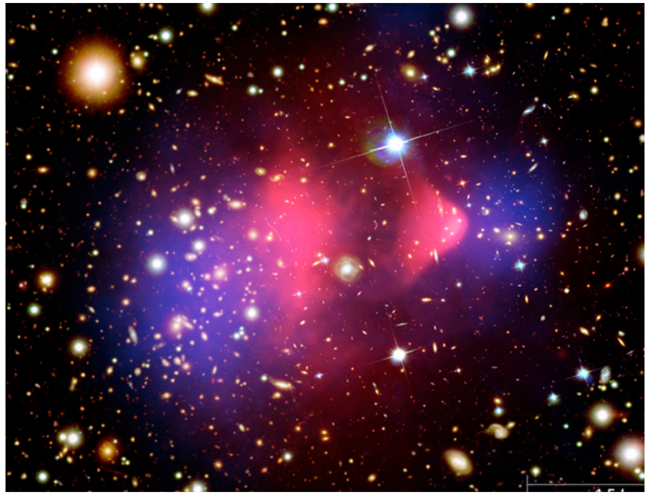
Evidence for the Dark Matter

1, Large Scale Structure

$$\Omega_{DM}h^2 \sim 0.258$$



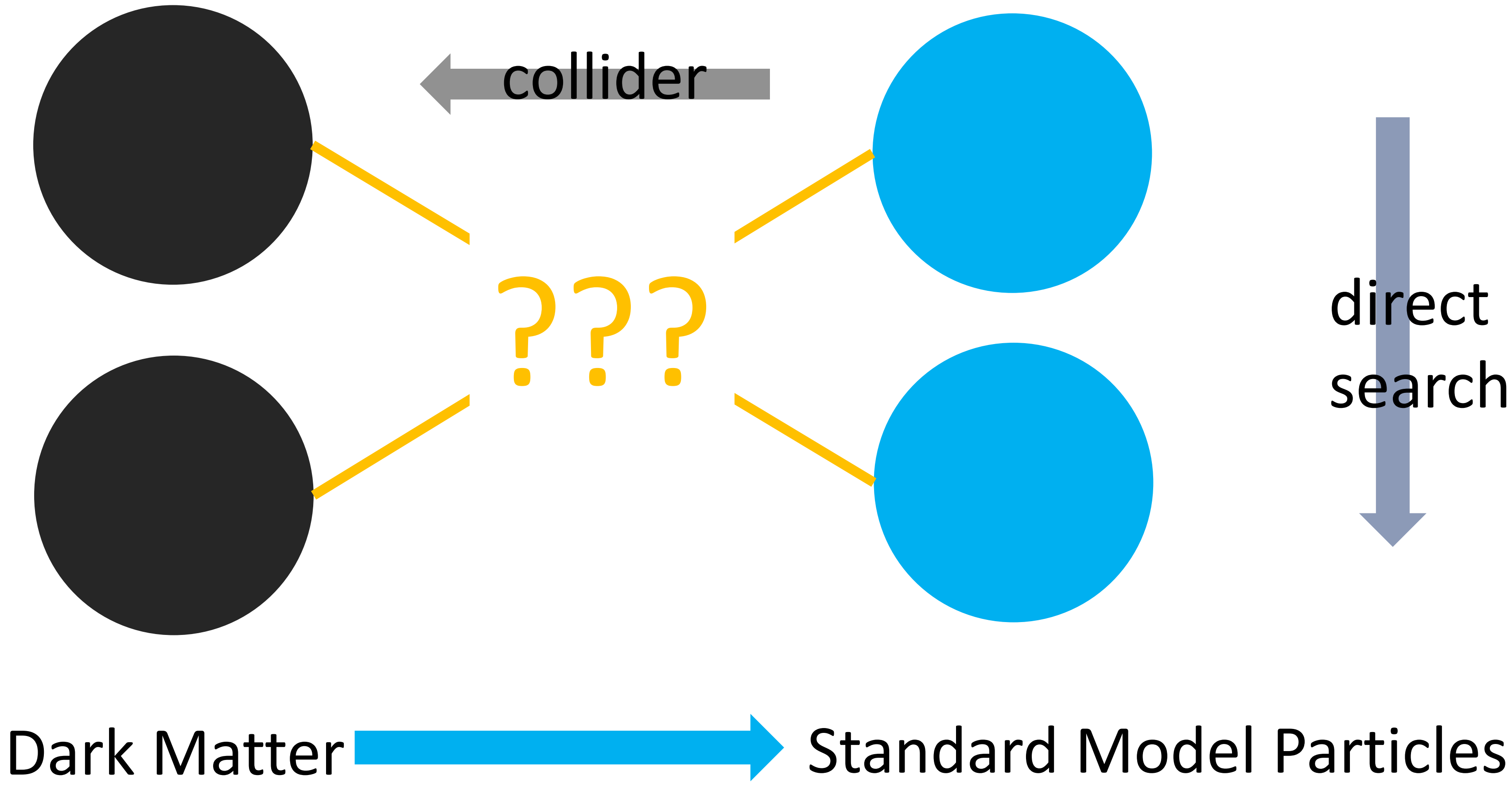
2, Rotation Curves of Galaxies



3, Bullet clusters

We need something with little electromagnetic interactions

Strategies:



Indirect Search

Advantages of CTA:

DM + DM -> (particles in the Standard Model)

DM+DM -> 2 γ

DM+DM -> qq

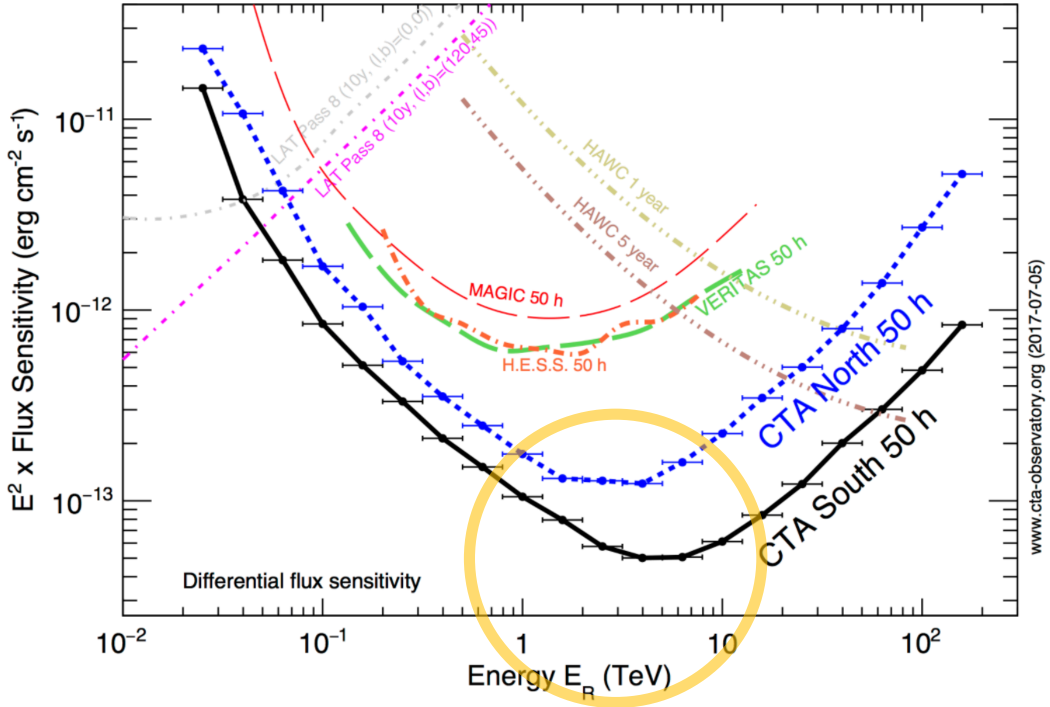
-> π^0+...-> γ +...

DM+DM -> W^+W^-

-> $\mu + n_\mu$+...-> γ +...

DM+DM -> $l^+ l^-$

-> $l^\pm$+ γ(CMB) -> γ +...



with $\Delta\theta \sim 0.03$ deg

Why 'TeV'?

DM as a thermal relic of our universe: $\Omega_{DM} h^2 \sim 0.258$

$$\frac{dn_{DM}}{dt} + 3Hn_{DM} = -< \sigma v > (n_{DM}^2 - n_{DM,eq}^2)$$

$$3Hn_{DM} \sim < \sigma v > n_{DM}^2$$ @ thermal freeze out (z_f)

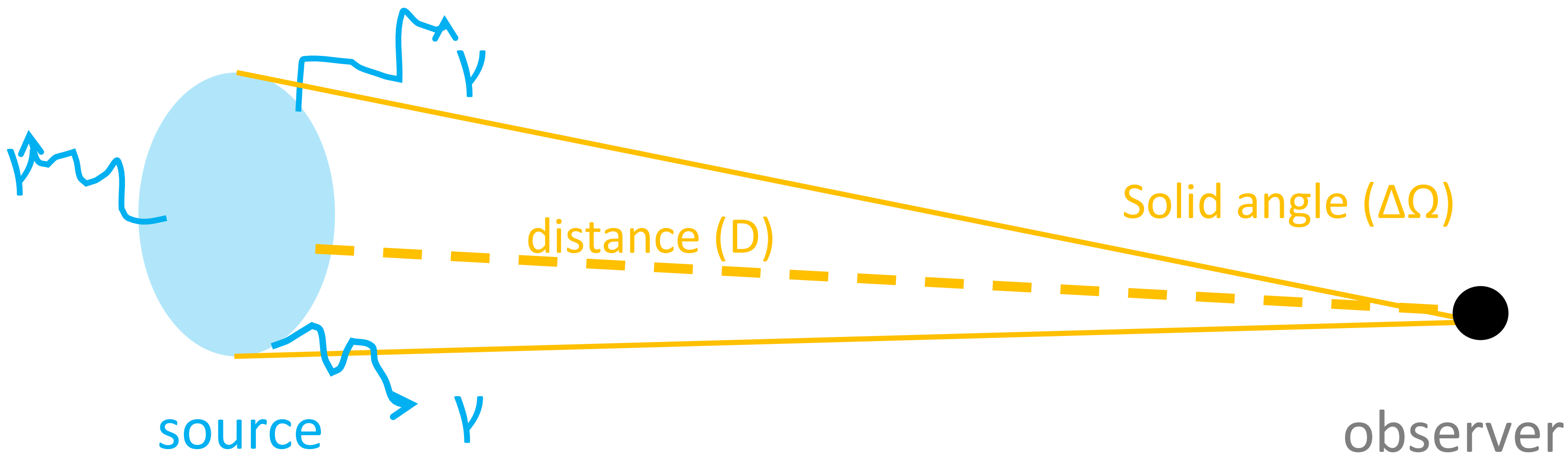
conserved $\frac{n_{DM}}{s} \sim \frac{H}{< \sigma v > s} \propto (< \sigma v > T)^{-1}$

$m_{DM}/T_{zf} \sim 20 - 30$

$$\frac{\rho_{DM}}{s} \propto m_{DM}(< \sigma v > m_{DM})^{-1} \propto < \sigma v >^{-1}$$

$$\Omega_{DM} h^2 = 0.1 \left(\frac{< \sigma v >}{3 \times 10^{-26} [cm^3 s^{-1}]} \right)^{-1}, < \sigma v > \sim \left(\frac{0.1}{\mathrm{TeV}} \right)^{-2}$$

gamma-ray flux:

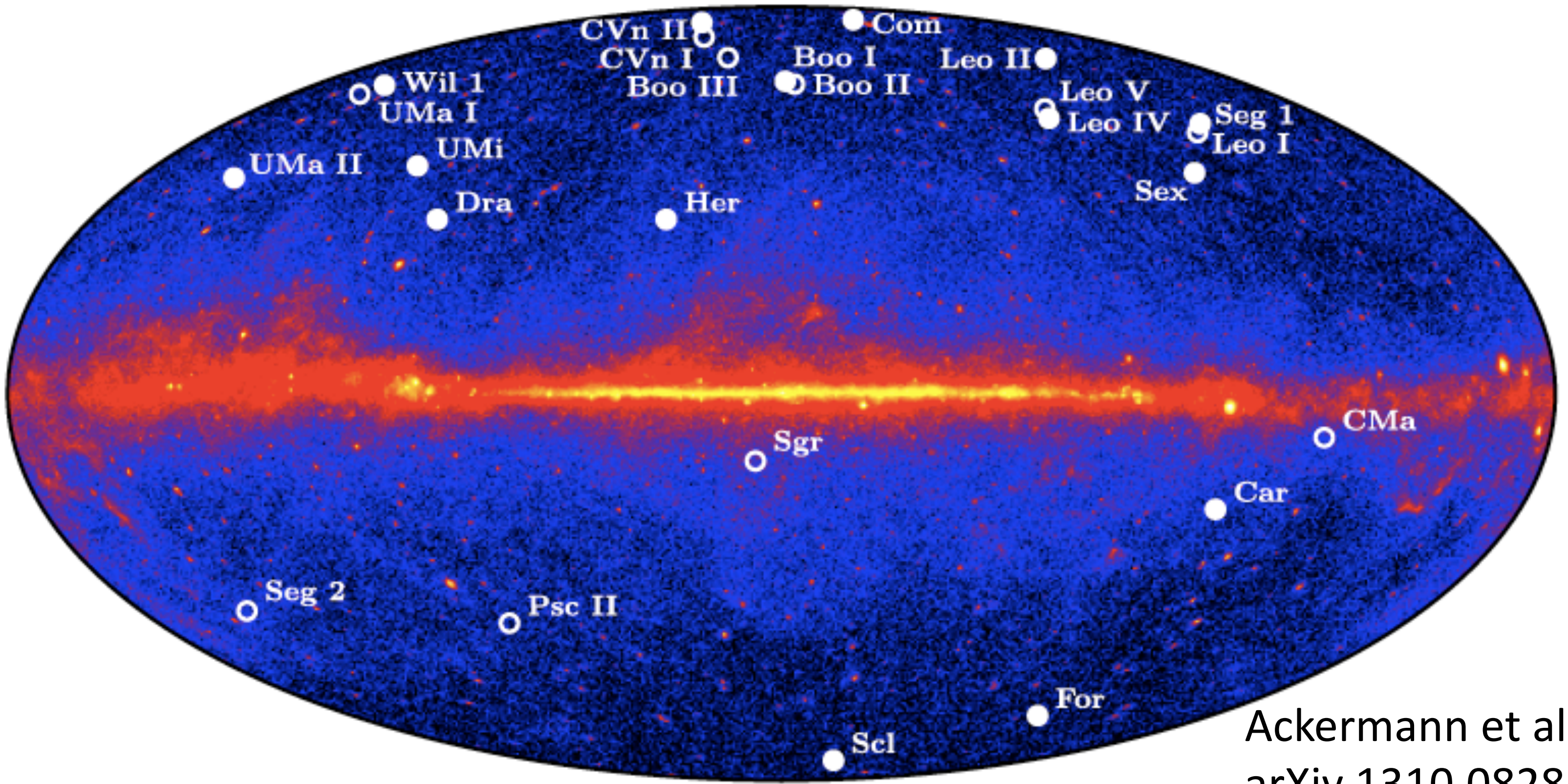


$$\phi(\Delta\Omega) = \frac{1}{4\pi}\frac{\langle\sigma v\rangle}{2m_{DM}^2}\int_{E_{min}}^{E_{max}}\frac{dN_\gamma}{dE_\gamma}dE_\gamma \times \int_{\Delta\Omega}\int_{LoS}\rho_{DM}^2\, dl\, d\Omega'$$

J-factor[GeV^2/cm^5]

denser is better

target: dwarf spheroidal galaxies (dSph)



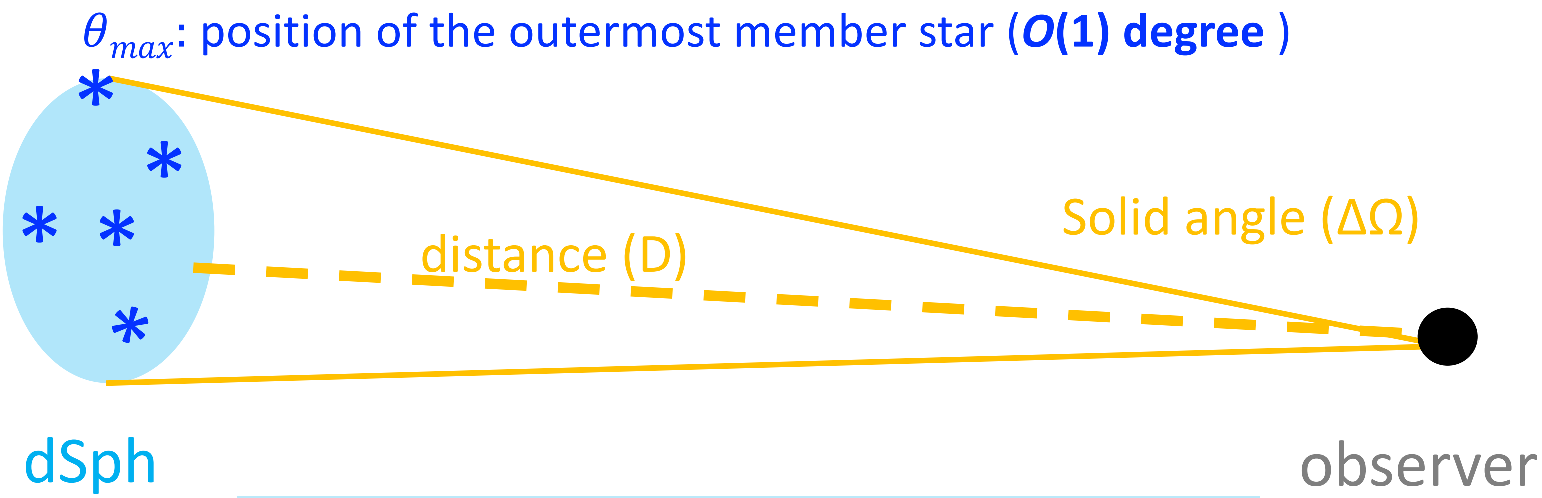
Ackermann et al., 2014, arXiv 1310.0828

1, galactic center : $J=10^{22}$-10^{24} ◎ , contamination △

2, dwarf spheroidal galaxies (dSphs) : $J=10^{17}$-10^{20} ○ , contamination ○

Methods

spatial extension of dSphs



$$J = \int_0^{\theta_{max}} 2\pi \sin\theta \, d\theta \int_{LoS} \rho_{DM}^2(r) ds$$

$\rho_{DM}(r)$ & extension θ_{max} is derived from stellar kinematics data

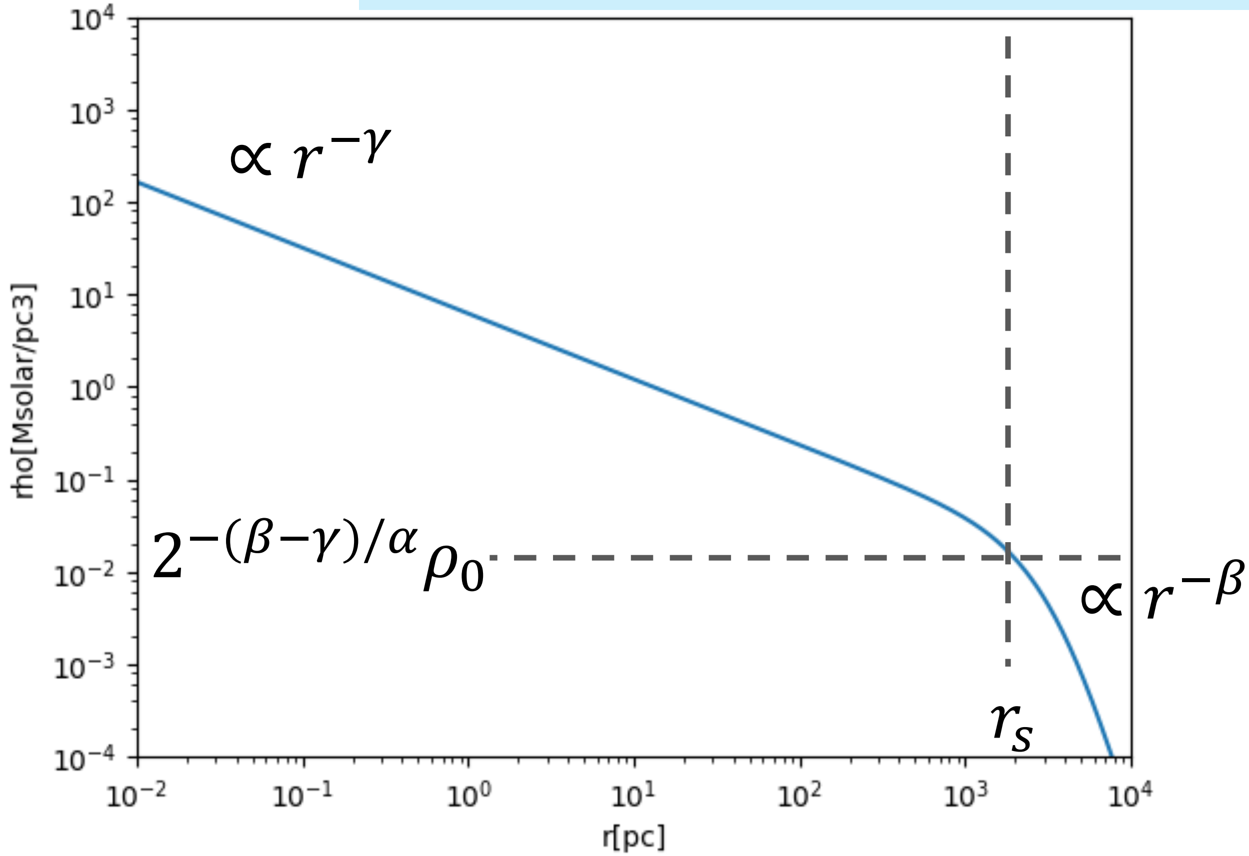
see Geringer-Sameth et al., 2015 (spherical)
Hayashi et al., 2016 (axisymmetric), etc.

We take the density profile of dSphs into account

DM profile of dSph

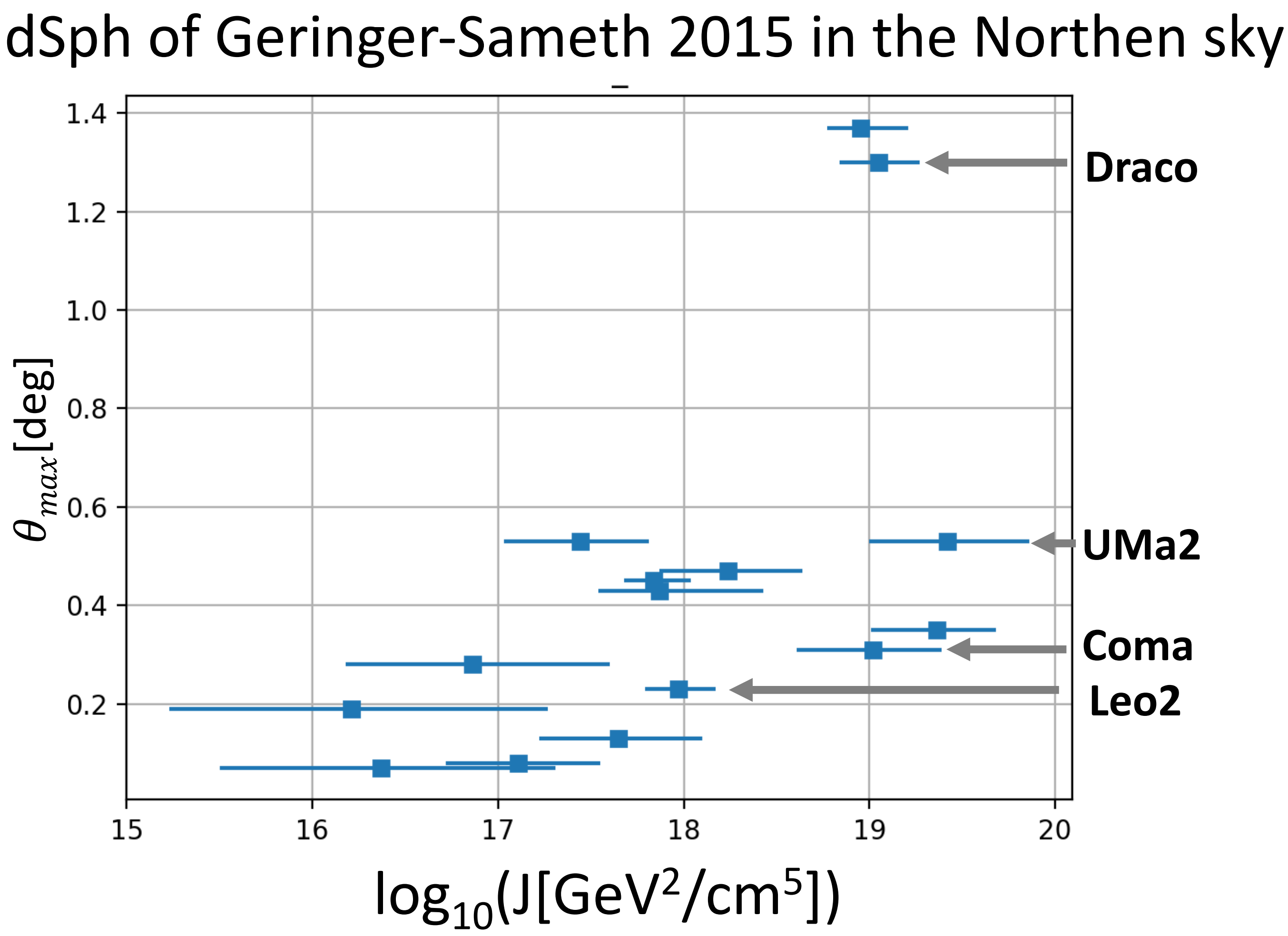
generalized NFW

$$\rho_{DM}(r) = \frac{\rho_0}{\left(\frac{r}{r_s}\right)^{\gamma}\left(1+\left(\frac{r}{r_s}\right)^{\alpha}\right)^{\frac{\beta-\gamma}{\alpha}}}$$



stellar kinematics data gives $(\alpha, \beta, \gamma, \rho_s, r_s)$

source selection

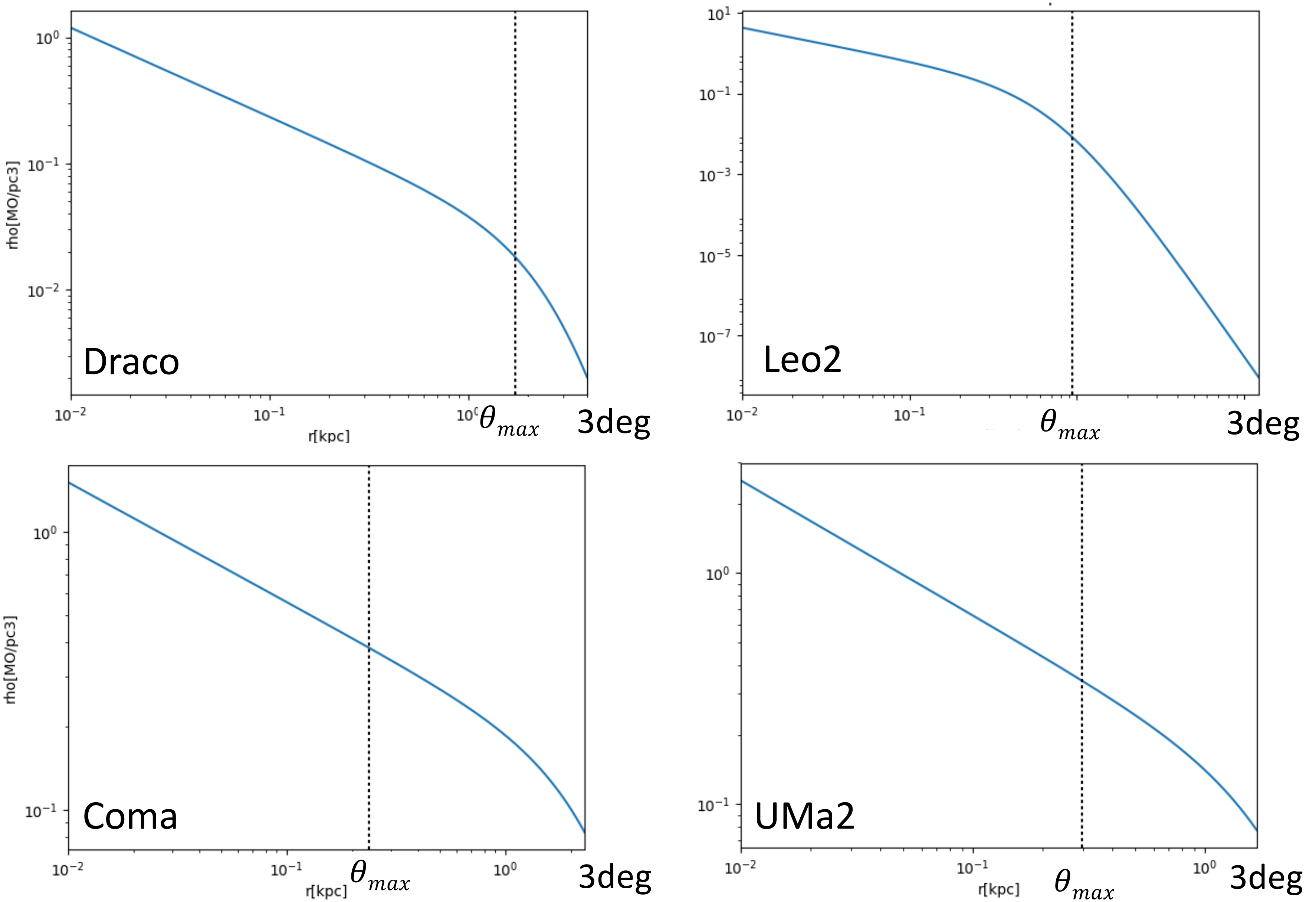


Targets: compact , dense dSph

name	ra [deg]	dec [deg]	dist [kpc]	θ_{max} [deg]	$\log_{10}(J_{\theta max})$ [GeV^2/cm^5]	$\log_{10}(J_{<0.5^\circ})$ [GeV^2/cm^5]
Draco	260	57.9	76	1.3	19.05	18.84
Coma	186	23.9	44	0.31	19.02	19.02
Leo II	168	22.2	233	0.23	17.97	17.97
Ursa Major II	133	63.1	32	0.53	19.42	19.42

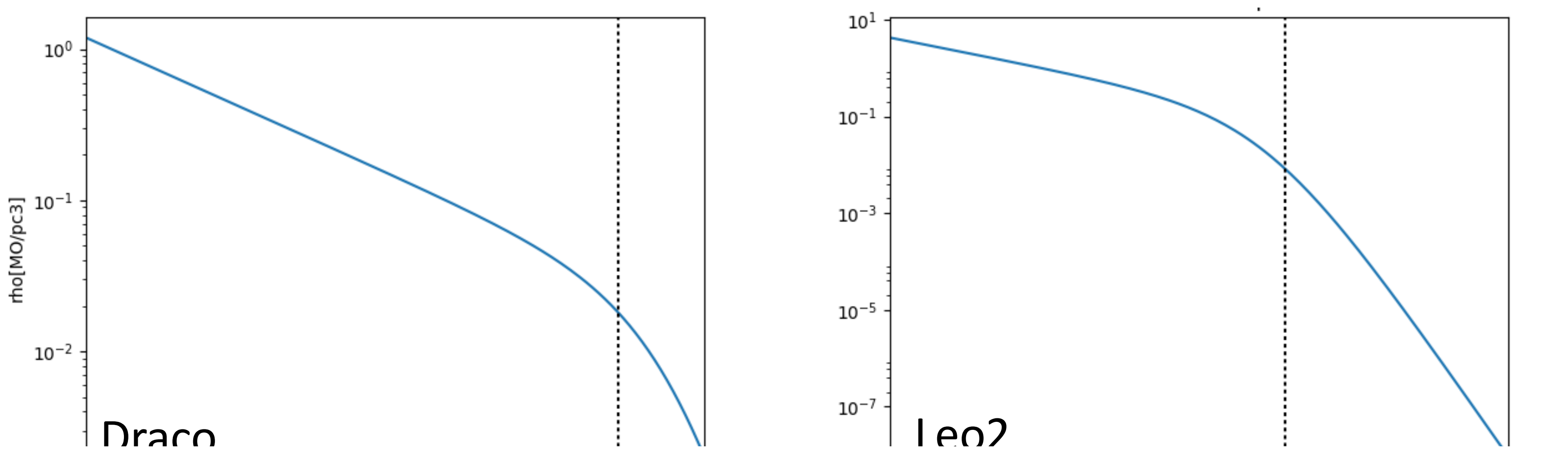
(Geringer-Sameth et al., 2015)

Profiles:

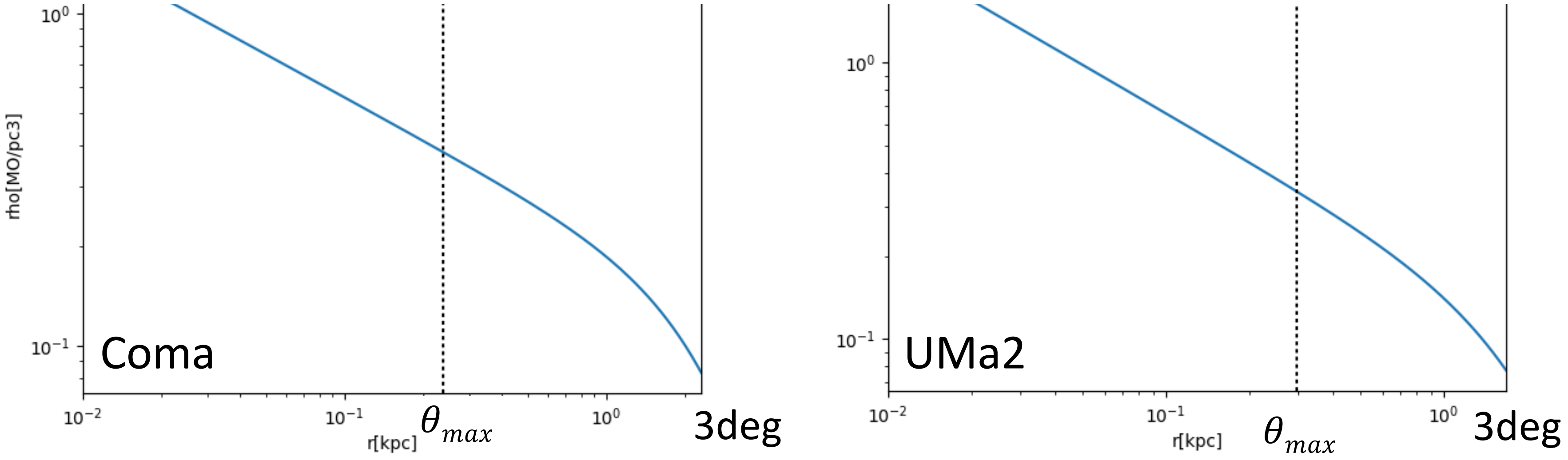


Draco
rho[MO/pc3]
r[kpc]
θ_{max}
3deg
Leo2
θ_{max}
3deg
Coma
rho[MO/pc3]
r[kpc]
θ_{max}
3deg
UMa2
r[kpc]
θ_{max}
3deg

Profiles:

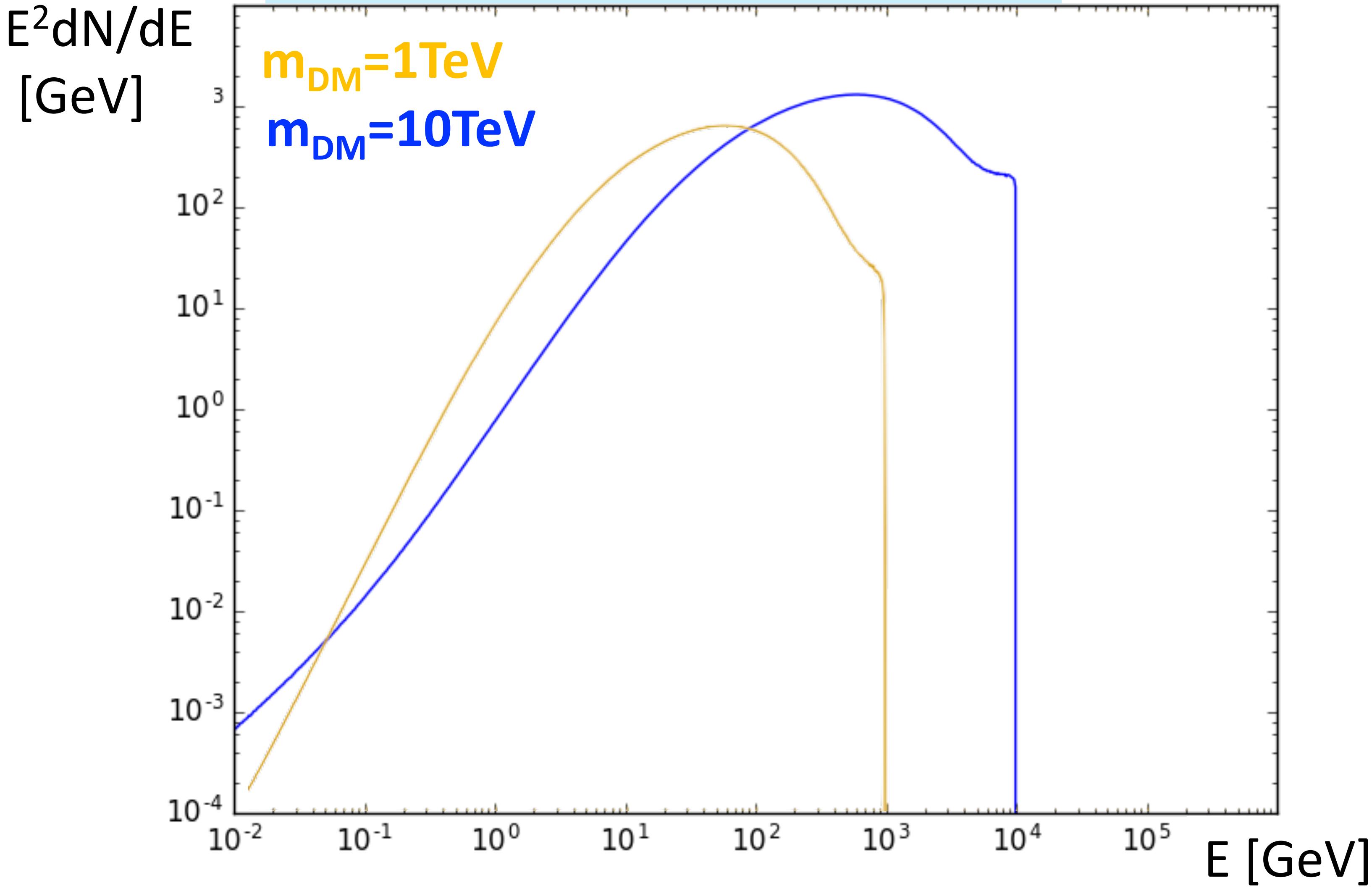


It is important to take these structures into account.
Then, what kind of DM do we search in these dSphs?



Particle Physics Model

e.g. DM + DM -> W^+ + W^-



motivated in Wino DM model

Conclusion

Conclusion

- CTA is very suitable for dark matter (DM) search
- dwarf spheroidal galaxies (dSphs) are good targets because of their clear environments
- We should be careful about the spatial structure of dSphs when we search DM in those with CTA
- CTA is expected to reach $<\sigma v> \sim 10^{22} - 10^{23}\mathrm{cm}^3/\mathrm{s}$ with 50h observations for dSph DM search