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Multi-TeV (brane-world) Dark Matter: a brief overview

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Outlook

- Model independent Multi-TeV Dark Matter (DM):
 - ➔ motivation & previous works (Galactic Center)
 - ➔ TeV DM searches in dwarf irregular galaxies with the High Altitude Water Cherenkov (HAWC) Observatory
 - ➔ Multi-wavelength prospects and the Square Kilometre Array (SKA) (Draco dwarf spheroidal galaxy)
- Multi-TeV brane-world DM
- Conclusions

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Dark Matter searches

DM Model and spin dependent
 $\text{GeV} < m_{\text{DM}} < \text{TeV}$

DM Model Independent and
 $\text{MeV} < m_{\text{DM}} < \text{PeV}$

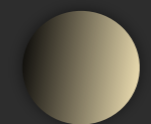
Indirect detection



DM

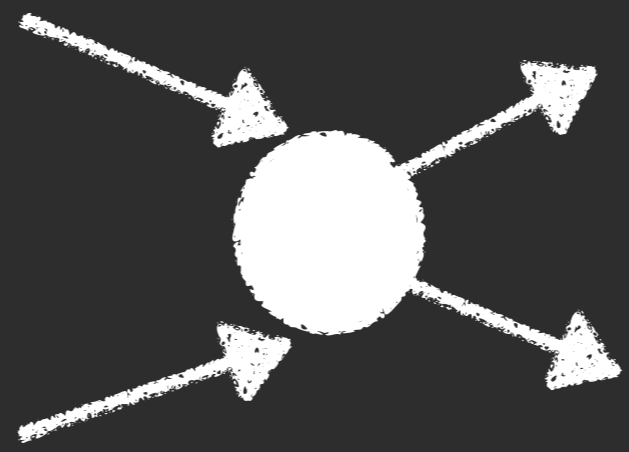


χ Particles



SM

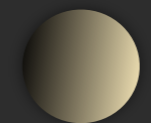
(quarks, bosons, leptons)



DM



Energy $\equiv \chi$ Mass



SM

Channel $\equiv \chi$ Model

Direct detection
(Underground experiments)



DM Model dependent and
 $\text{GeV} < m_{\text{DM}} < \text{TeV}$

Detection at Colliders (CERN, LHC etc..)



Motivation

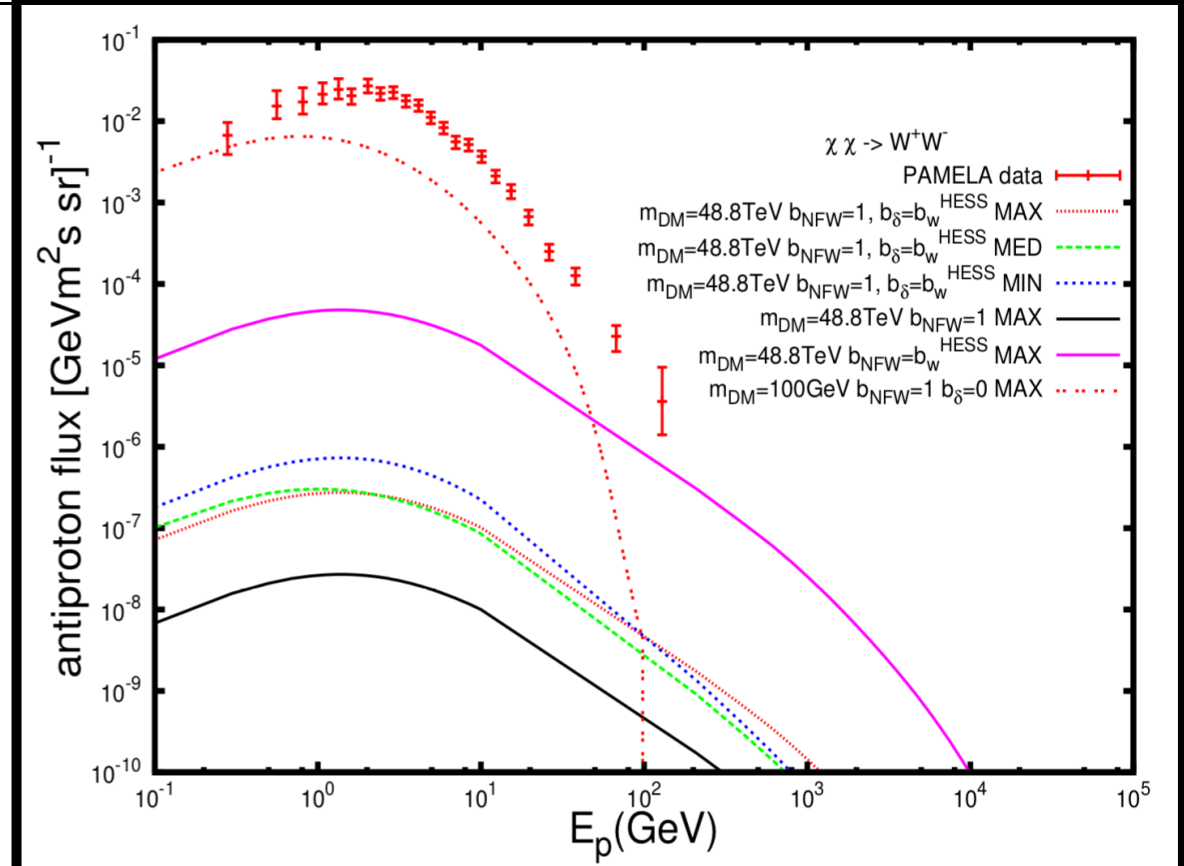
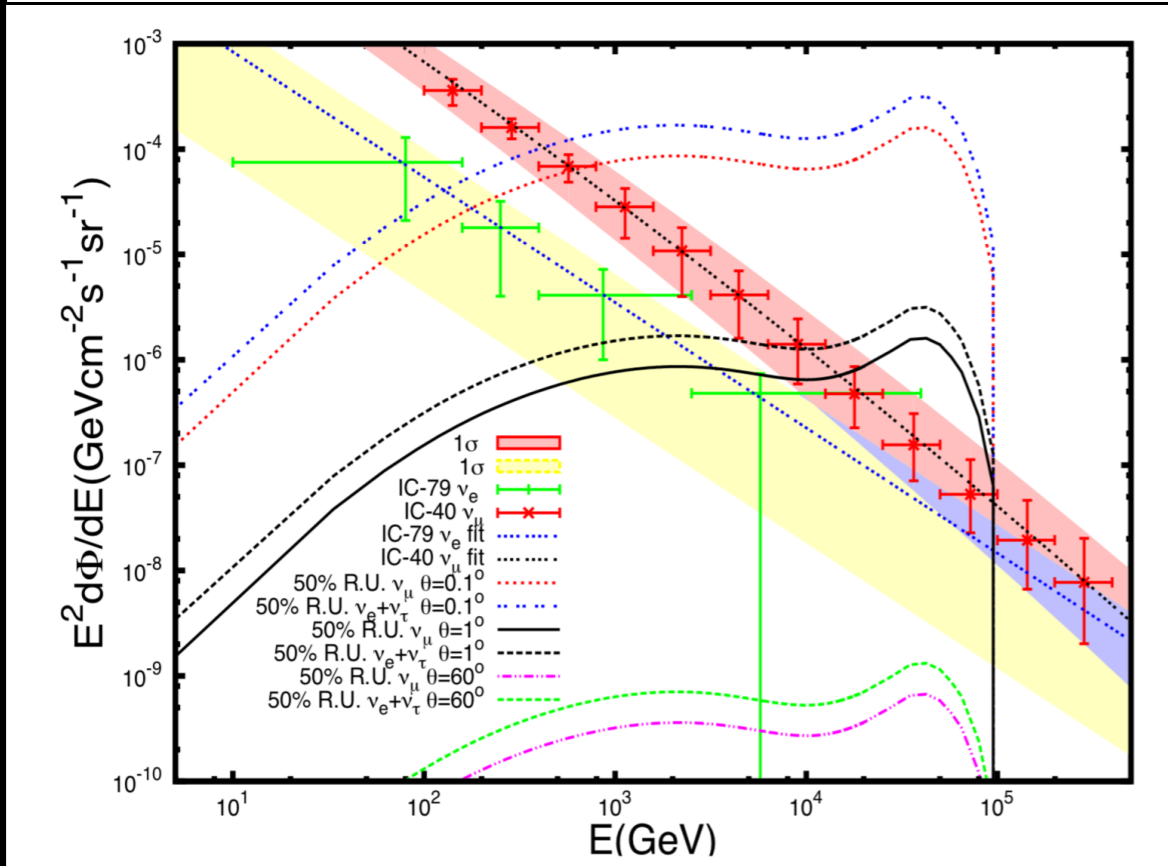
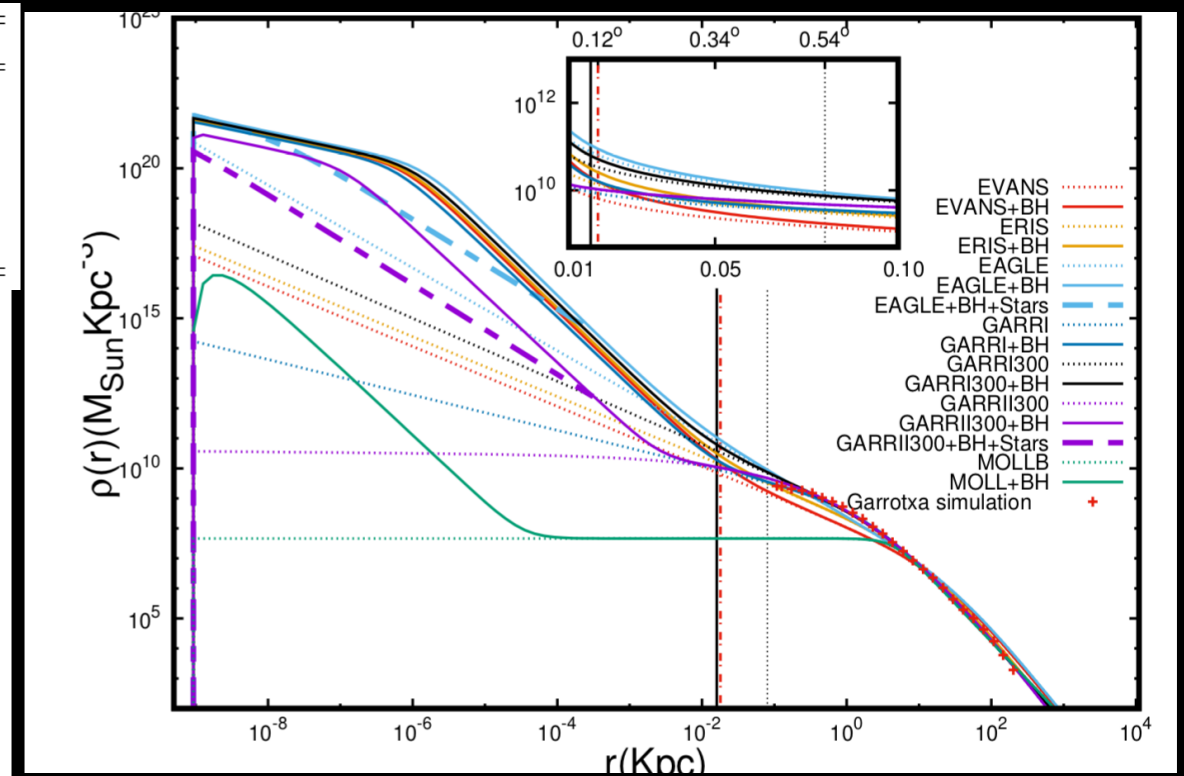
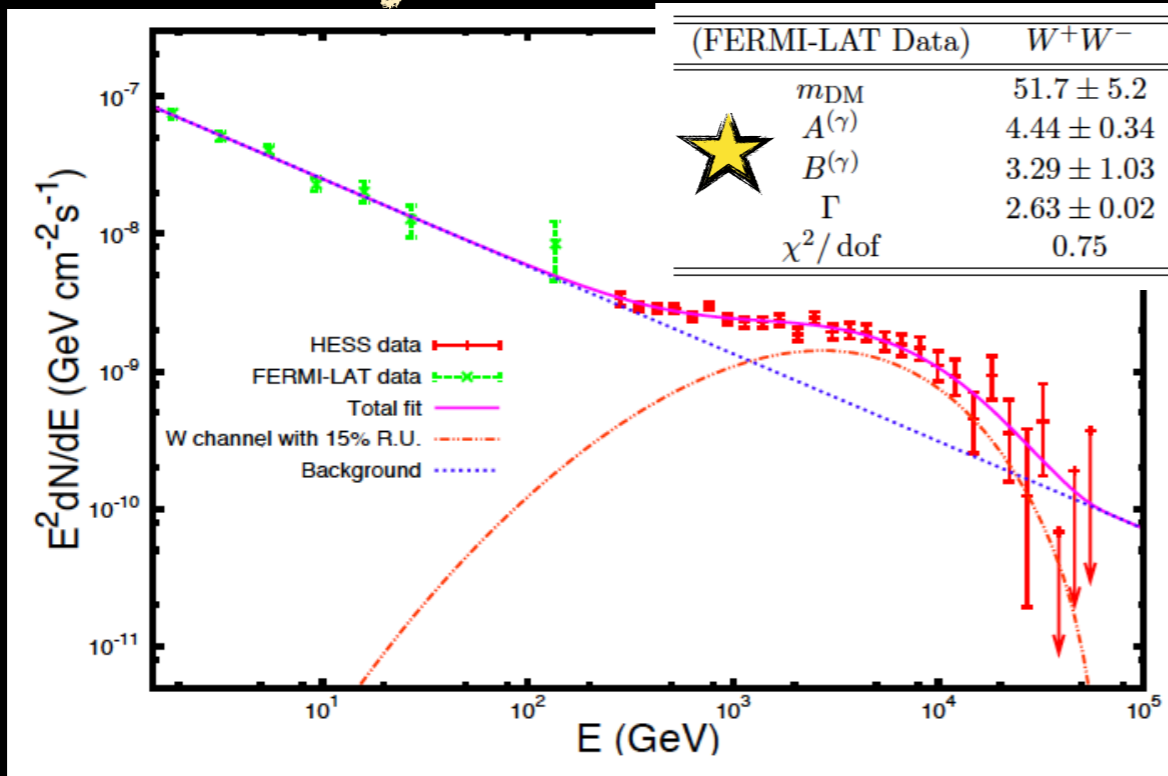
- No detection of any DM signatures at colliders below few TeV
- Strong tension emerges between the DAMA/NaI and DAMA/LIBRA claim and the null results from several underground experiments, such as CDMS, XENON10, CRESST I, CoGeNT, TEXONO, and Super-Kamiokande
- Many claims of prospective gamma-ray signatures from MeV-GeV DM candidates (Fermi-LAT GeV-excess, emission lines, etc...)

No conclusive evidence for DM so far.

Previous works: the Galactic Center

(gamma rays)

(DM distribution)



V.G., Front. Astron. Space Sci., 05 April 2019

(neutrinos)

(antiprotons)

Previous works

- Model independent Multi-TeV DM candidate well fits the GC cut-off by HESS (2012) -> Multimessenger analyses are in agreement with neutrino (2014) & antiproton (2015) data...

plenty of recent data and different analyses about related topics that should be mentioned.. updated analyses required for a comprehensive discussion.. work in progress!

- Such a model requires a 10^3 enhancement, which could be produced by a black hole induced DM spike

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TeV DM @ dwarf irregular galaxies

Dwarf spheroidal (dSph) galaxies



The Draco Spheroidal Dwarf Galaxy

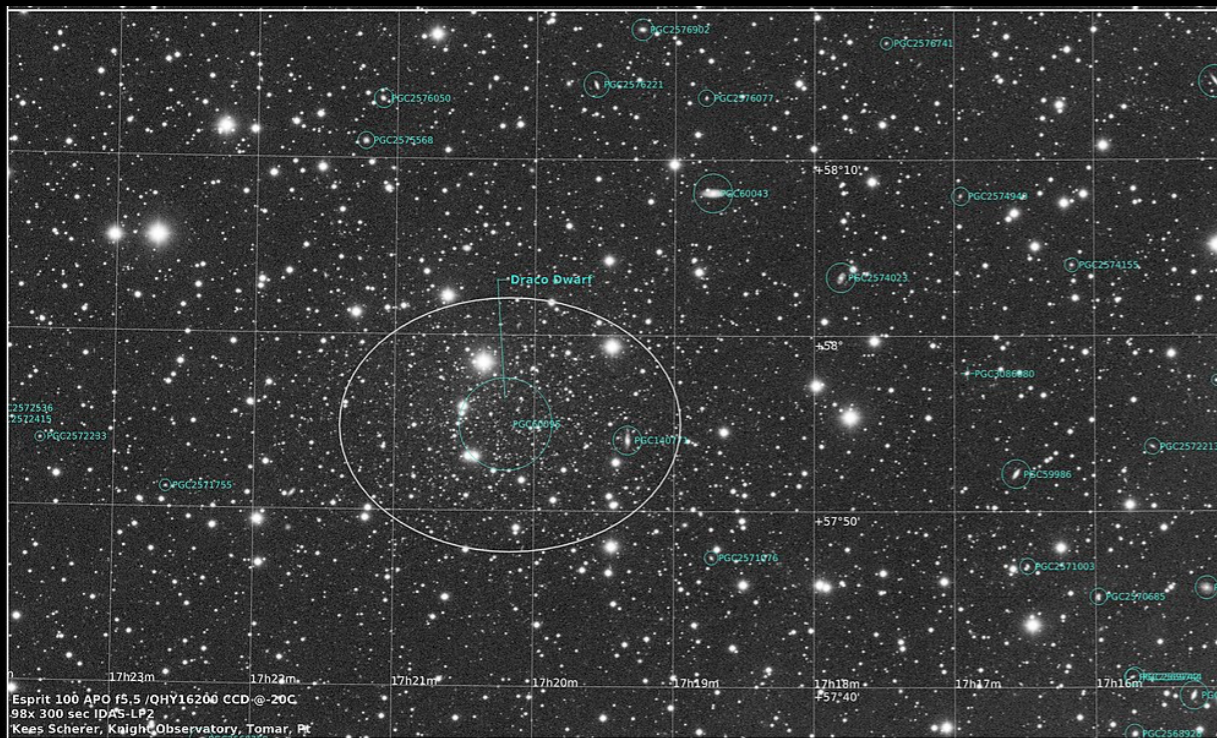
Credit: Keesscherer [CC BY-SA 4.0
(<https://creativecommons.org/licenses/by-sa/4.0>)]

Dwarf irregular (dIrr) galaxies

TeV DM @ dwarf irregular galaxies

Dwarf spheroidal (dSph) galaxies

Dwarf irregular (dIrr) galaxies



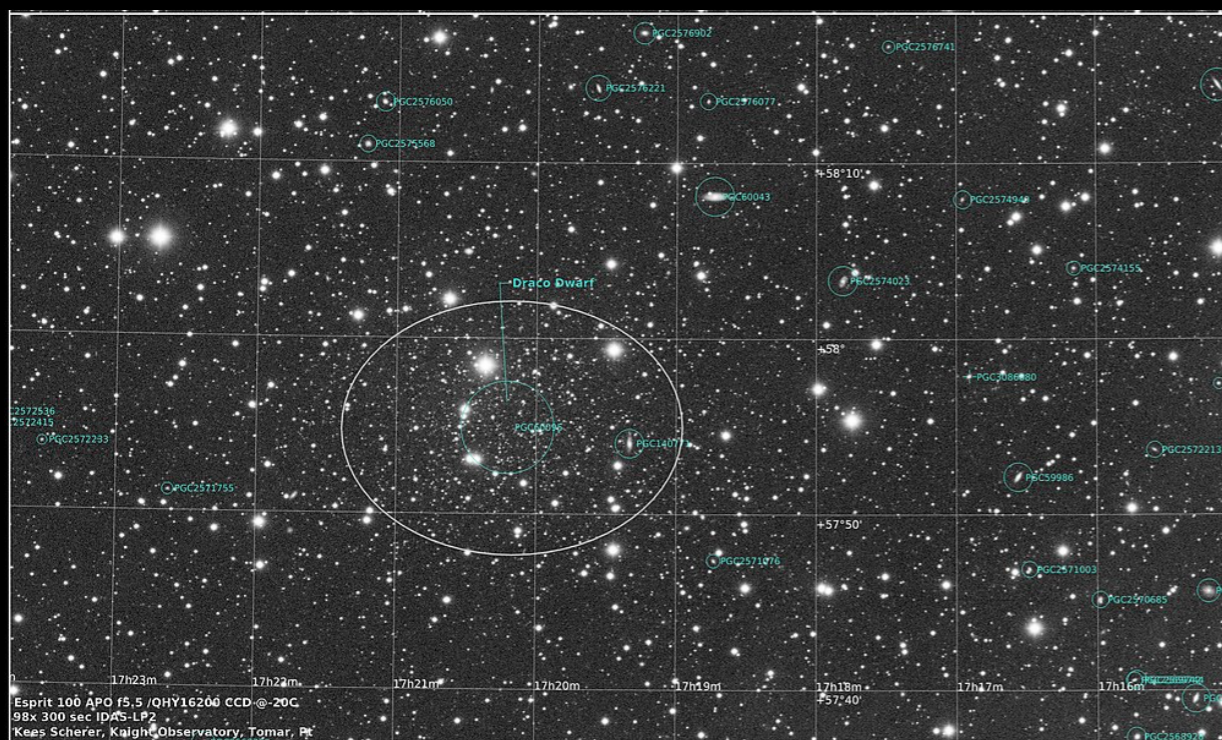
The Draco Spheroidal Dwarf Galaxy

Credit: Keesscherer [CC BY-SA 4.0

(<https://creativecommons.org/licenses/by-sa/4.0/>)]

TeV DM @ dwarf irregular galaxies

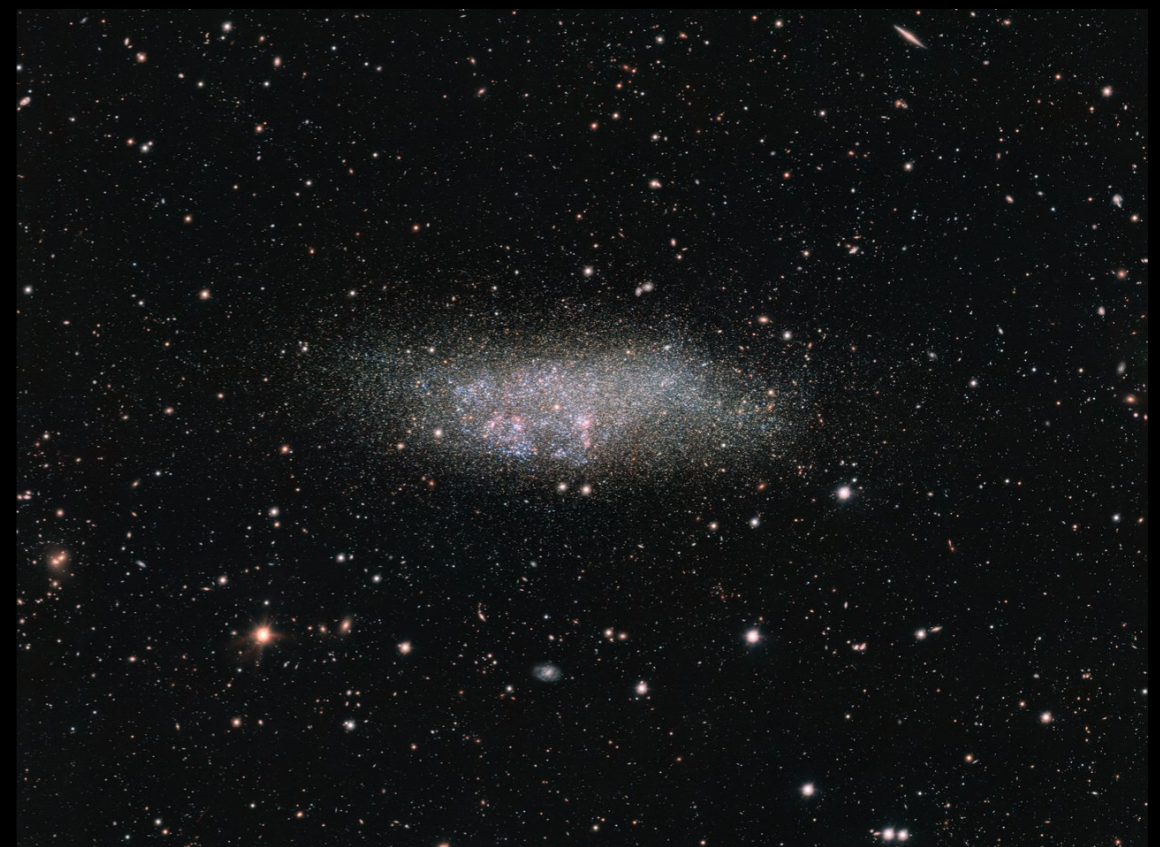
Dwarf spheroidal (dSph) galaxies



The Draco Spheroidal Dwarf Galaxy

Credit: Keesscherer [CC BY-SA 4.0
(<https://creativecommons.org/licenses/by-sa/4.0>)]

Dwarf irregular (dIrr) galaxies



The WLM galaxy on the edge of the Local Group

Credit: ESO

TeV DM @ dwarf irregular galaxies

Dwarf spheroidal (dSph) galaxies

Milky Way satellites
 $d < 0.5$ Mpc

Pressure supported objects
(Jeans theory - tidal stripping - phase space function)

DM dominated objects $M_{\text{halo}} 10^6$ - 10^8

10^{14} (Segue 2) $<$ J-factors $<$ 10^{19} (Draco)
(within the uncertainty)

Old star population
and negligible astrophysical background
in gamma rays

Well-know targets
for indirect searches of DM

Dwarf irregular (dIrr) galaxies

Local Volume galaxies
 0.5 Mpc $< d <$ 10 Mpc

Rotationally supported objects
(rotation curve)

DM dominated objects $M_{\text{halo}} 10^8$ - 10^{10}

$10^{14} <$ J-factors $<$ 10^{18}

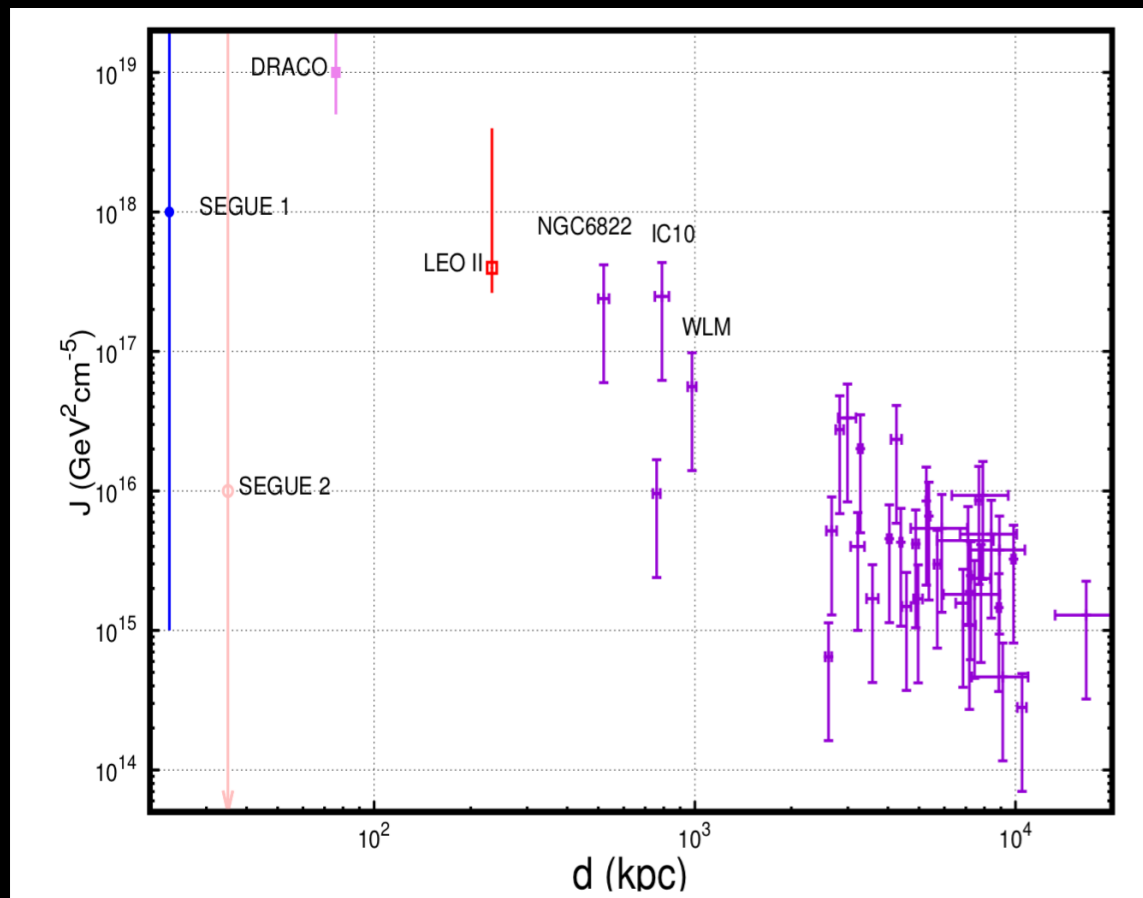
Previous work: Star forming region
and negligible astrophysical background
in gamma-rays? **Yes!**

VG, E. Karukes, P. Salucci, Phys. Rev. D 96, 083001 (2017)

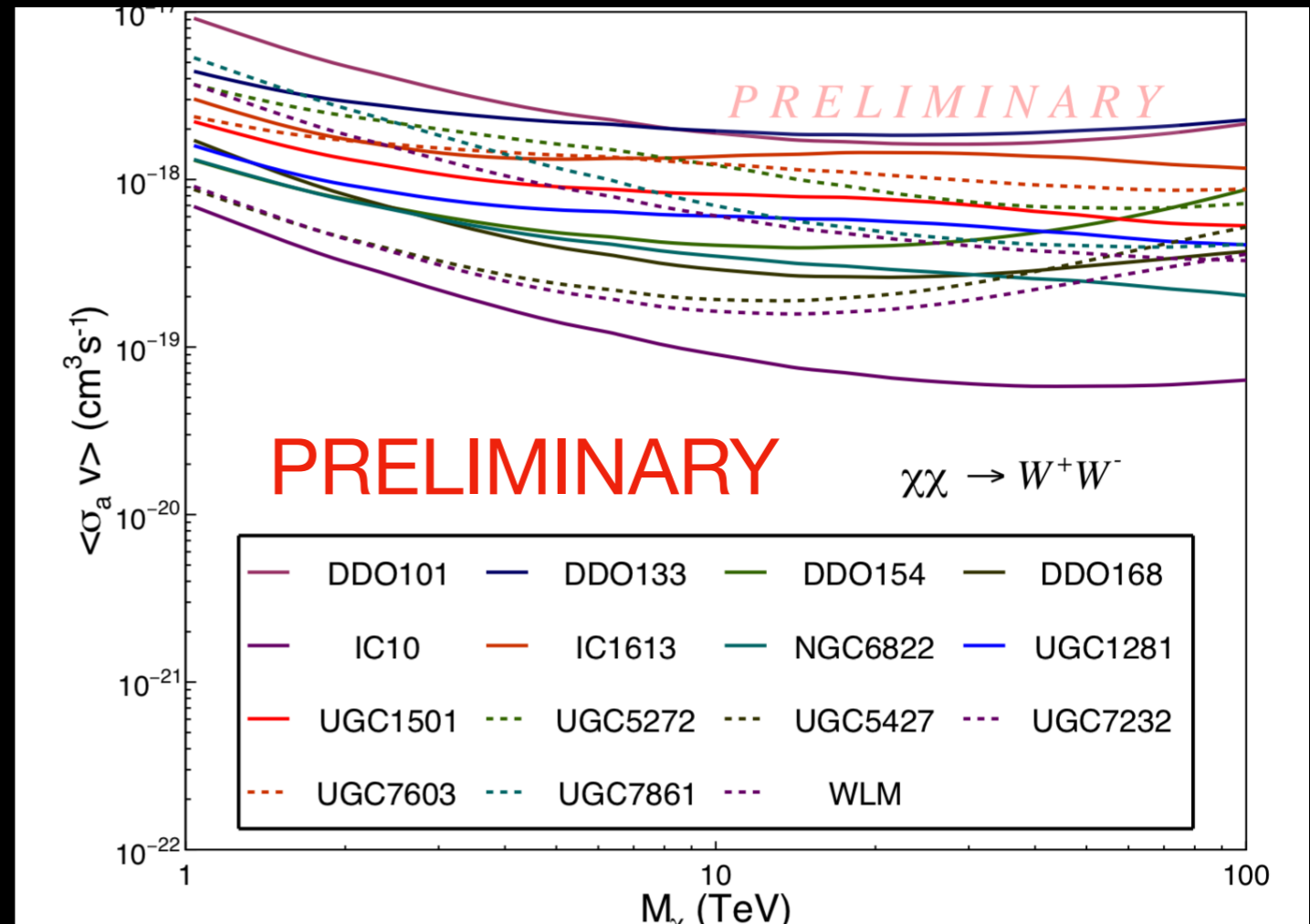
never analyzed
in the context of gamma-ray DM searches

TeV DM with HAWC @ dlrrs

- HAWC Observatory (Mexico) with large sky coverage
- No gamma-ray signal detected from dlrrs
- Point-like analysis for dSphs applied to dlrr galaxies



VG, E. Karukes, P. Salucci, Phys. Rev. D 96, 083001 (2017)



S. H. Cadena, R. Alfaro, A. Sandoval, E. Belmont, H. León, V. G., E. Karukes, P. Salucci for the HAWC Collaboration, HAWC-ICRC/2017/36. (2017)

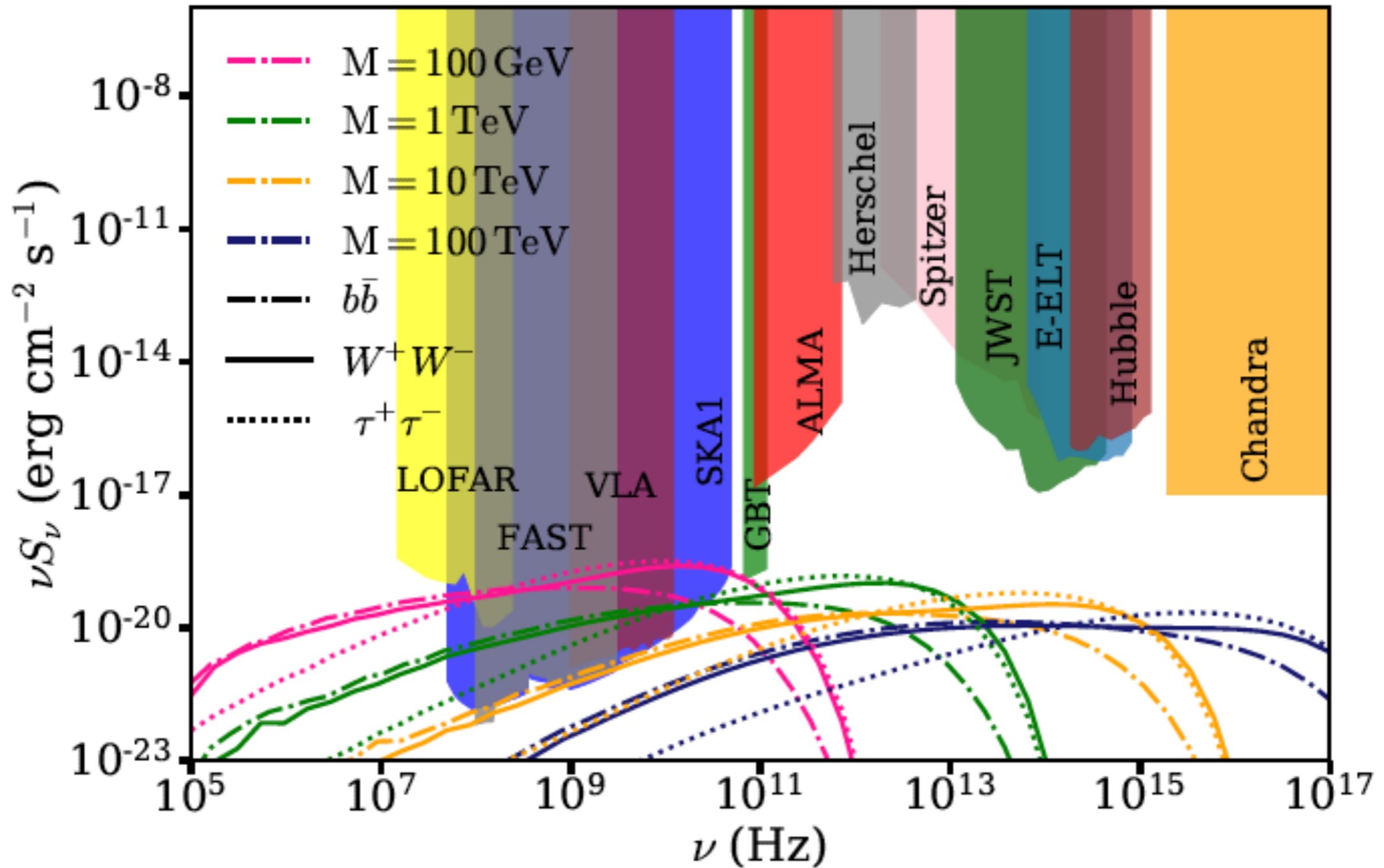
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Multi-wavelength prospects: Draco dSph

J. A. R. Cembranos, A. de la Cruz-Dombriz, V. G. , M. Mendez-Isla arXiv:1905.11154, submitted

(Model independent
synchrotron radio emission)



(talk by Miguel Méndez Isla) "Particle dark matter searches with the Square Kilometre Array"

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Multi-TeV DM candidates

- **Brane-world dark matter**

(e.g. J. A. R. Cembranos, A. Dobado and A. L. Maroto , Phys.Rev.D68:103505,2003)

- **Heavy Minimal Dark Matter**

(e.g. C. Garcia-Cely, A. Ibarra, A. S. Lamperstorfer, M. H.G. Tytgat, JCAP 1510 (2015) no.10, 058;
A. Cuoco, J. Heisig, M. Korsmeier, M. Krämer, JCAP 1804 (2018) no.04, 004)

- **Inverse Seesaw and Portal Dark Matter**

(e.g. C. Pongkitivanichkul, N. Thongyoi, P. Uttayarat, arXiv:1905.13224)

The branon DM candidate

$$\alpha = 1 \dots N$$

$$\mathcal{L}_{Br} = \frac{1}{2} g^{\mu\nu} \partial_\mu \pi^\alpha \partial_\nu \pi^\alpha - \frac{1}{2} m_{DM}^2 \pi^\alpha \pi^\alpha + \frac{1}{8f^4} (4\partial_\mu \pi^\alpha \partial_\nu \pi^\alpha - m_{DM}^2 \pi^\alpha \pi^\alpha g_{\mu\nu}) T^{\mu\nu}$$

- ✓ Branons are mass eigenstates of the fluctuations in the extra-space directions

-> massive particles

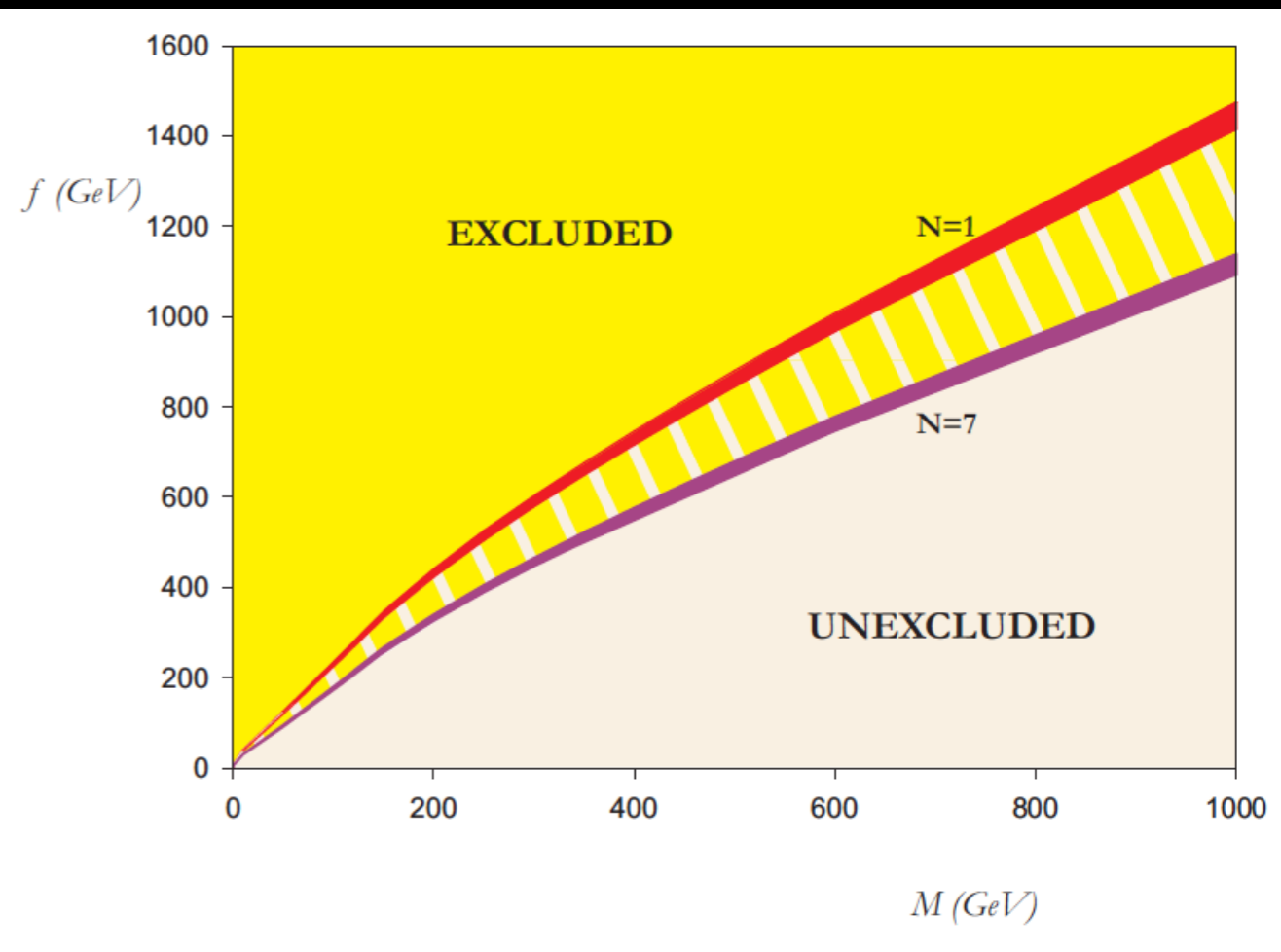
- ✓ Their couplings are suppressed by the tension f^4

-> weakly interacting

Natural
WIMP
candidate

Thermal candidate

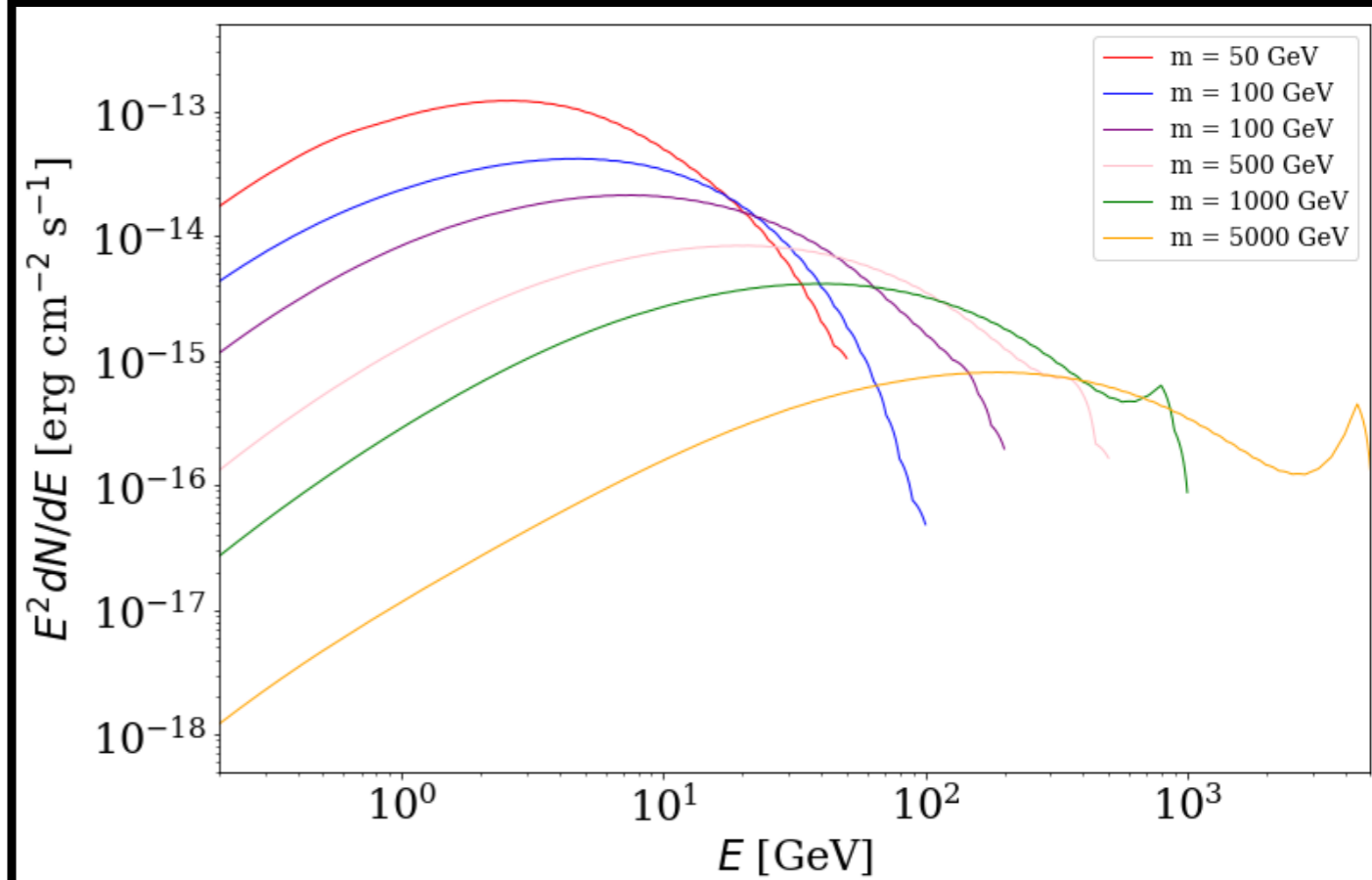
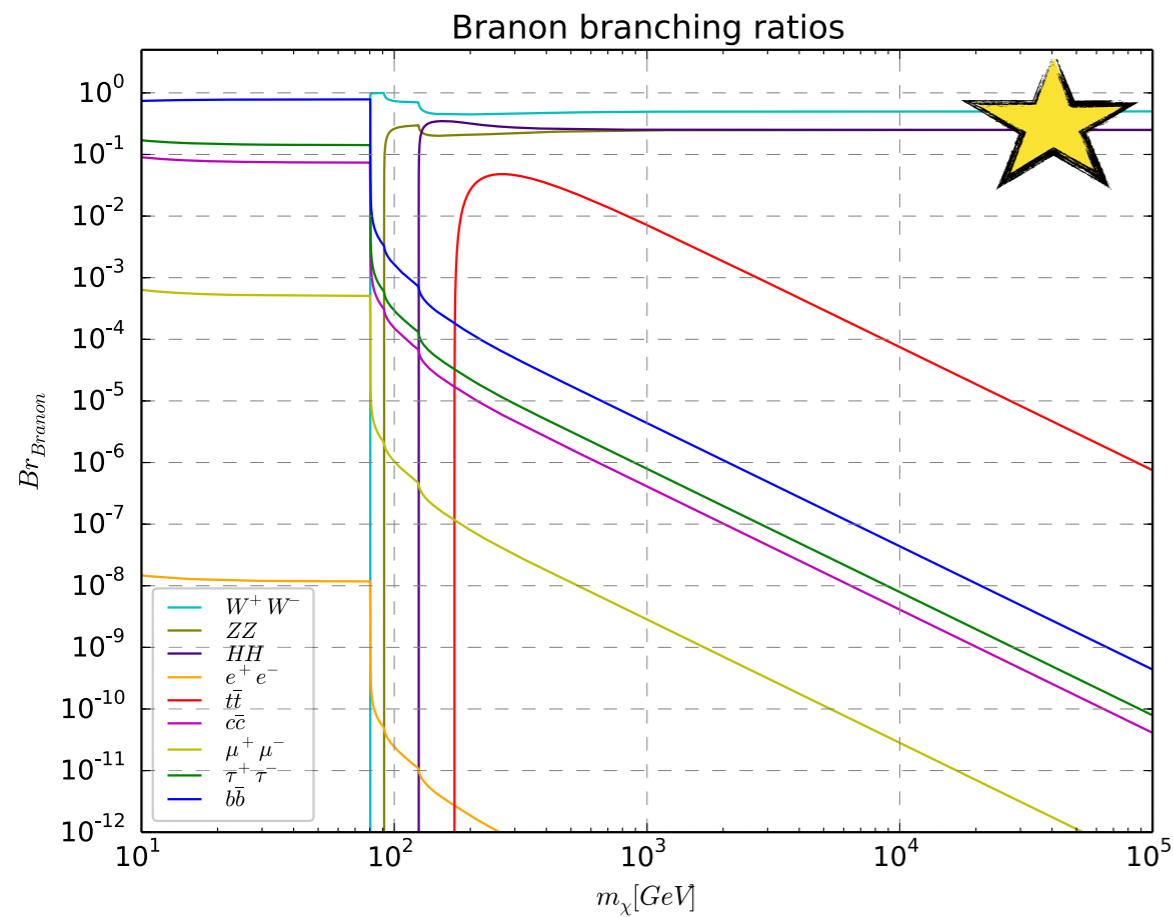
J.A.R. Cembranos, A. Dobado, A.L. Maroto, Phys.Rev.D68:103505,2003



The branon DM feature: gamma rays

T. Miener, V. G., D. Nieto Castaño, in preparation

A. Aguirre-Santaella, V. G., D. Nieto Castaño,
M. A. Sánchez-Conde, in preparation



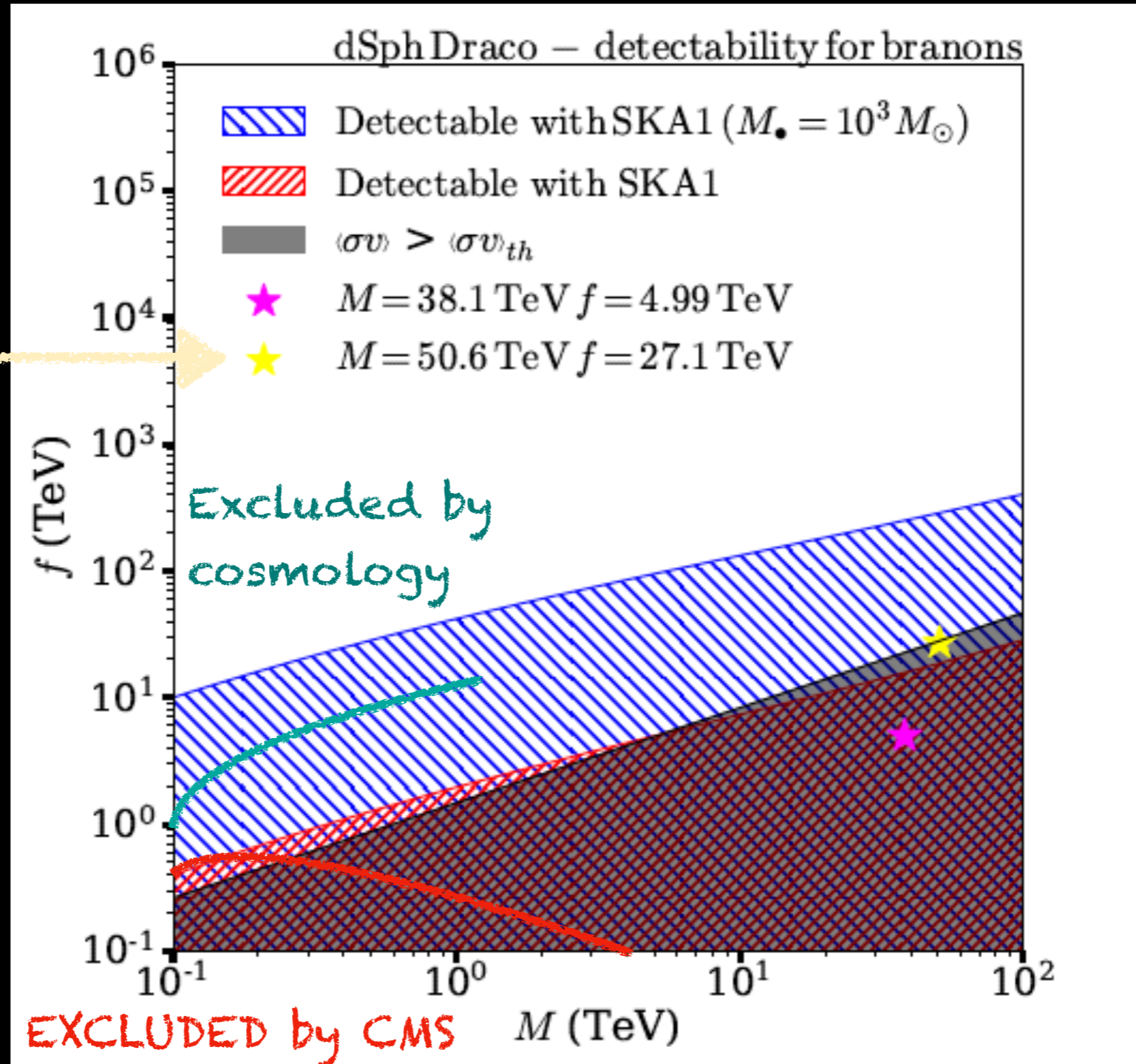
(talk by Tjiark Miener)

(poster by Alejandra Aguirre-Santaella)

“Constraining branon dark matter from observations of dwarf spheroidal galaxies with the MAGIC Telescopes”

“CTA sensitivity to branon dark matter models”

Branons @ Draco dSph with SKA



GC Multi-TeV
branon candidate

J.A.R. Cembranos, A.
Dobado, A.L. Maroto,
Phys.Rev.D68:103505,2003

CMS
Collaboration

Physics Letters B
Volume 755, 10
April 2016, Pages
102-124

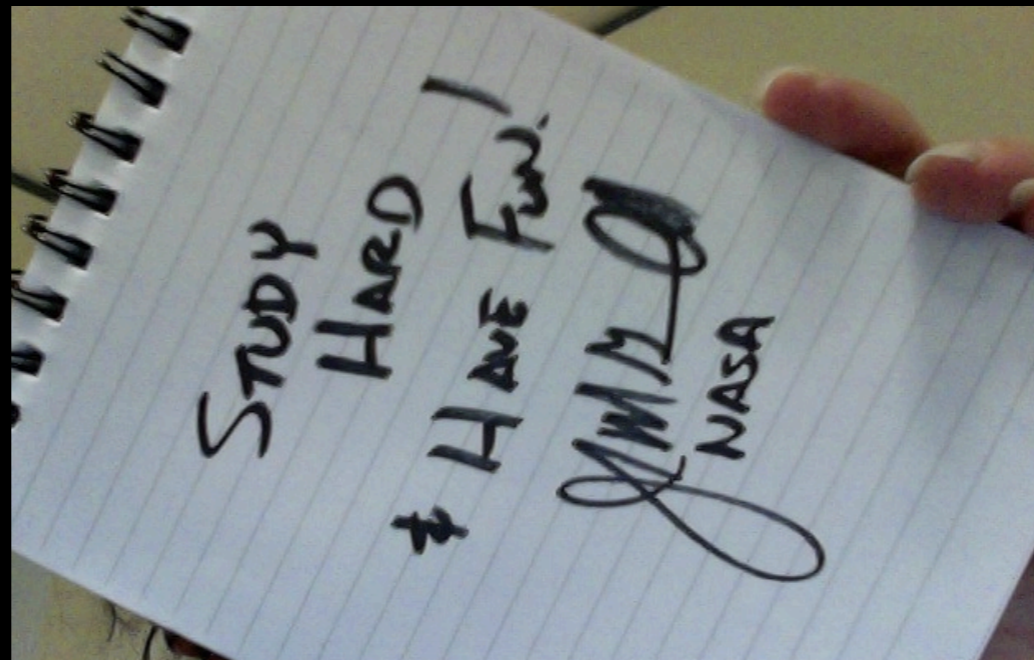
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Conclusions

- I hope I have convinced you that searching indirect signatures from multi-TeV DM candidate is a worth effort and represents the next frontier in the era of TeV observatories.
- Branon represents one prospective multi-TeV DM candidate. The study of particle physics nature of multi-TeV DM candidate at colliders is a challenge and represents a new frontier in physics.
- By analysing data of the current (e.g. MAGIC and HAWC) and next generation (e.g. SKA and Cherenkov Telescope Array (CTA)) of observatories we will set further constrains on the branon multi-TeV DM candidate.
- Work in progress....

Thank you for your attention



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webpage: <https://vgammaldi.wordpress.com>

 @GammaldiV