PROSPECTS FOR INDIRECT DARK MATTER SEARCHES WITH THE CHERENKOV TELESCOPE ARRAY

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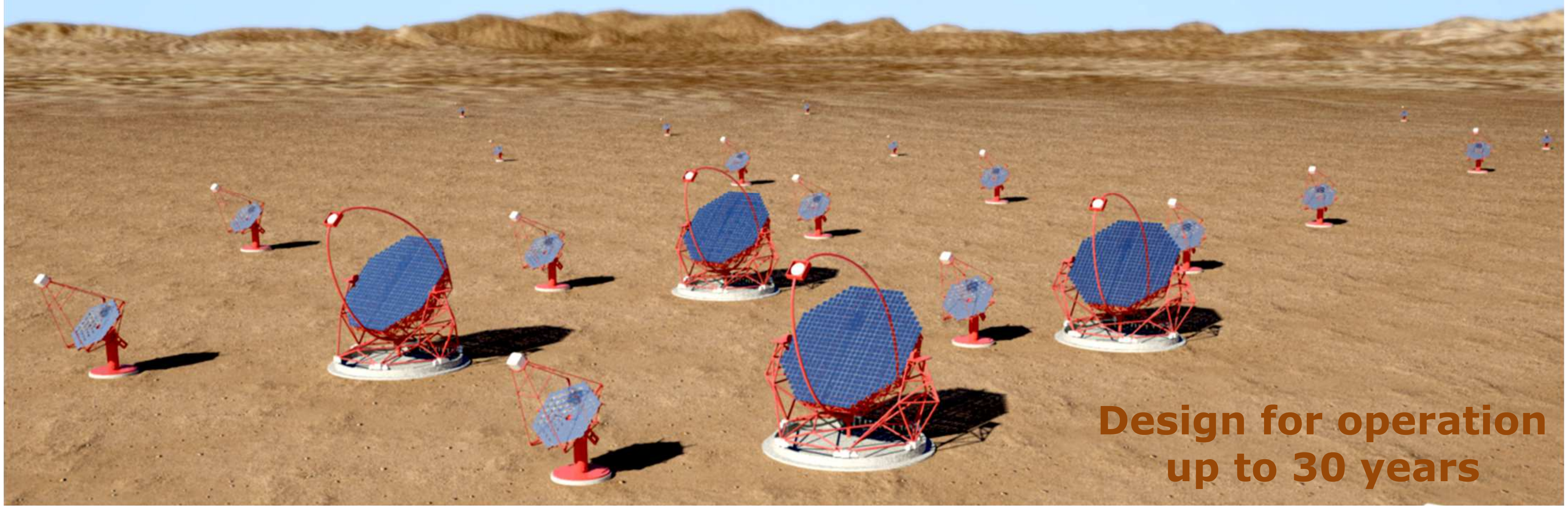
For CTA Consortium

CTA PROJECT

- Next generation ground based Gamma-ray Observatory
- Open observatory
- Two sites with total > 100 telescopes
  - Southern Site: Near Paranal in Chile
  - Northern Site: La Palma, Canary Islands
- 31 nations, ~ €300M project



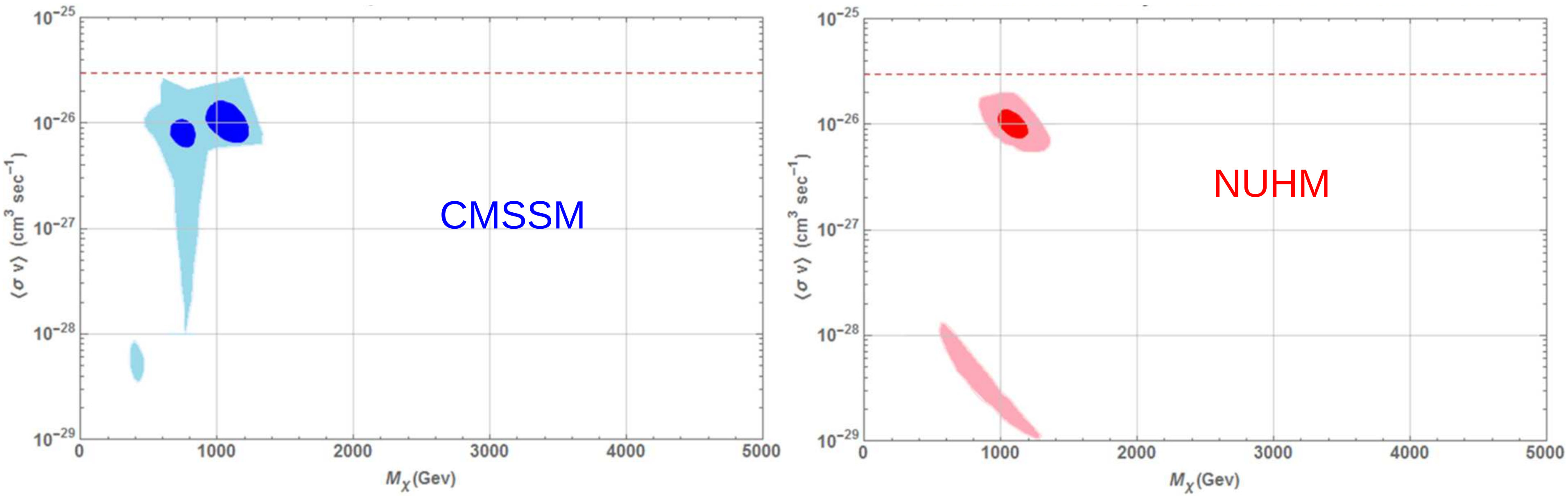
EXPECTATIONS FOR WIMP DM

In thermal picture of early Universe, relic density and annihilation cross-section are related

$$\Omega_{DM} h^2 \propto \frac{1}{< \sigma_{\chi\chi}\, v >} \qquad \text{for} \quad \Omega_{DM} h^2 = 0.1$$

$< \sigma_{\chi\chi} v > = 3 \times 10^{-26}$ cm^3 sec^{-1} “thermal” cross-section

Roszkowski et al., arXiv:1405.4289, expectations for common SUSY models

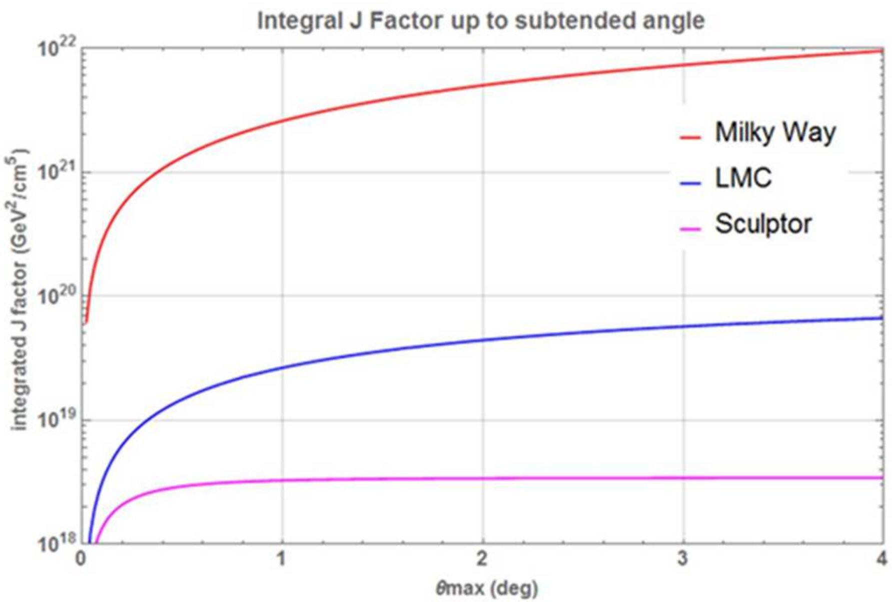


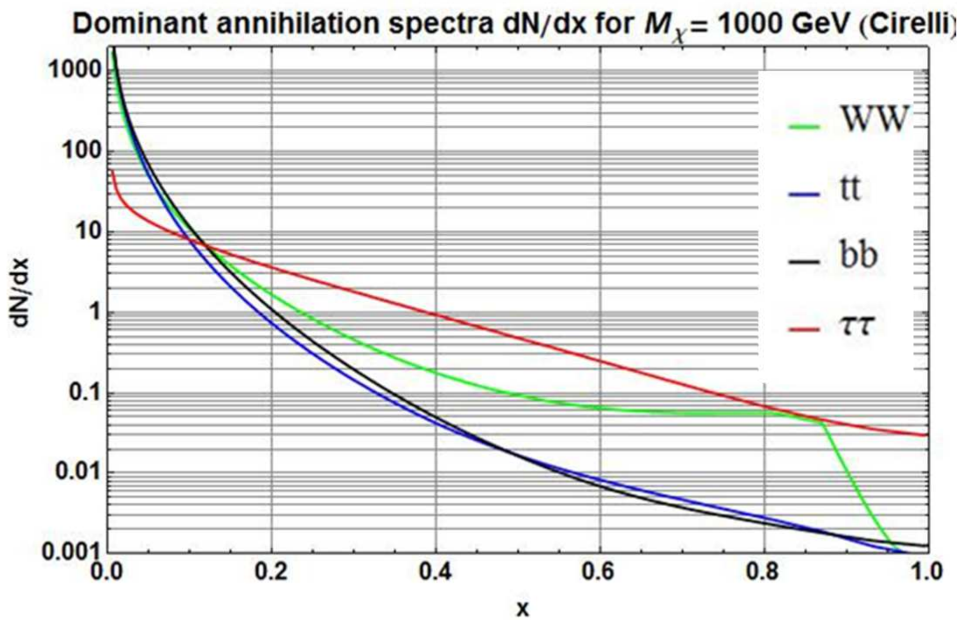
Many SUSY models give M_{χ}: 0.5 to 2.5 TeV with $<\sigma v>$ 5×10^{-27} to 3×10^{-26} cm^3 sec^{-1}

RATES FOR DM ANNIHILATION

Event rate: $N_{DM} = \frac{t_{obs}\ \mathrm{J}(\Delta\Omega) < \sigma\, v>}{8\,\pi\, M_\chi{}^2} \int_{E_{min}}^{E_{max}} \frac{dN_{DM}}{dE}(E)\, A_{eff}(E)\, dE$

J-factor: $\mathrm{J}(\Delta\Omega) = \int_{\Delta\Omega} d\Omega \int_{line-of-sight} \rho^2[r(l)]dl$





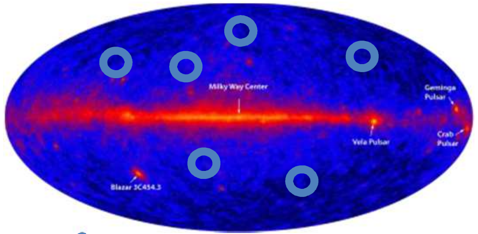
Milky Way galaxy largest J-Factor

W^+W^- dominate mode in pMSSM at 1 TeV

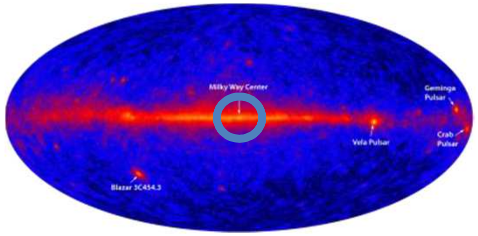
POSSIBLE TARGETS

Strong signal

Galaxy clusters



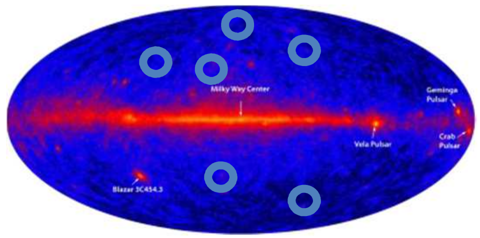
Galactic Center halo



Large Uncertainties

Robust Constraints

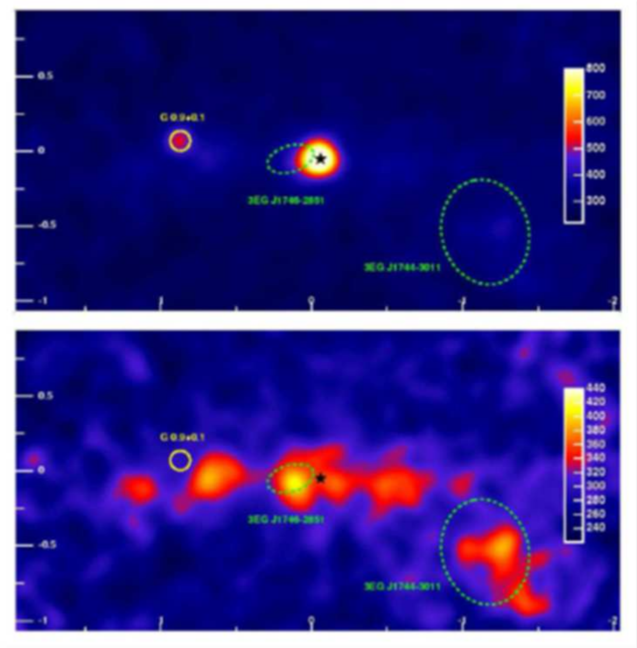
Dwarf Galaxies



CHOICES FOR DM OBSERVATIONS

CTA Field of View ~ 5-7° (with acceptance constant ~2.5°)

Milky Way Galactic Halo



Large Magellanic Cloud

Dwarf Galaxies

Astrophysics sources in observation field
Backgrounds for dark matter
Motivation for observations

No sources
Clean targets for DM
Observation only DM

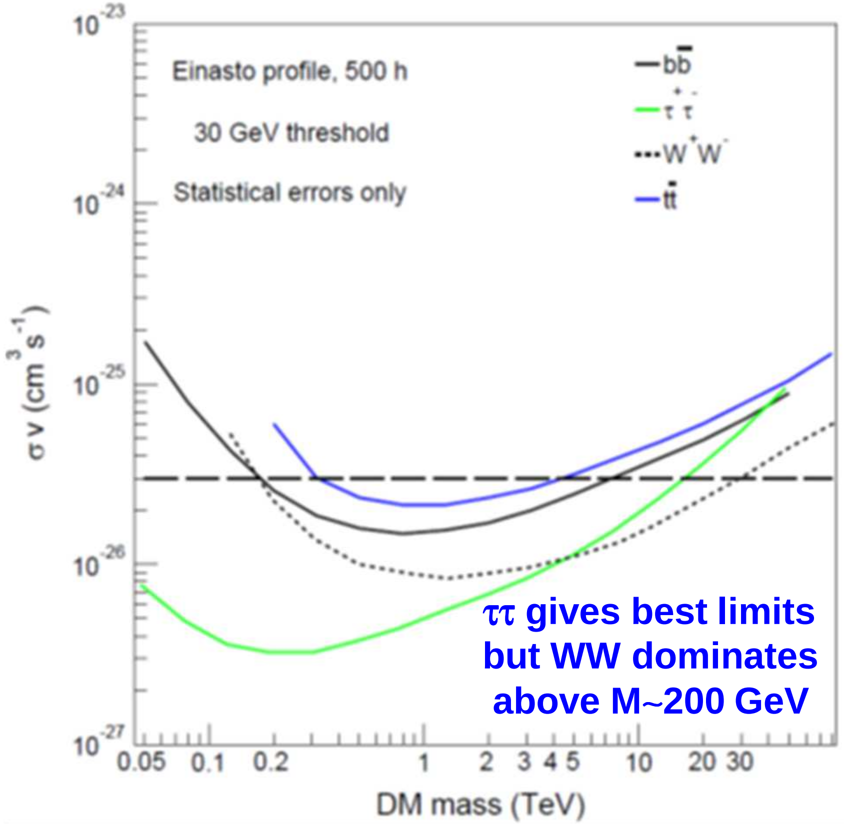
CTA DARK MATTER STRATEGY

- Focus on the brightest target: the Galactic Centre Halo
- Any hints for a DM signal at the GC needs cross-checked in a different (cleaner) environment
- If there is a detection :
  - σv high enough: check DM signal towards best dwarf galaxy
  - Small σv: deeper observations of GC region
- If no detection :
  - focus observations on the best target at that time

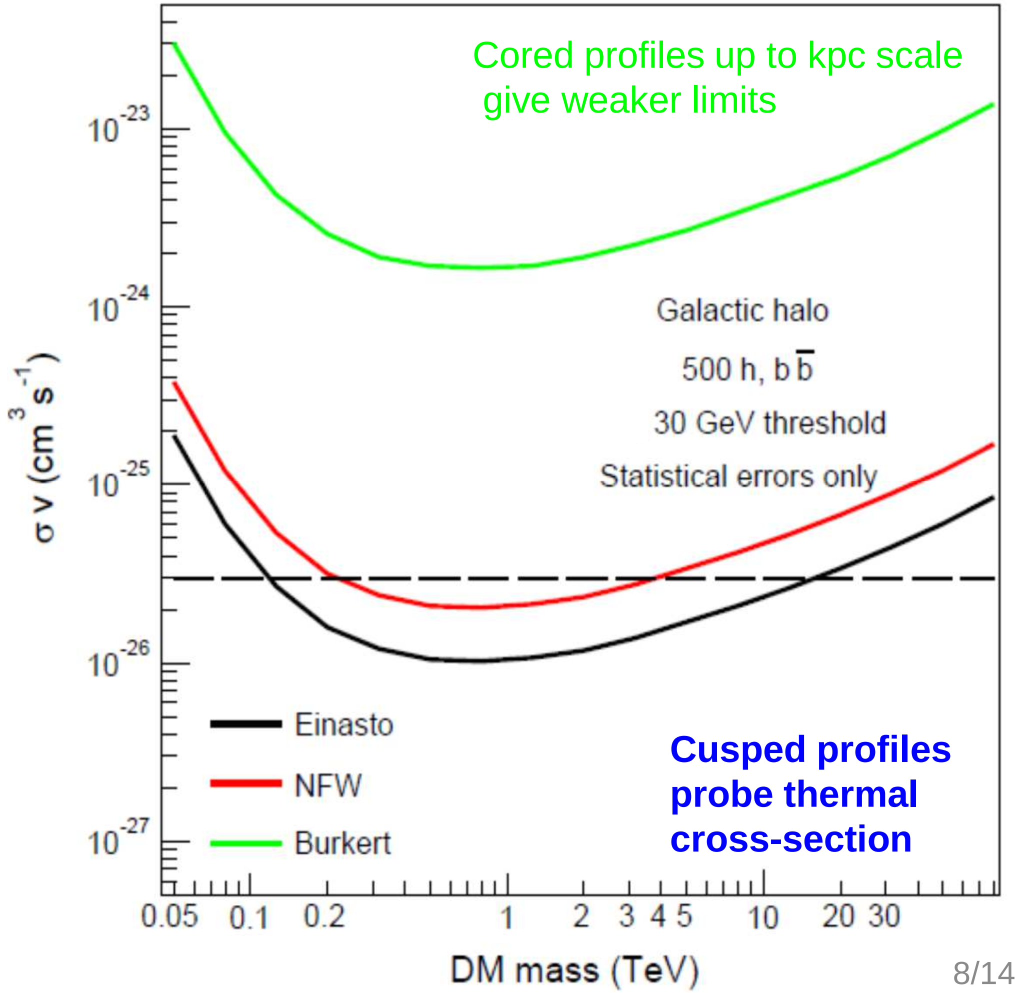
GALACTIC HALO SENSITIVITY

Investigations of “Physics Systematics”

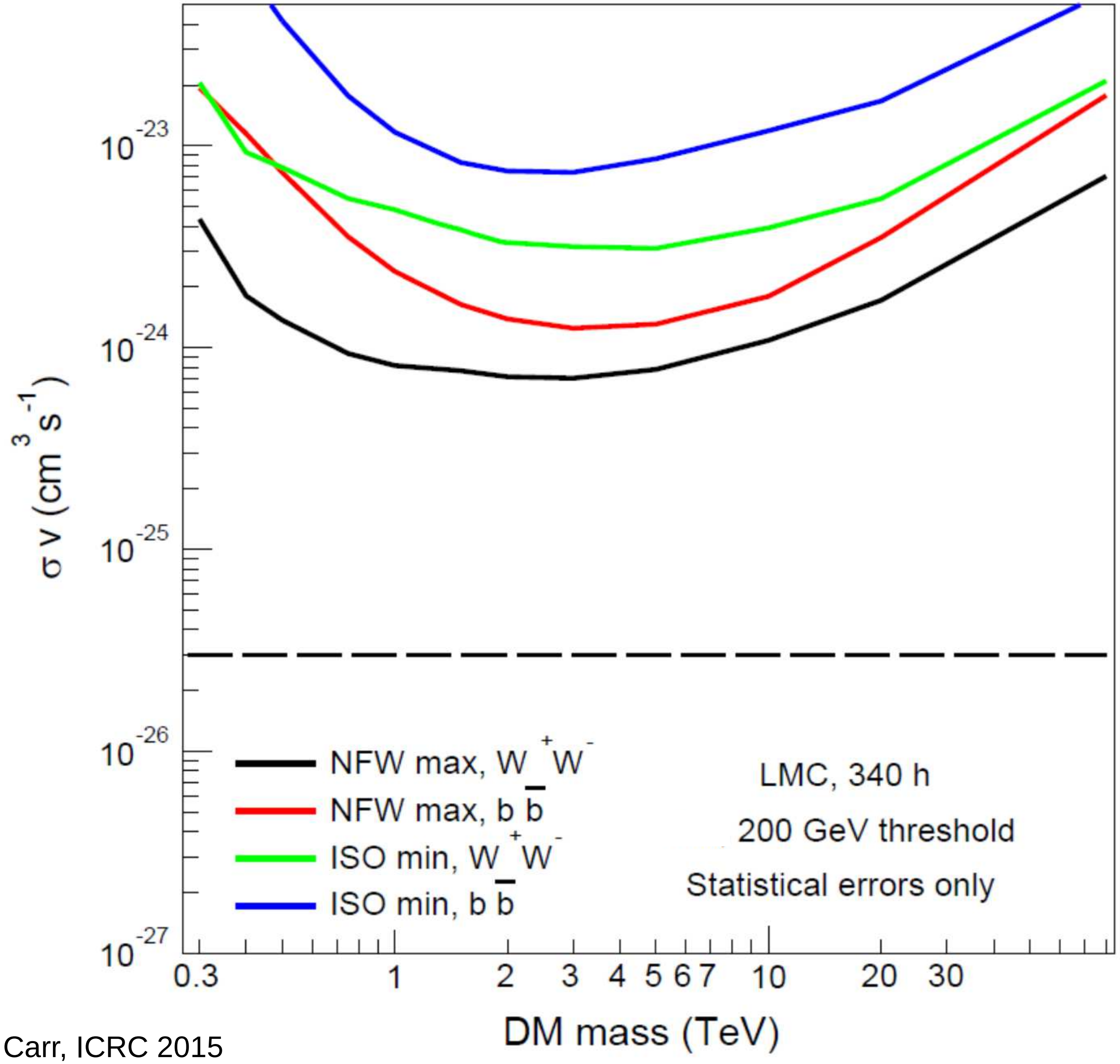
Variations in annihilation mode



Variations in dark matter density profile



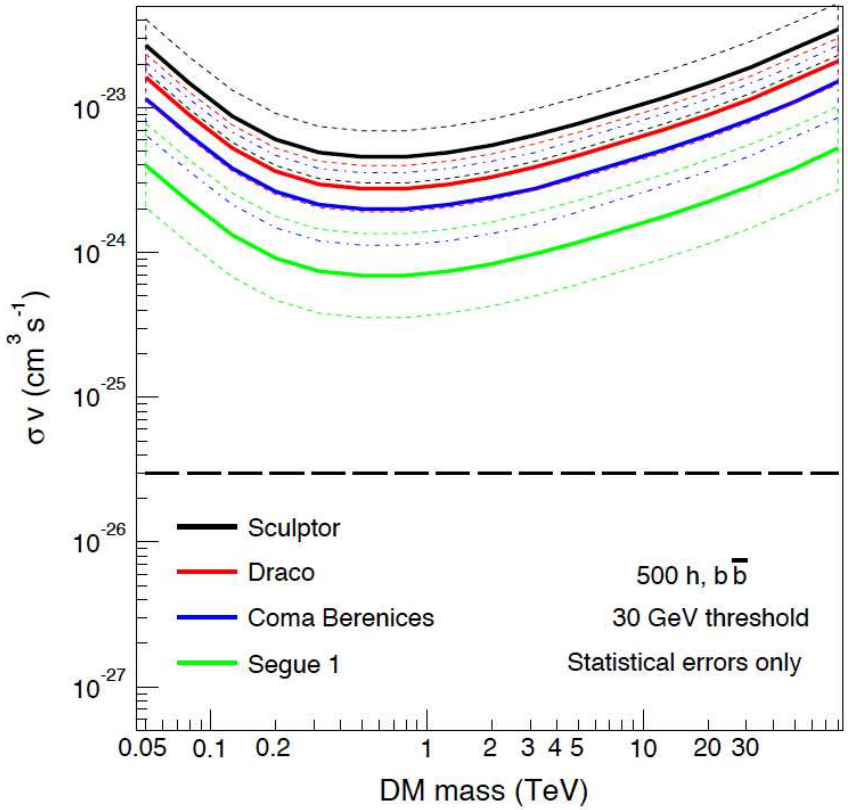
LARGE MAGELLANIC CLOUD



LMC has diffuse gamma-ray background as well TeV sources as recently published by HESS: Science 347, 405(2015).

So has similar systematics issues as Milky Way Galaxy Halo.

DWARF GALAXIES



Target	Dec. [deg.]	Distance [kpc]	$\log_{10}$ (J/GeV^{2}cm^{-5})
Sculptor	-83.2	79	18.47 ± 0.18
Draco	+34.7	82	18.69 ± 0.16
Coma Berenices	+23.4	44	18.83 ± 0.25
Segue 1	+16.1	23	19.31 ± 0.29

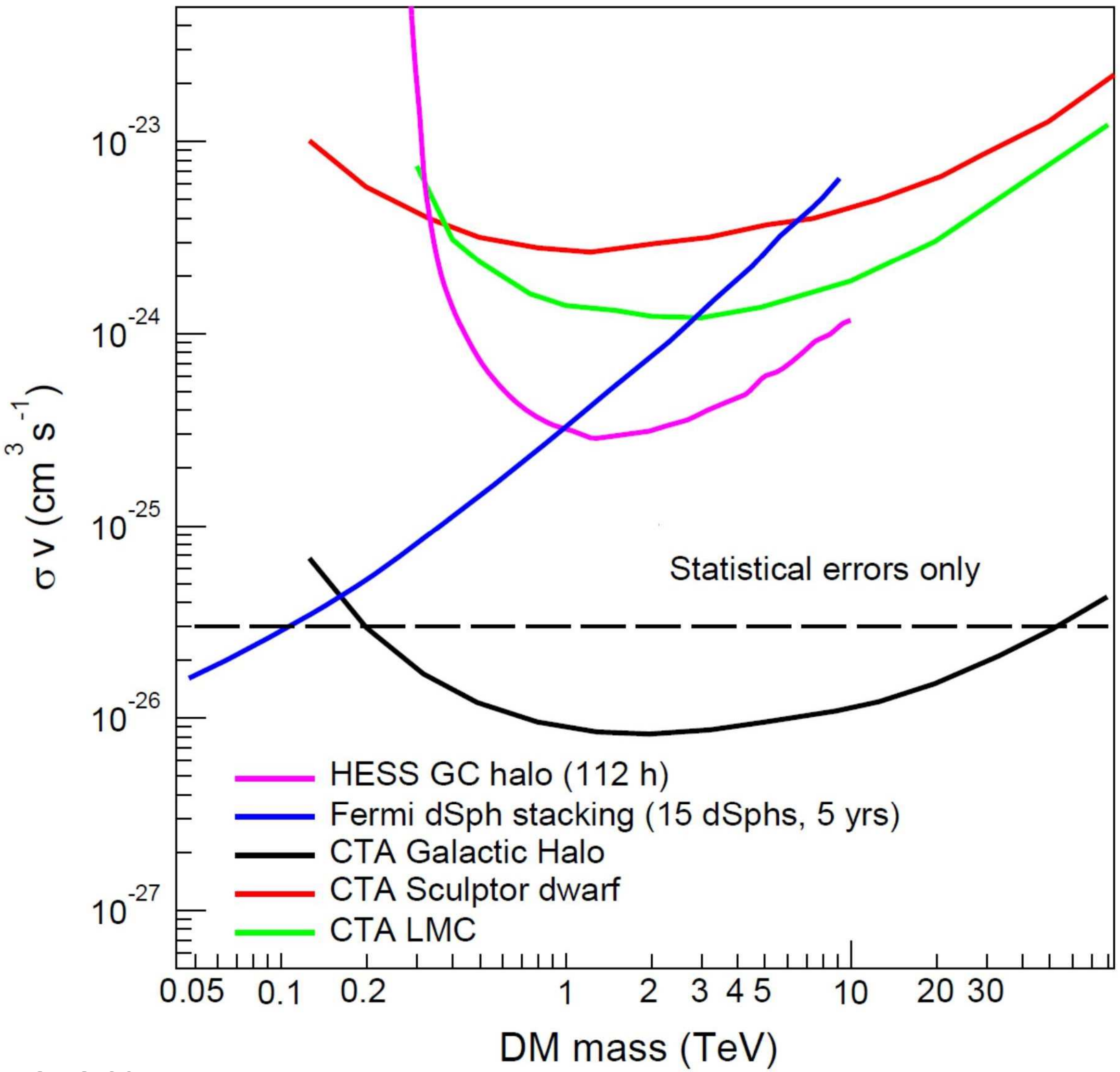
N.B. recent doubts on Segue 1 J-factor due to interlopers in stellar-kinematic samples.
V. Bonnivard et al., arXiv:1506.08209

Much further work needed to quantify J-factors for ultra faint dwarf galaxies

New dwarf galaxy candidates discovered from the DES survey in the Southern Sky e. g. Reticulum II. Other surveys will also be active soon (Pan-STARRS, LSST, …).

Will choose most promising targets before observations with latest knowledge.

SENSITIVITY OF MAIN TARGETS

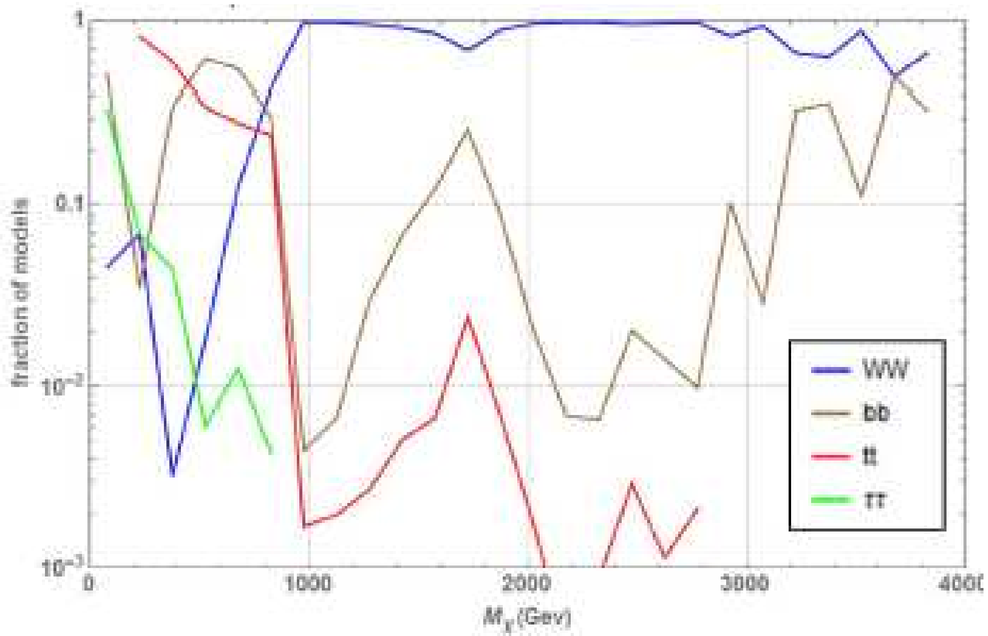


- For Galactic Halo with cuspy profile CTA can probe below thermal cross-section
- Systematics must be controlled to attain statistically possible sensitivity

DARK MATTER MODELS

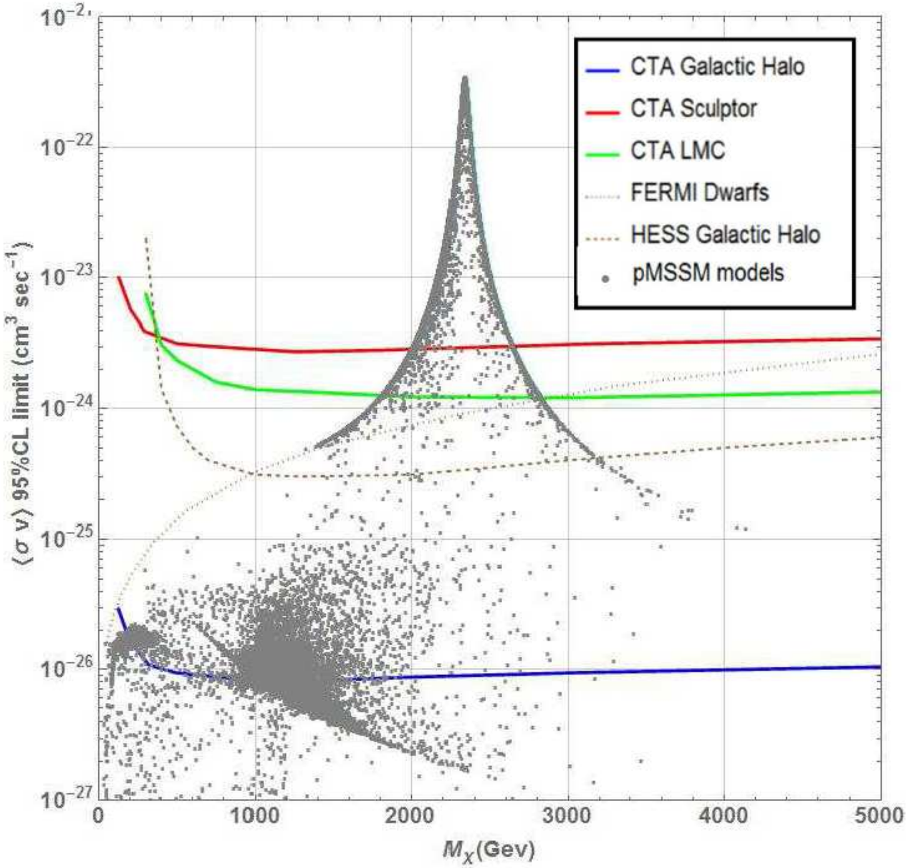
From pMSSM scan Roszkowski L et al, JHEP 1502, 014(2015).

Proportion of models with dominant annihilation mode



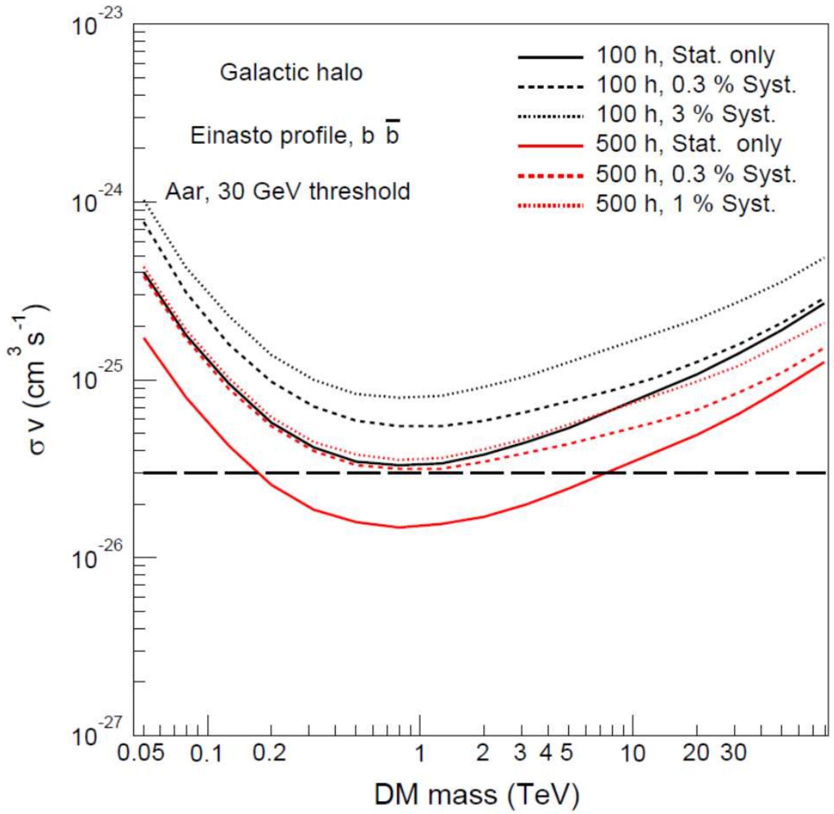
>800 GeV WW most probable mode

pMSSM models surviving experimental constraints



CTA can probe majority of surviving pMSSM models

SYSTEMATIC ERRORS



Treatment of *uncorrelated* systematic errors following method of Silverwood et al, JCAP 03:05, 5 (2014).

However, real instrumental and background systematics are *correlated.*

Extensive work in progress to evaluate and plan actions to control systematics.

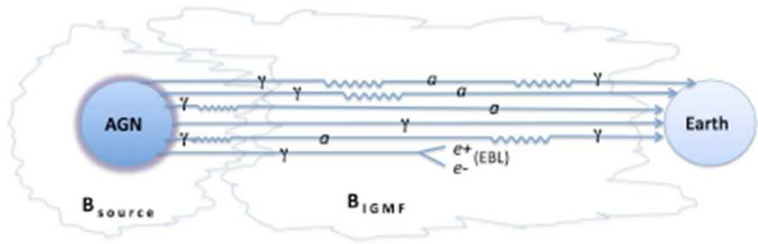
SUMMARY

- Great possibility to discovery dark matter with Galactic Centre observations
  - CTA is the unique player in some regions of the parameter space with TeV Dark Matter
- CTA has good prospects for reaching WIMP models with thermal relic cross-section for masses > 200 GeV
  - First time ever that natural scale for the cross section can be probed
- CTA also is sensitive to Axions-Like Particles in part of phase space relevant for Dark Matter
- Fermi/CTA will be able to probe thermal WIMPs from a few GeV up to a few tens of TeV
- CTA will be complementary to LHC/direct searches/astrophysical probes

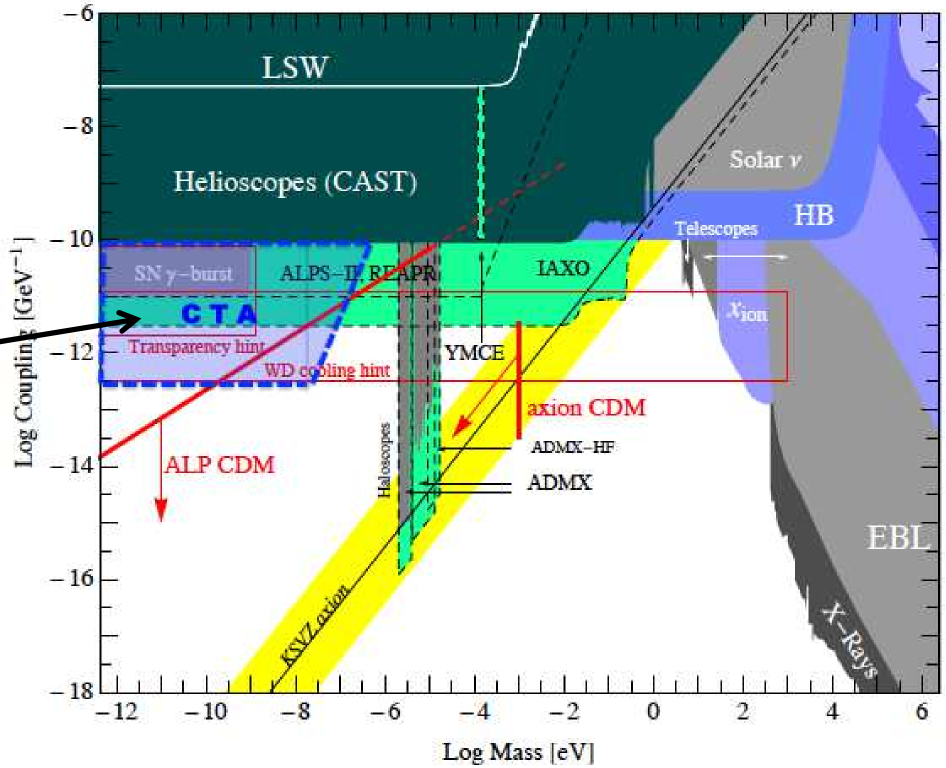
BACKUP SLIDES

AXION-LIKE PARTICLE SEARCHES

- Conversion of gamma-rays to/from axion-like particles (ALPs) can create
  - distinctive features in the spectra of gamma-ray sources ;
  - increased transparency of the universe by reducing the EBL absorption

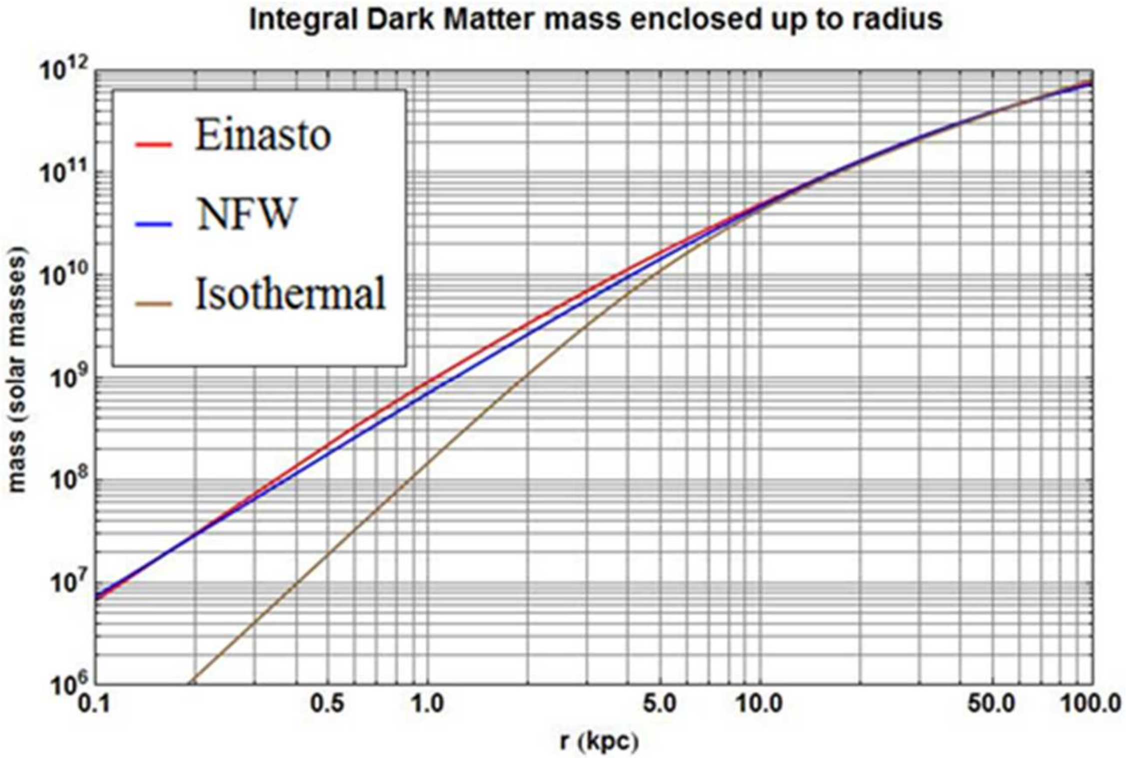


- Parameter space probed by CTA
  - Some ALP CDM models can be tested at neV mass scale



DARK MATTER DENSITY PROFILES

- NFW: $\rho(r) = \rho_s \frac{r_s}{r}\left(1+\frac{r_s}{r}\right)^2$
- Einasto: $\rho(r) = \rho_s \, exp\left\{-\frac{2}{\alpha}\left[\left(\frac{r}{r_s}\right)^{\alpha}-1\right]\right\}$
- Isothermal: $\rho(r) = \rho_s \frac{1}{1+(r/r_s)^2}$
- Burkert: $\rho(r) = \rho_s \frac{1}{(1+r/r_s)(1+(r/r_s)^2}$



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