On the verge of the next generation of TeV dark matter searches

The CTA Consortium[†] represented by **Michele Doro***

*University and INFN Padova michele.doro@pd.infn.it

[†]see http://www.cta-observatory.org/consortium_authors/authors_2018_08.html for full author list

TeV DM talks at TeVPA 2018

Monday 27 August 2018

Dark Matter: 1

14:00	[115] Latest results on dark matter searches using the H.E.S.S. telescopes	Dr. POIREAU, Vincent
14:20	[17] Dark Matter searches with the MAGIC telescopes	Dr. VAZQUEZ ACOSTA, Monica
14:40	[327] The VERITAS Dark Matter and Astroparticle Physics Program	Mr. KELLEY-HOSKINS, Nathan
15:00	[75] Robust estimate of dark matter distributions in the Galactic dwarf spheroidals	Dr. HAYASHI, Kohei
15:15	[265] Model-independent constraints on dark matter annihilation in dwarf spheroidal galaxies	SANDICK, Pearl
15:30	[11] Refined Dark Matter Spectra for Cherenkov Telescopes	Mr. RODD, Nicholas

Dark Matter - -1 /amme

Wednesday 29 August 2018

11:30	[356] Indirect DM searches	CALORE, Francesca

Thursday 30 August 2018

Dark Matter: 5 -

15:15	[34] A Search for Dark Matter Annihilation in the Milky Way Halo	CHANG, Laura
15:30	[51] Probing the sensitivity of the Cherenkov Telescope Array to Dark Matter in the Galactic Center	Mr. ECKNER, Christopher

CTA DARK MATTER CONVENERS

Miguel Angel Sanchez Conde
miguel.sanchezconde@uam.es

Aldo Morselli
aldo.morselli@roma2.infn.it

Current IACTs

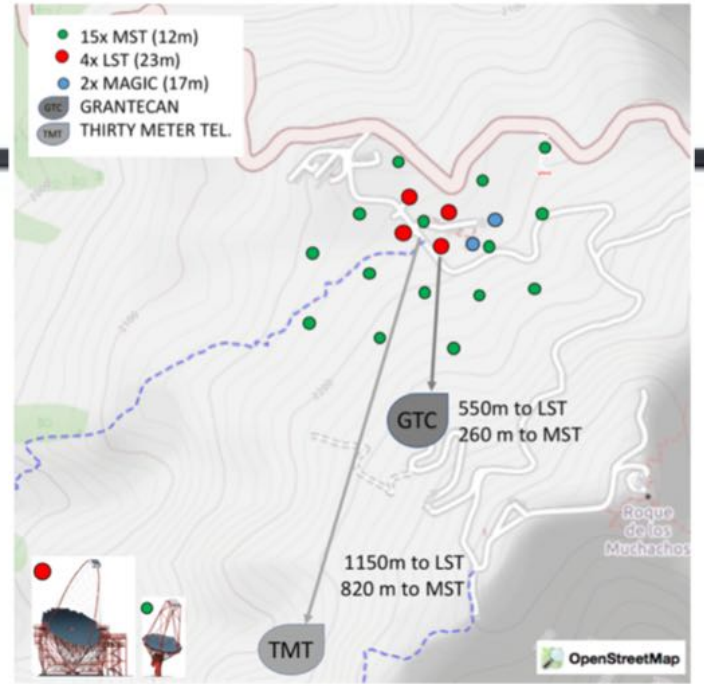
IACT	Year	Nr. tels & diameter	Location
~~Whipple~~	~~1968~~	~~1×12 m~~	~~Arizona, USA~~
H.E.S.S.	2003	4×12 m+1×28 m	Gambserg, Namibia
MAGIC	2004	2×17 m	La Palma, Spain
VERITAS	2007	4×12 m	Arizona, USA

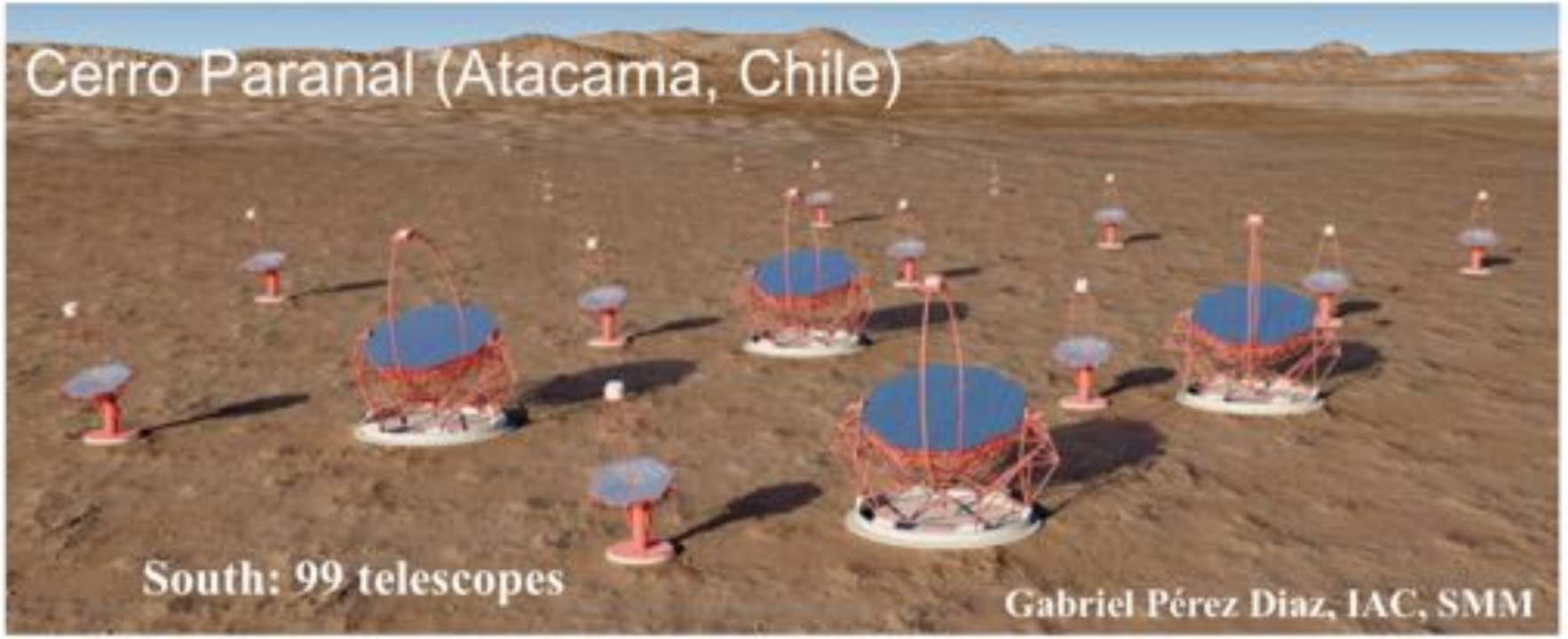
Table 1: Current major operating ground-based Cherenkov telescopes. Given are the starting year, the array multiplicity and dish diameter *in the latest configuration*, and the location.

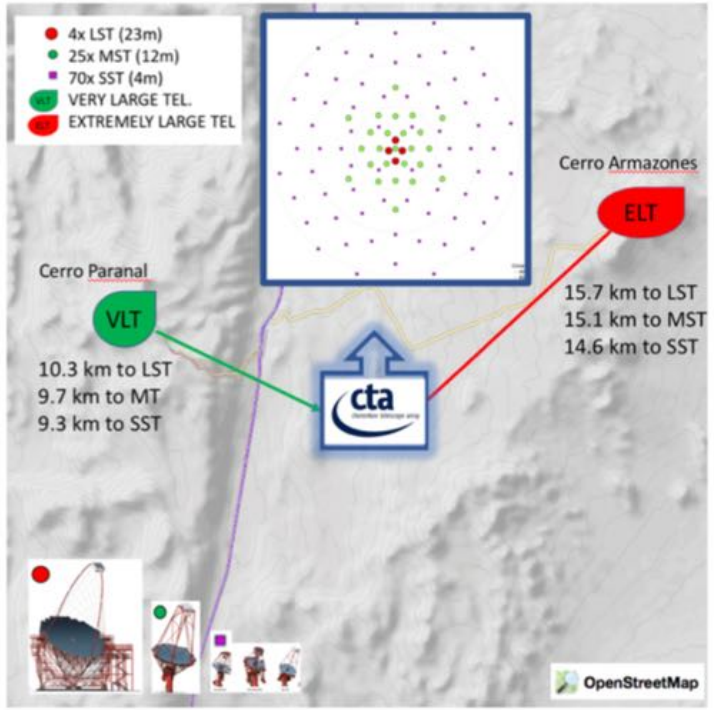
MD NIMA742 (2014) 99-106

Two CTA arrays

M.Gaug, MD, MNRAS accepted 10.1093/mnras/sty2188→

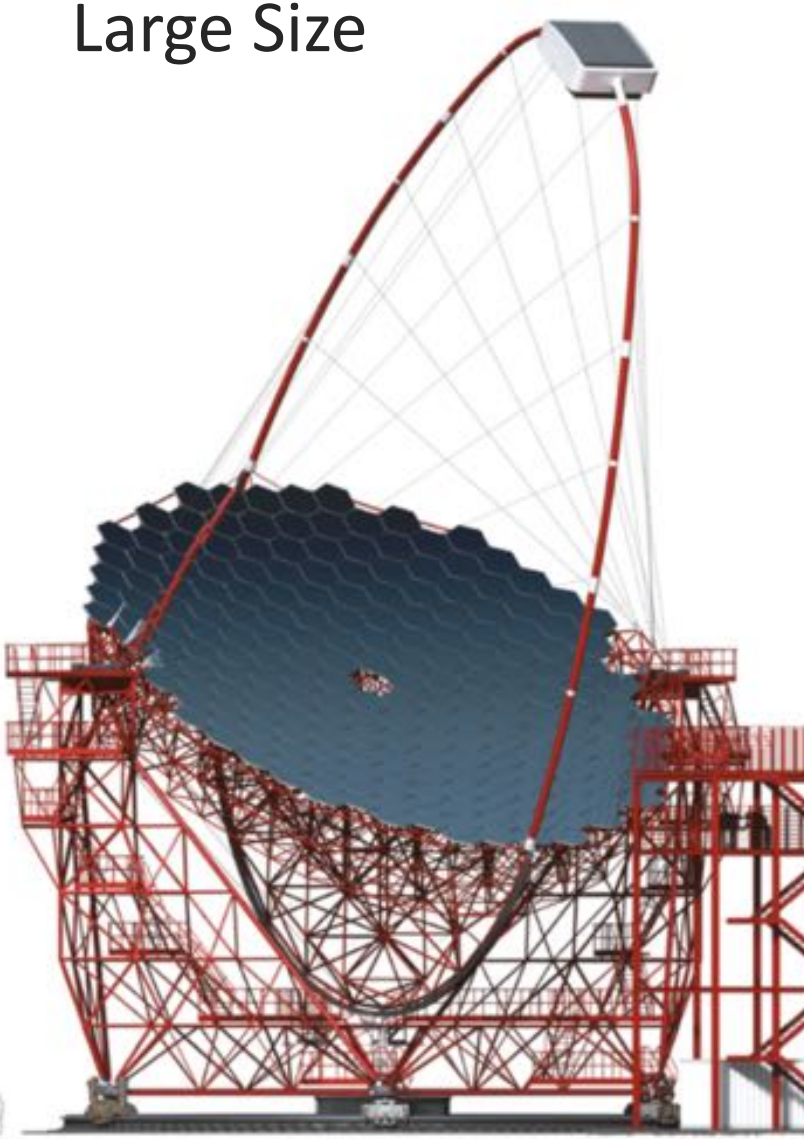






Three telescope sizes

Large Size



Medium Size

2017 Begin Pre-Construction

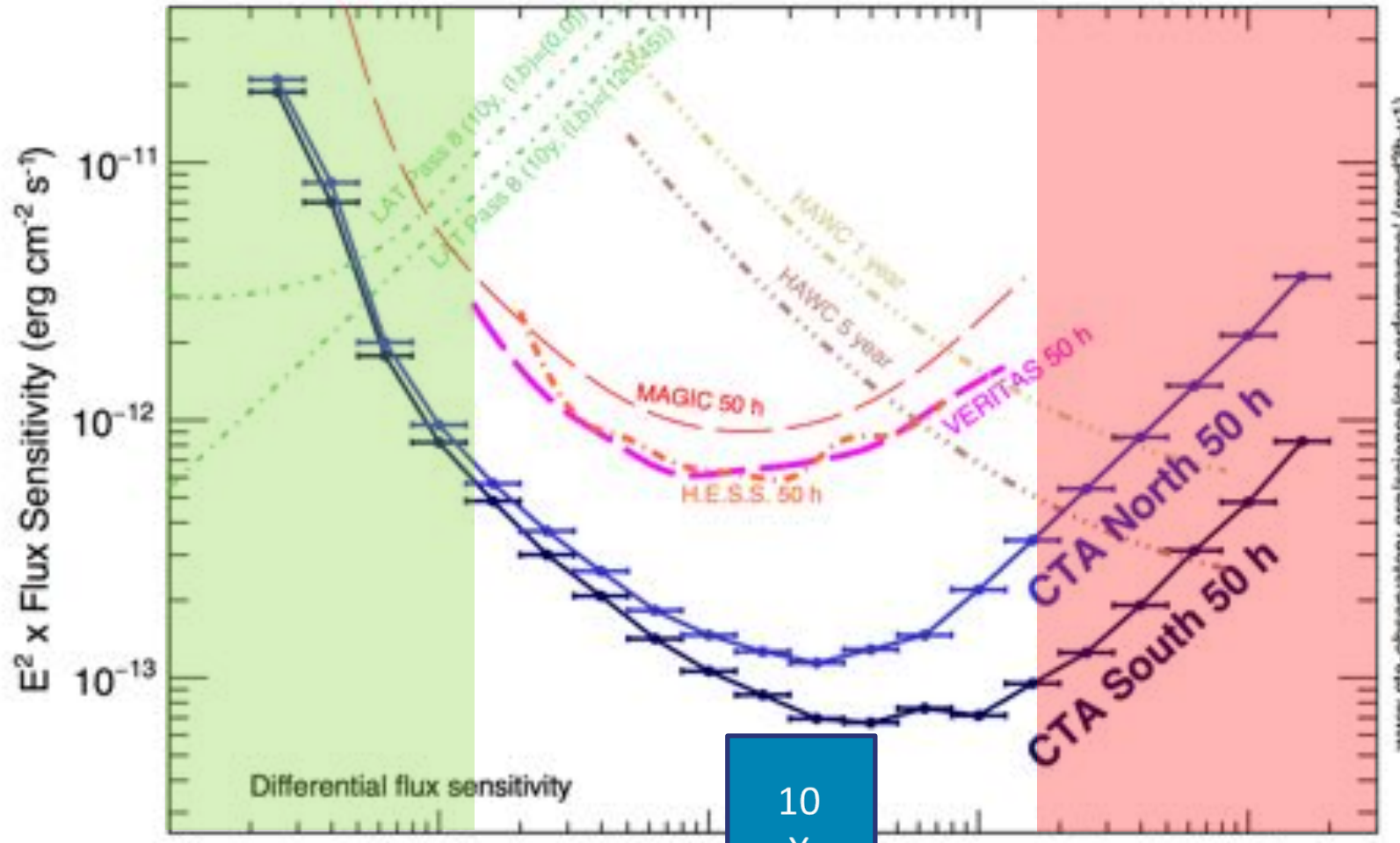
2022 Begin Operation

2022-25 Commissioning and Early Science

2025 Construction completion

Small Size

A sensitivity leap

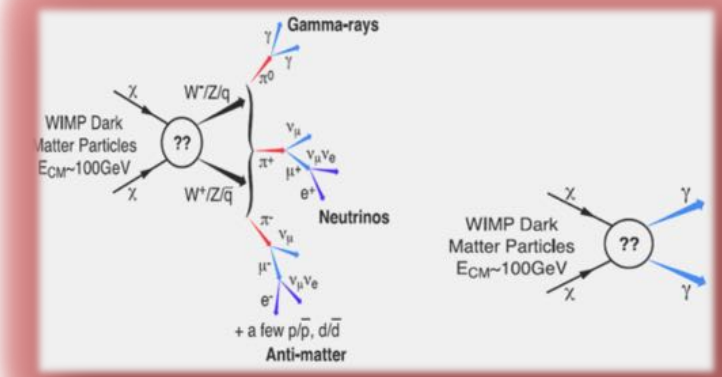


LOWER ENERGY THRESHOLD

HIGHER ENERGY REACH

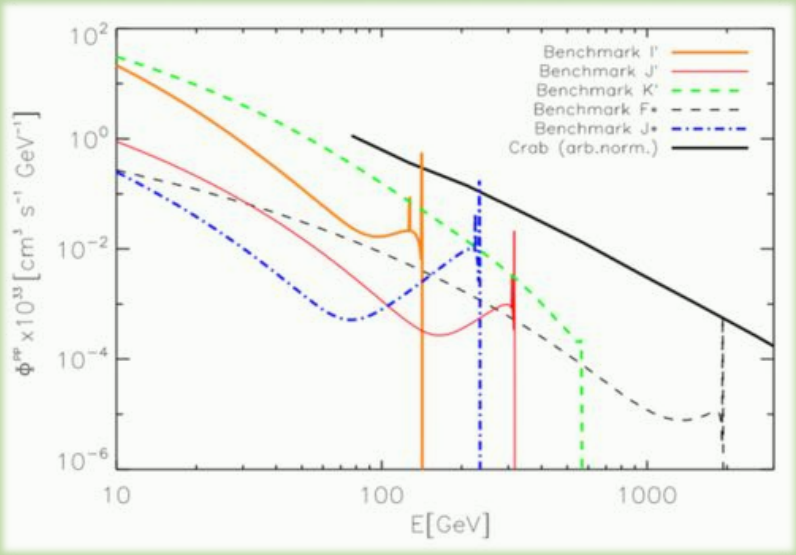
10 X BETTER

Four reasons for DM searches with gamma-rays

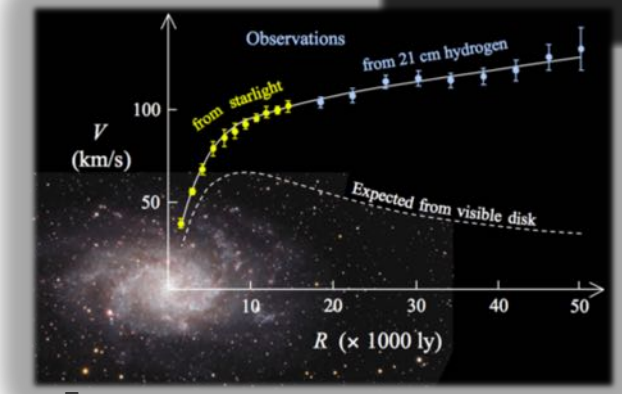


Interaction with SM

Features in spectra, and not distorted

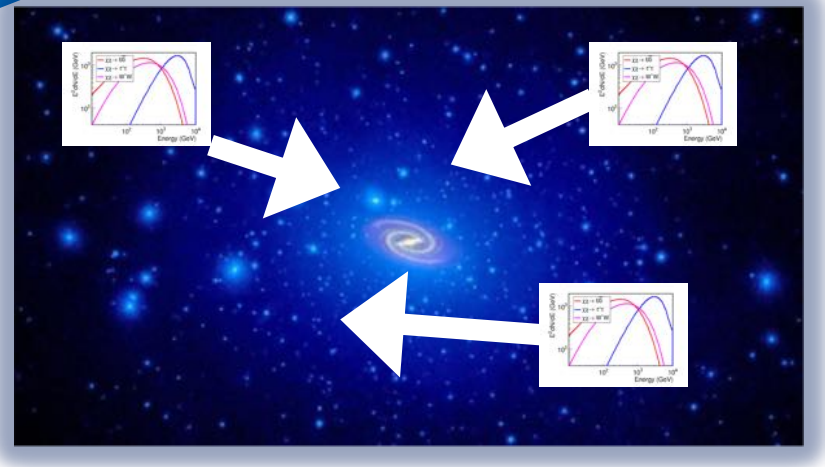


Point where DM is expected



γ

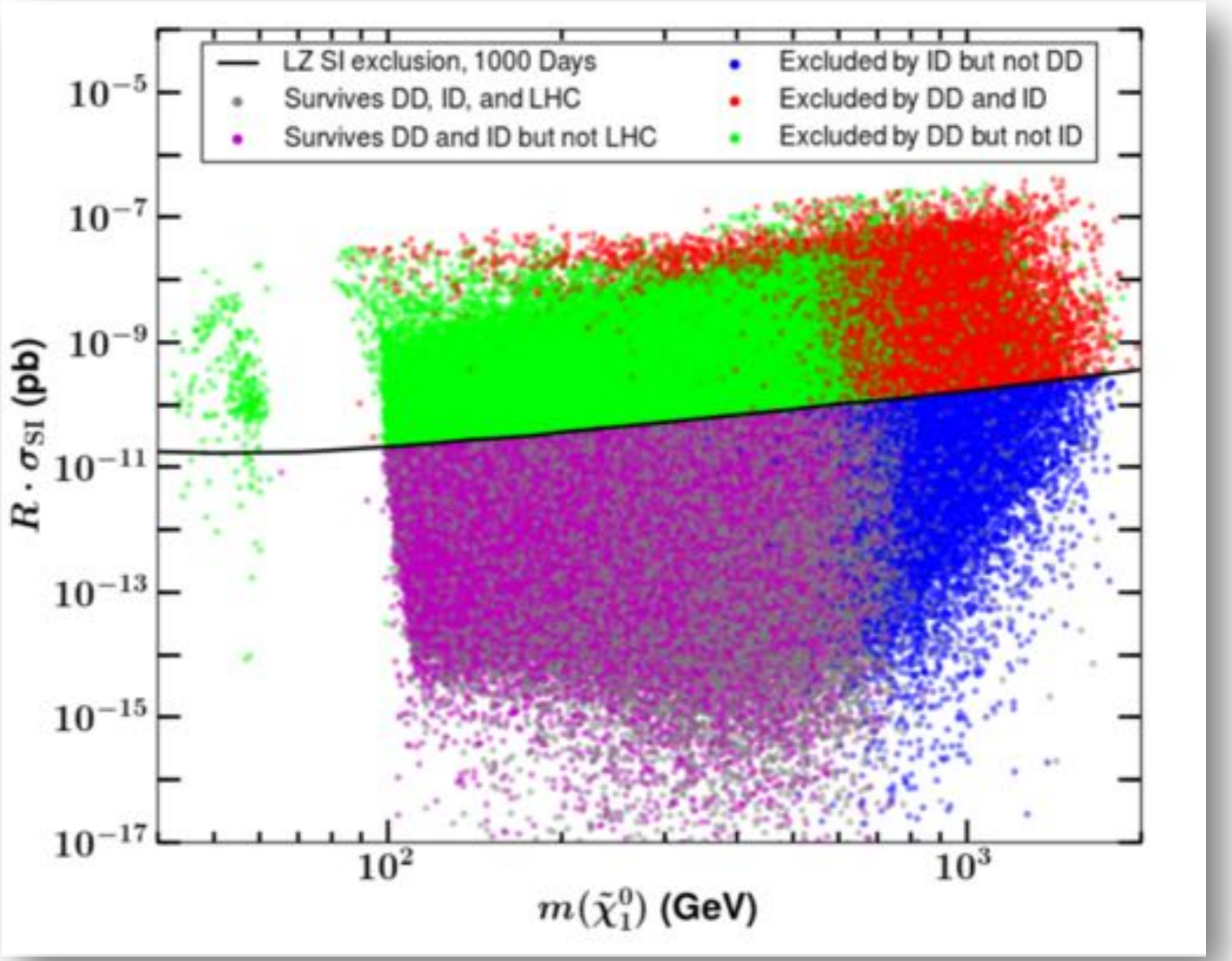
Universality of spectra



Complementarity

- Where overlap: **cross-validation possible**
- Some regions **uniquely probed by CTA**

PHYSICAL REVIEW D **91,** 055011 (2015)



- Excluded by ID but not DD
- Excluded by DD and ID
- Excluded by DD but not ID

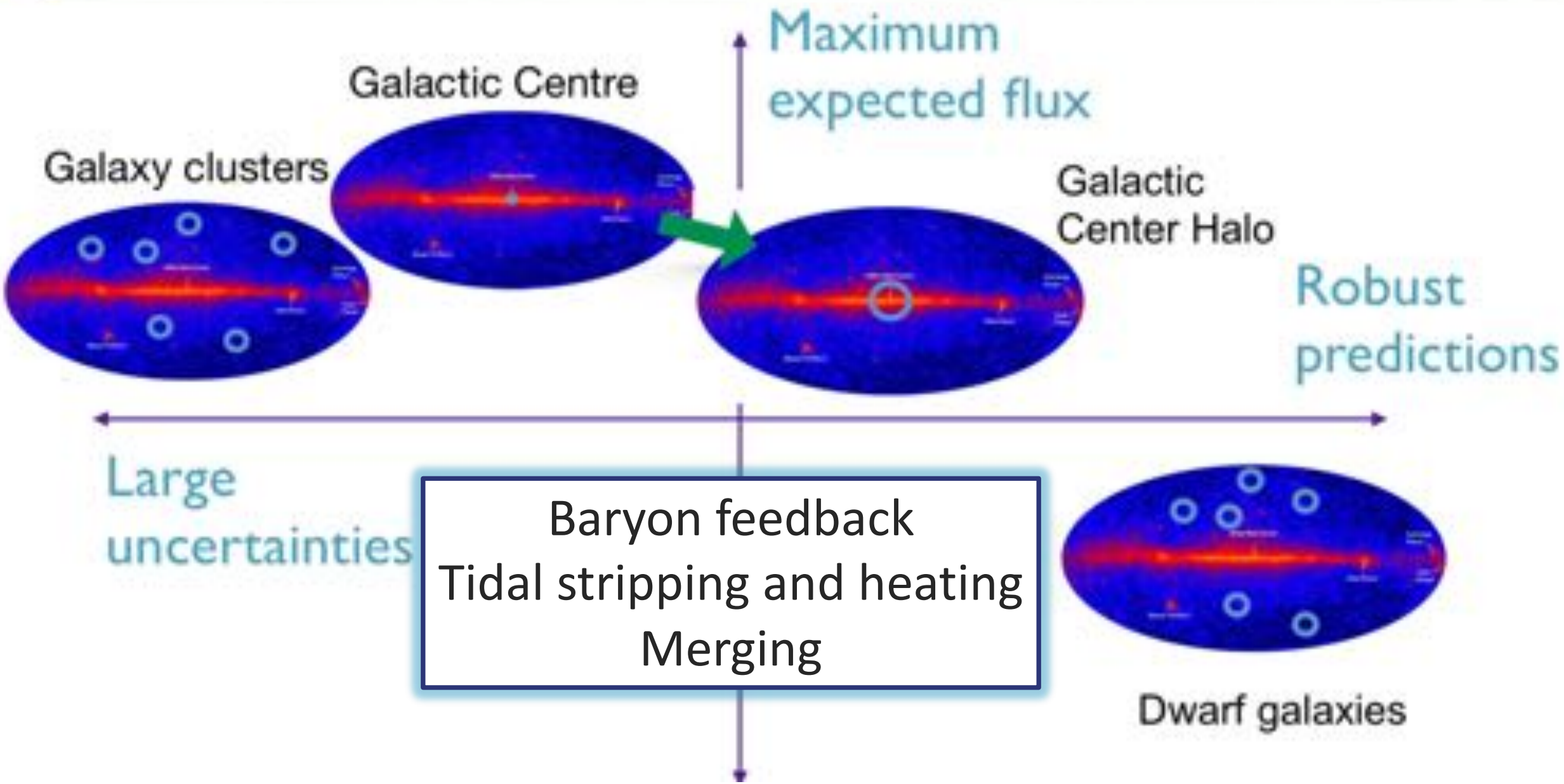
What influences the flux on Earth

$$\frac{d\Phi(\Delta\Omega)}{dE'} = \frac{d\Phi^{\rm PP}}{dE'} \times J(\Delta\Omega)$$

	Particle Physics factor:	Astrophysical factor:
Annihilation:	$\frac{d\Phi^{\rm PP}}{dE'} = \frac{1}{4\pi}\frac{\langle\sigma_{\rm ann}v\rangle}{2m_\chi^2}\frac{dN}{dE'}$	$J_{\rm ann}(\Delta\Omega) = \int_{\Delta\Omega}\int_{los}\rho^2(l,\Omega)dld\Omega.$
Decay:	$\frac{d\Phi^{\rm PP}}{dE'} = \frac{1}{4\pi}\frac{1}{\tau_\chi m_\chi}\frac{dN}{dE'}$	$J_{\rm dec}(\Delta\Omega) = \int_{\Delta\Omega}\int_{los}\rho\ (l,\Omega)dld\Omega.$
	Large uncertainties from Fund. Phys. No target dependences (straightforward stacking analysis)	Large uncertainties from DM profiles (robust limits from less uncertain targets)

- Hunting the **highest J-factor**
- Left with huge **uncertainties in the particle physics**

Different target classes



IACTs: tested several target classes

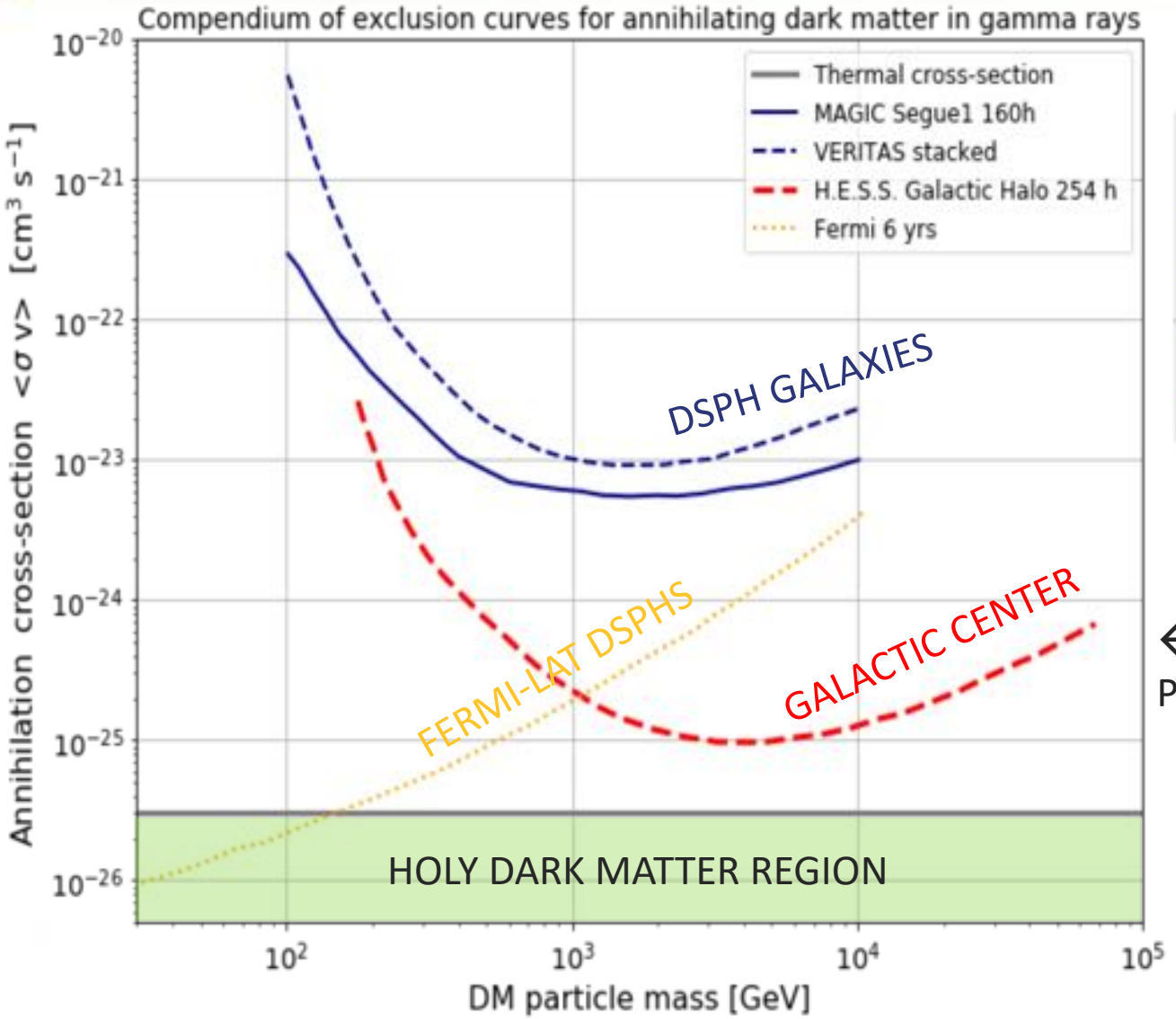
Target	Year	Time	Experiment
Globular Clusters			
M15	2002	0.2	Whipple
	2006 – 2007	15.2	H.E.S.S.
M33	2002 – 2004	7.9	Whipple
M32	2004	6.9	Whipple
NGC 6388	2008 – 2009	27.2	H.E.S.S.
Dwarf Satellite Galaxies			
Draco	2003	7.4	Whipple
	2007	7.8	MAGIC
	2007	18.4	VERITAS
Ursa Minor	2003	7.9	Whipple
	2007	18.9	VERITAS
Sagittarius	2006	11	H.E.S.S.
	–	–	H.E.S.S.
Canis Major	2006	9.6	H.E.S.S.
Willman 1	2007 – 2008	13.7	VERITAS
	2008	15.5	MAGIC
Sculptor	2008	11.8	H.E.S.S.
Carina	2008 – 2009	14.8	H.E.S.S.
	2008 – 2012	23	H.E.S.S.
Segue 1	2008 – 2009	29.4	MAGIC
	2010 – 2011	48	VERITAS
	2010 – 2013	158	MAGIC
Boötes	2009	14.3	VERITAS
Coma Berenices	2010 – 2013	8.6	H.E.S.S.
Fornax	2006? – 2012?	6	H.E.S.S.
Ursa Major 2	2014 – 16	95	MAGIC

Target	Year	Time	Experiment
Galaxy Clusters			
Abell 2029	2003 – 2004	6	Whipple
Perseus	2004 – 2005	13.5	Whipple
	2008	24.4	MAGIC
	2009 – 2017	202	MAGIC
Fornax	2005	14.5	H.E.S.S.
Coma	2008	18.6	VERITAS
The Milky Way central region			
MW Center	2004	48.7	H.E.S.S.
MW Center Halo	2004 – 2008	112	H.E.S.S.
	2004 – 2014	254	H.E.S.S.
Line searches			
Lines	2004 – 2008	112	H.E.S.S.
	2010 – 2013	158	MAGIC
	2004 – 2014	254	H.E.S.S.
Other searches			
IMBH	2004 – 2007	400	H.E.S.S.
	2006 – 2007	25	MAGIC
UFOs	–	–	MAGIC
	–	–	VERITAS
Particles searches			
All-electron	2004 – 2007	239	H.E.S.S.
	xx	xx	VERTIAS
	2009 – 2010	14	MAGIC
Moon-shadow	–	–	MAGIC

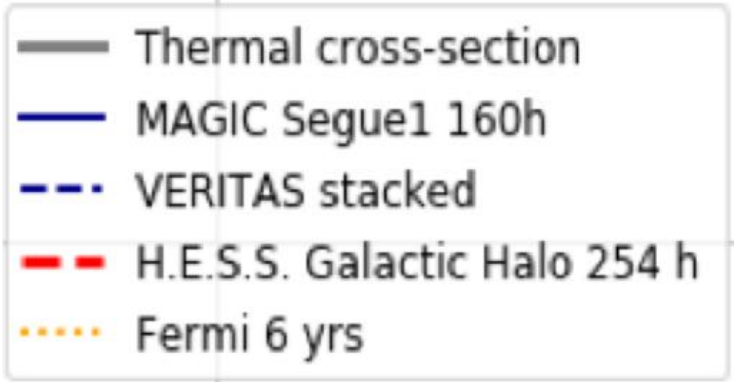
Big time-investment

← *Edited from MD, NIM A 742 (2014), to appear in Mukherjee, Zanin* ***„The Science Program of the Third Generation of IACTs for exploring cosmic gamma rays“***

Where are we now?

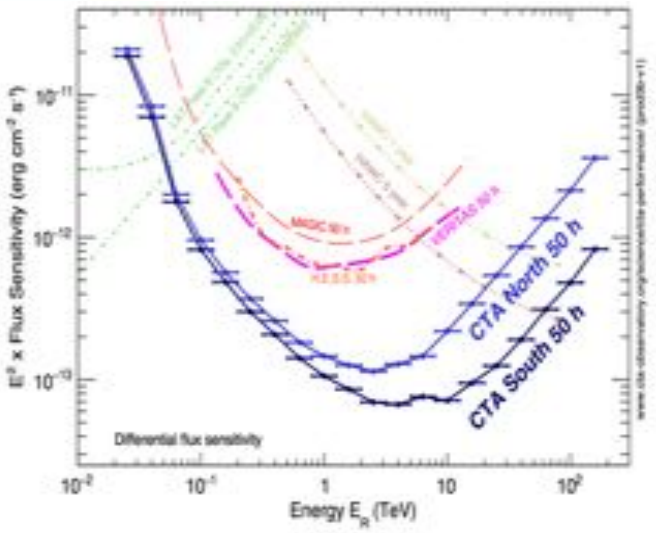


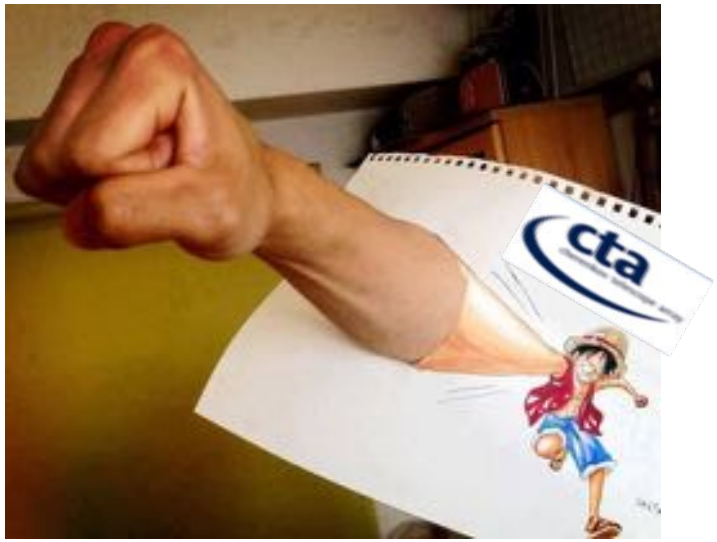
← Annihilation into $b\bar{b}$

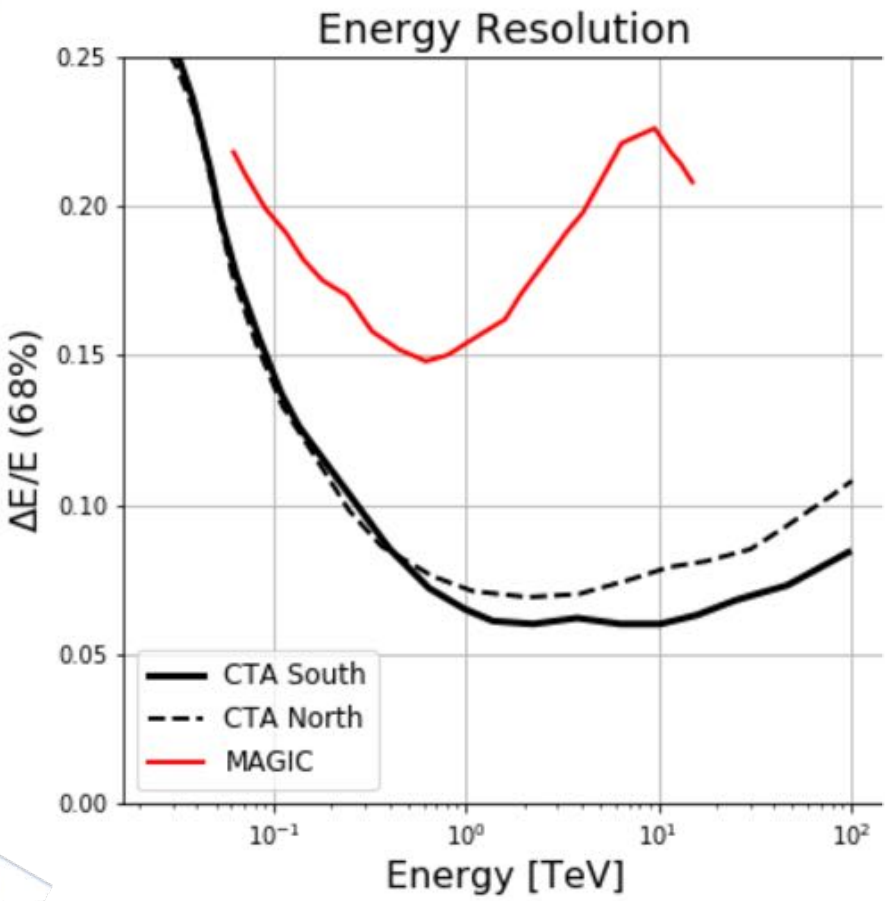


← See also VERITAS limits on Galactic Halo, Poster DM17

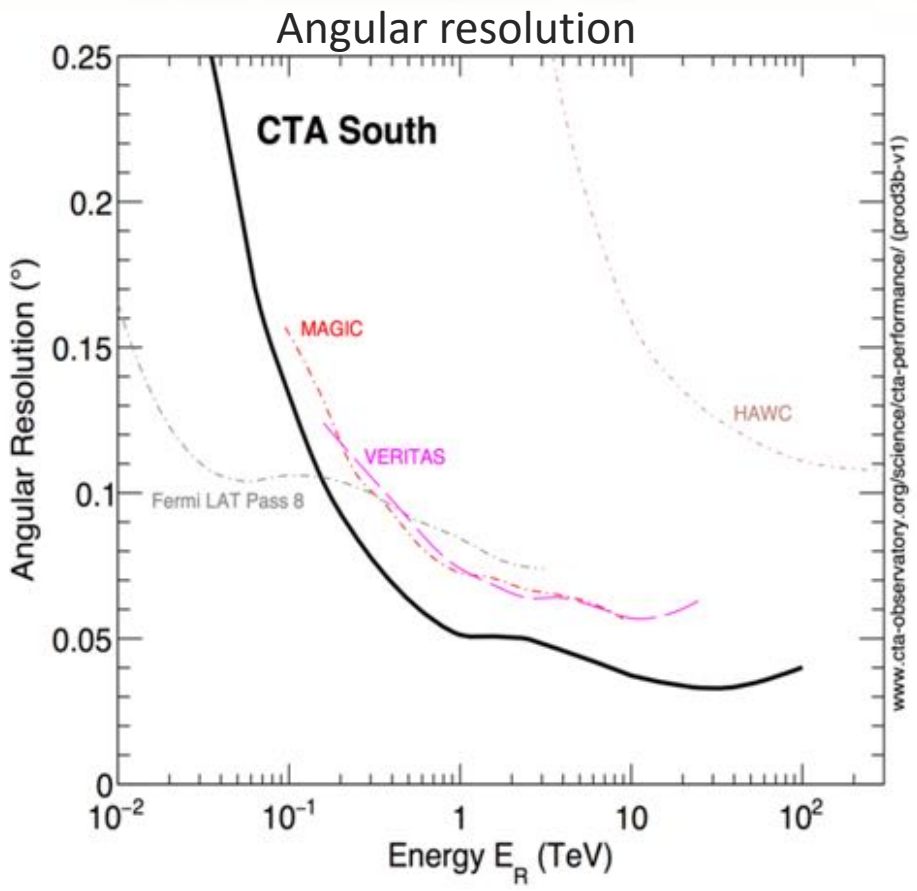
CTA energy and angular resolution







→spectral features



→ Morphology discrimination

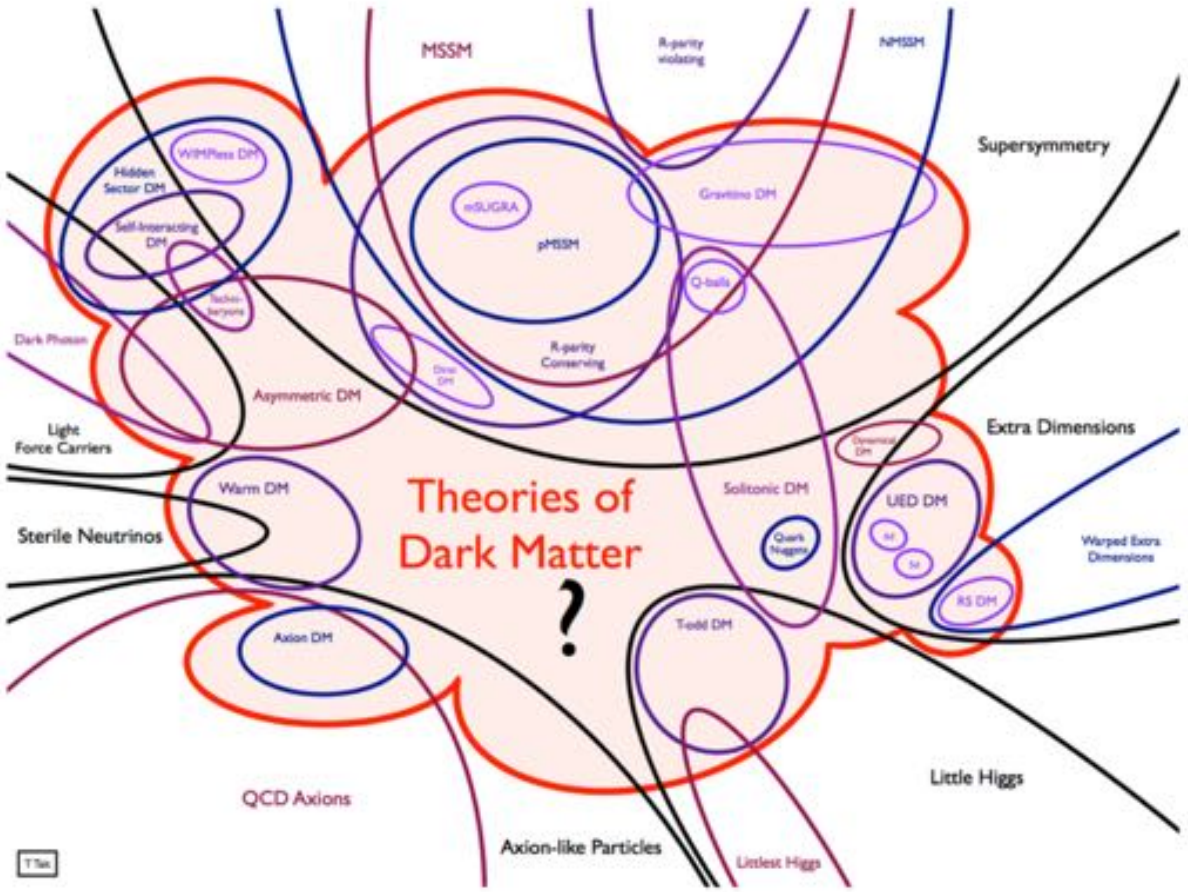
Questions?

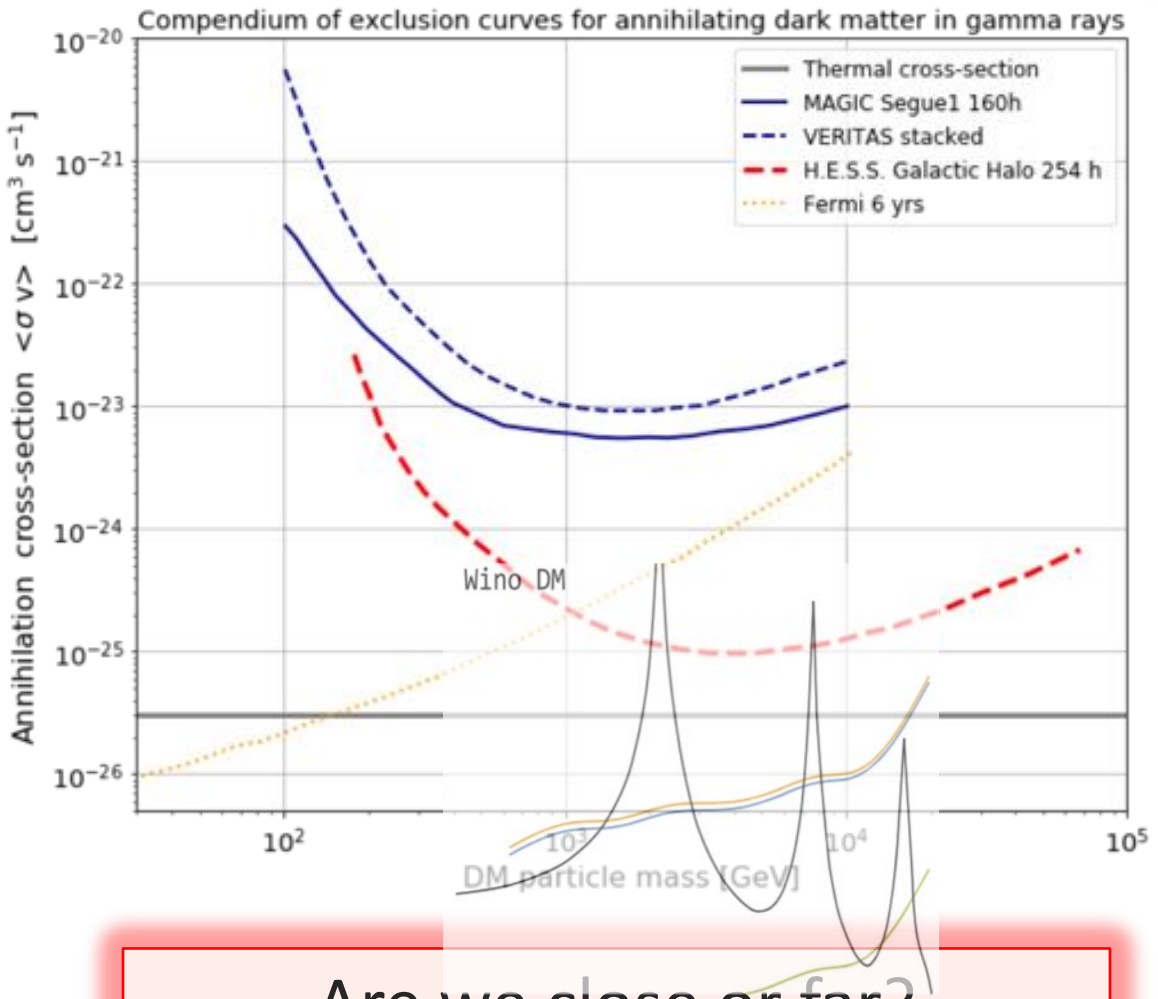
1. How to use this fist?

2. Where do we point CTA and for how long?

3. Is there anything we can do to arrive prepared?

Why the choice is not straightforward





Need a GeV-TeV DM particle somewhat interacting with SM

Are we close or far?

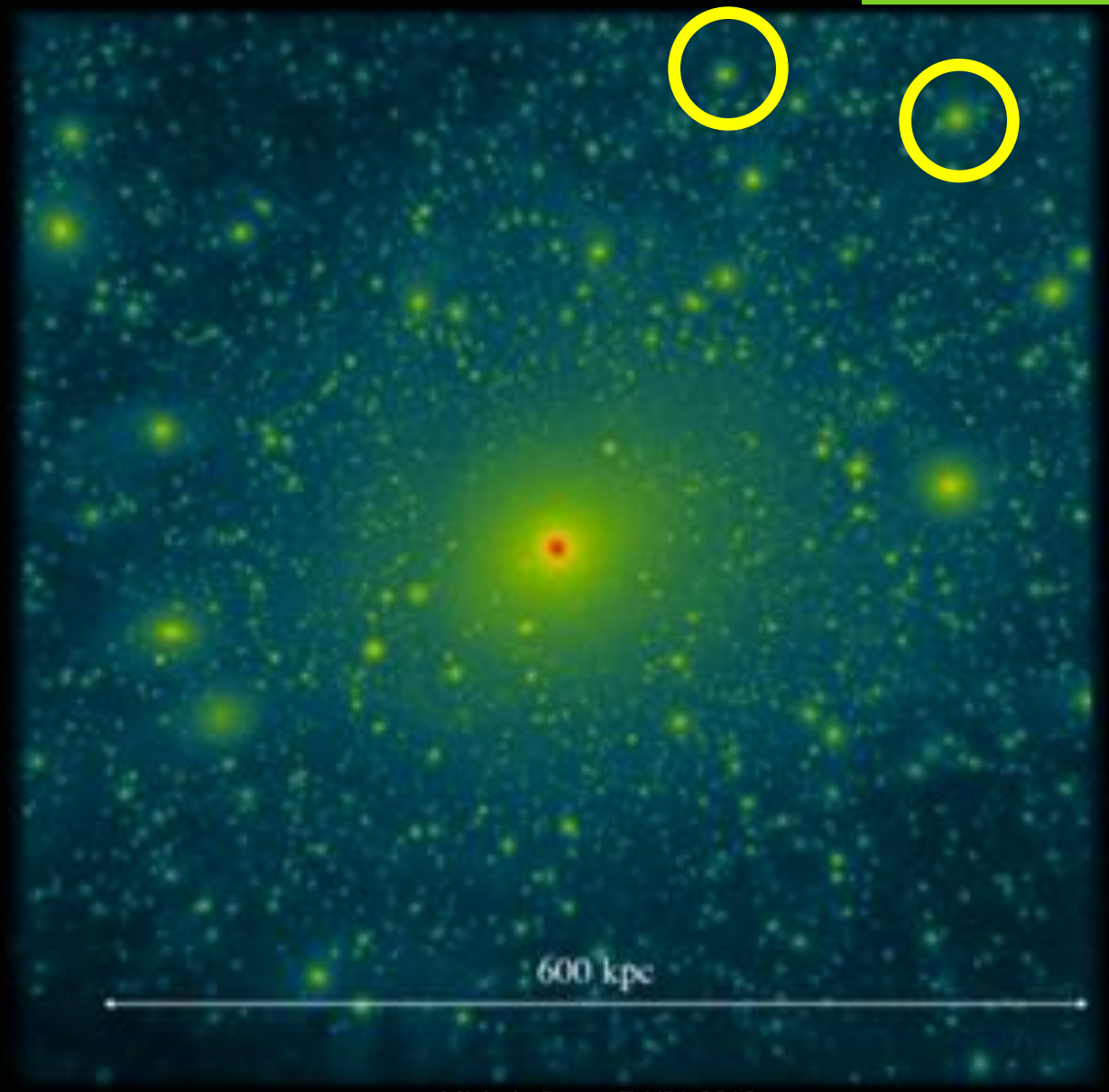
Strategy for observation #1: Galactic Center

Christopher Eckner,
Lily Yang,
Gabriela Zaharijas,
Anastasia Sokolenko
and others

15:30	[51] Probing the sensitivity of the Cherenkov Telescope Array to Dark Matter in the Galactic Center	Mr. ECKNER, Christopher

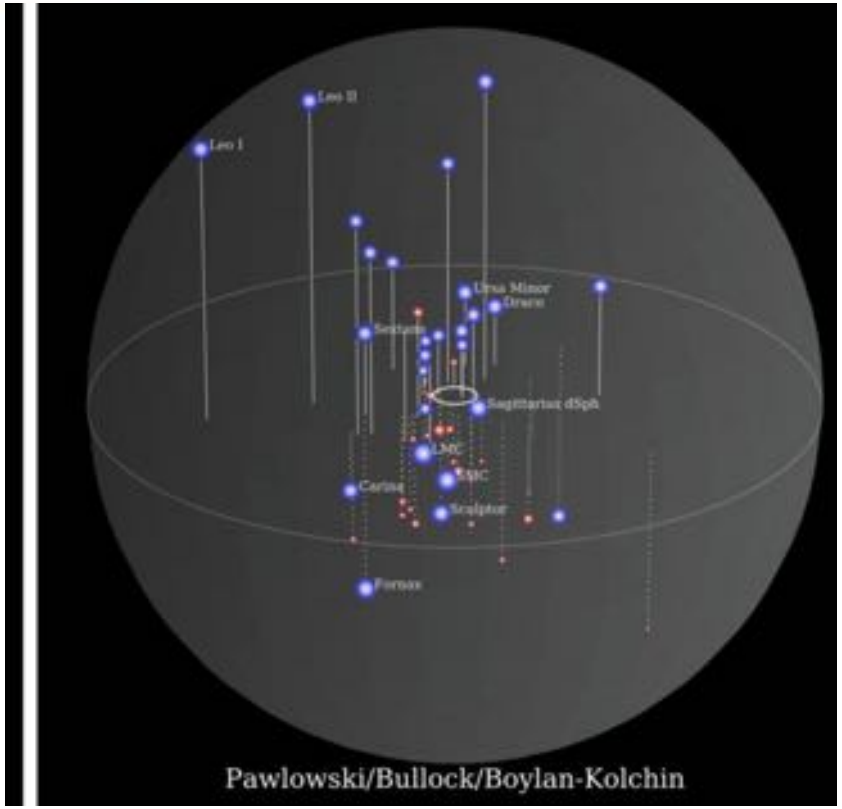
Strategy for observation #2 dSph

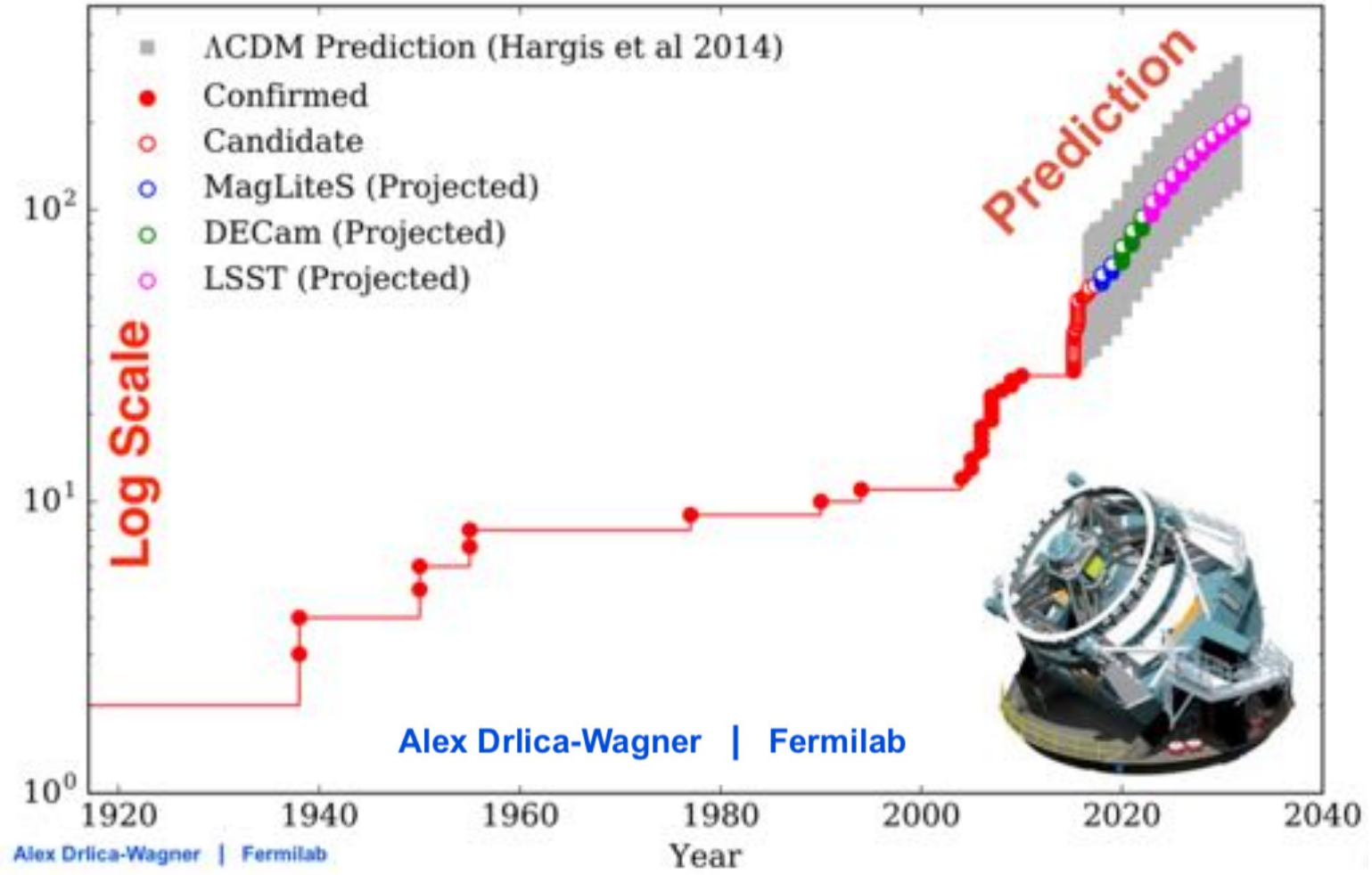
MD, G. Rodriguez, MA Sanchez-Conde, F. Saturni++



Not all subhalos are necessarily optically bright!

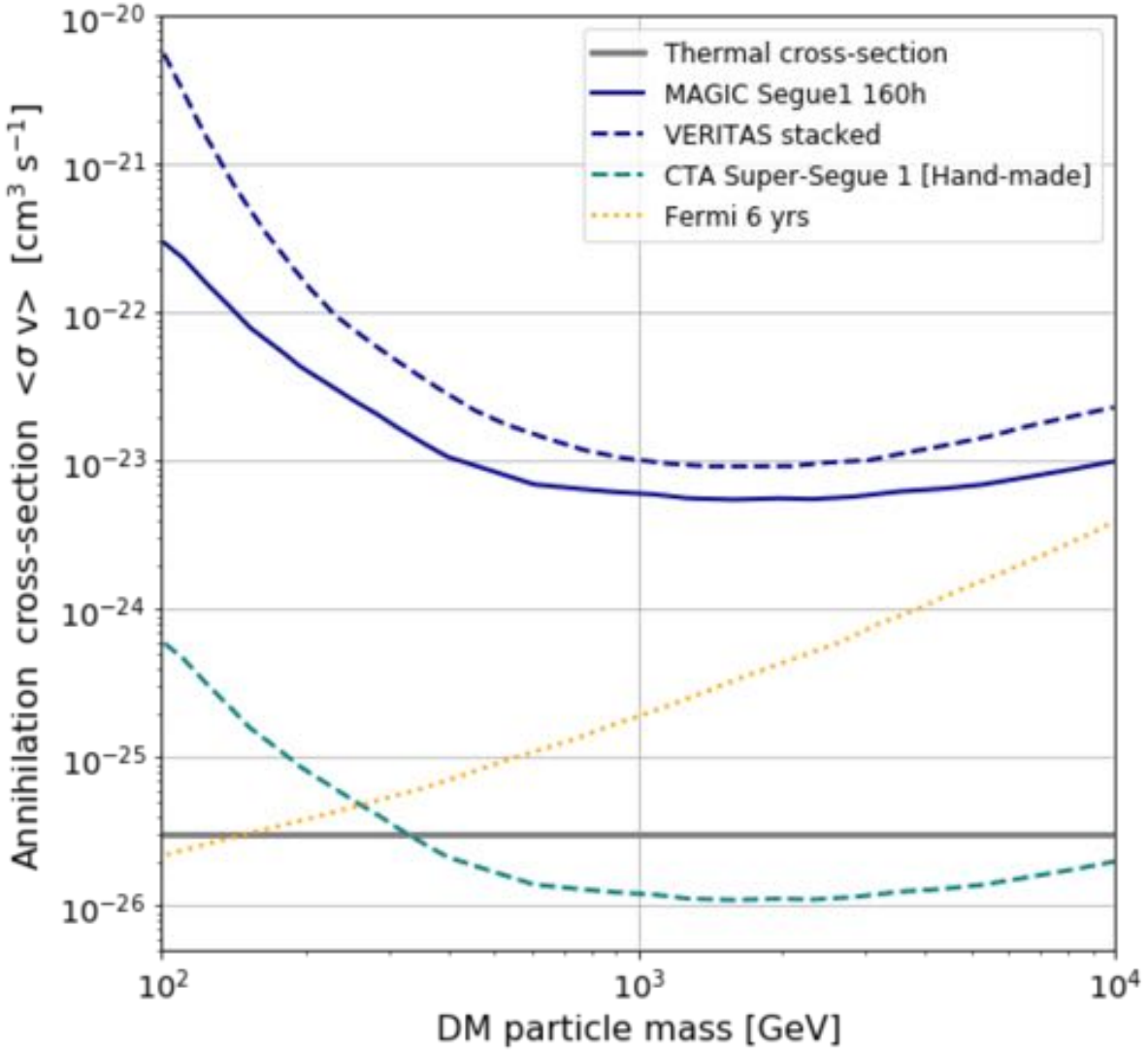
More visible dSphs coming



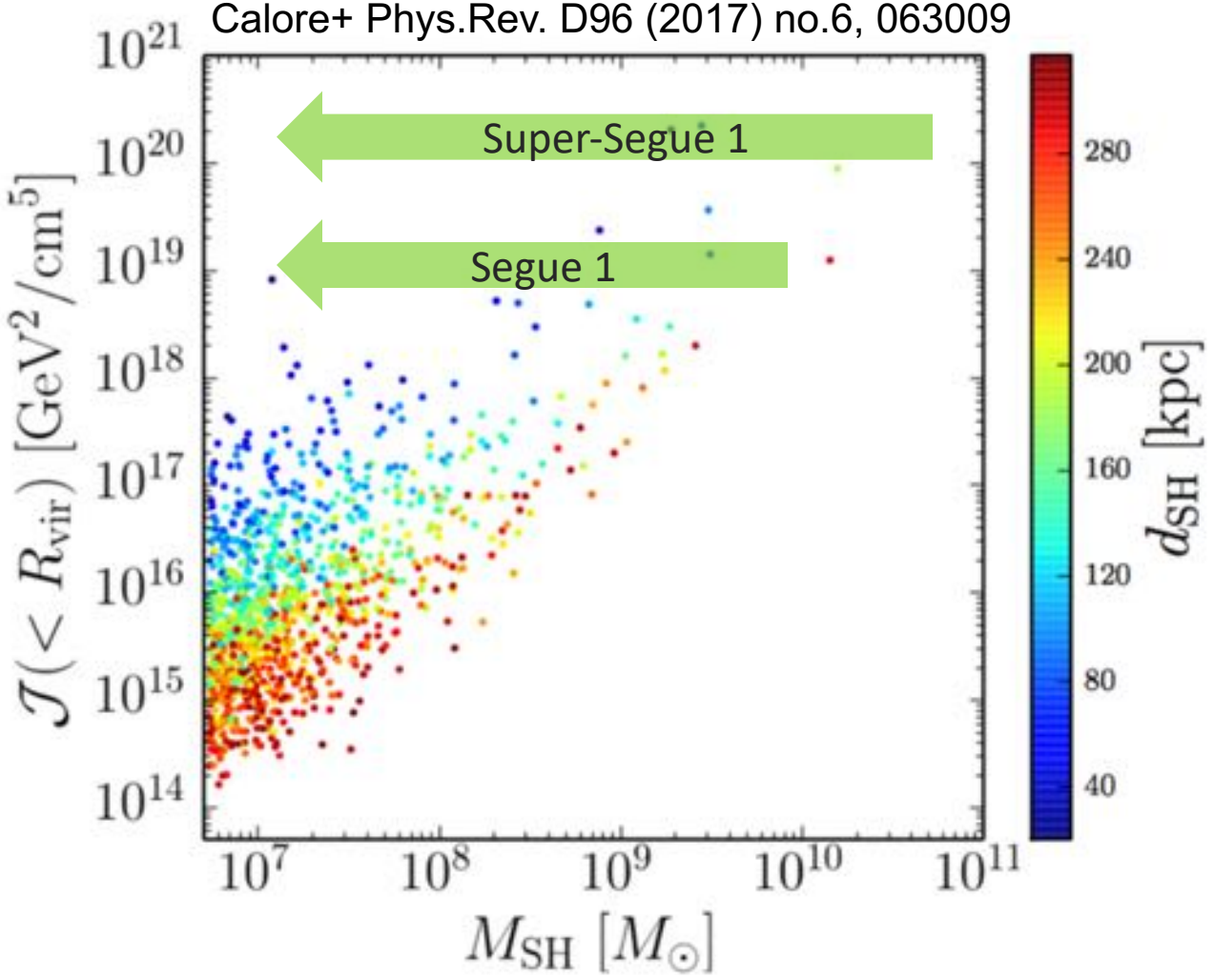


At the time of CTA, possibly *all* dSph will be discovered

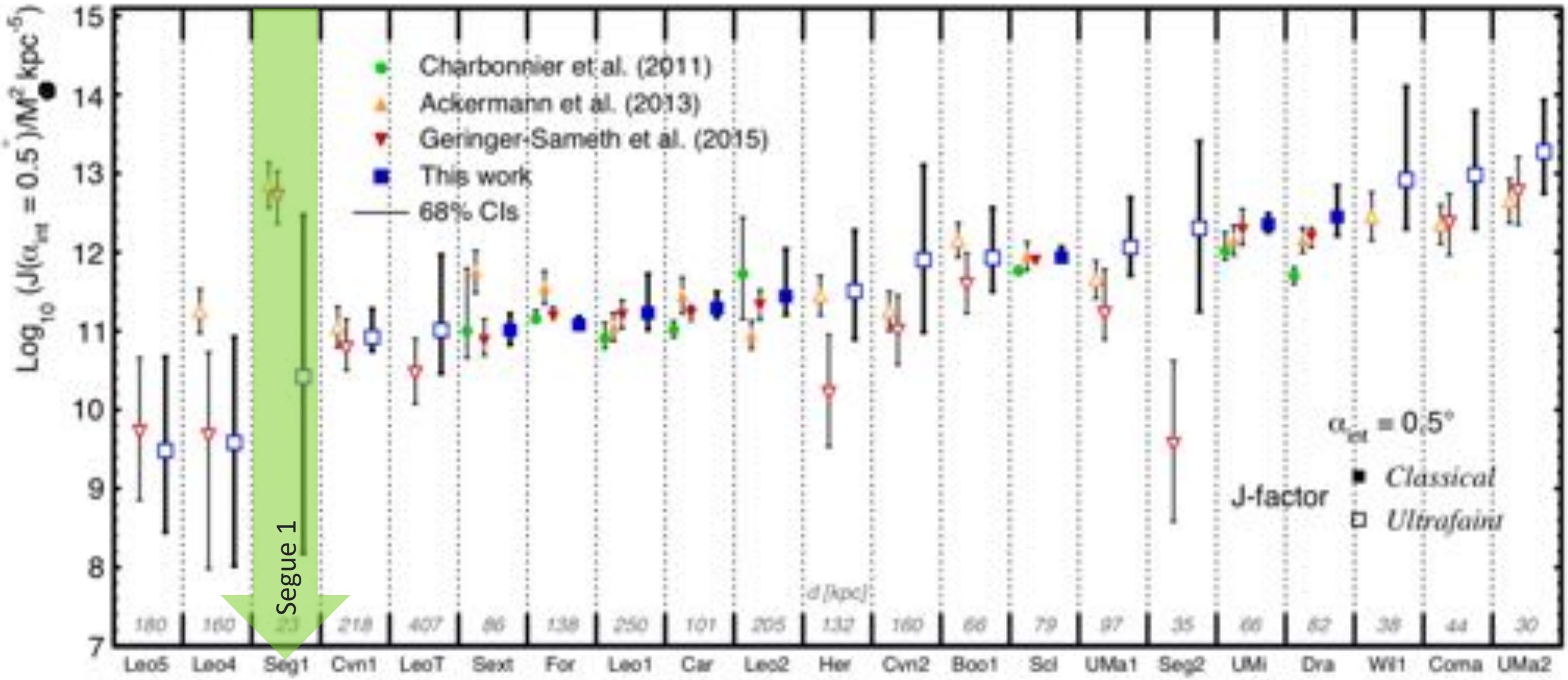
Need a high J-factor



Calore+ Phys.Rev. D96 (2017) no.6, 063009

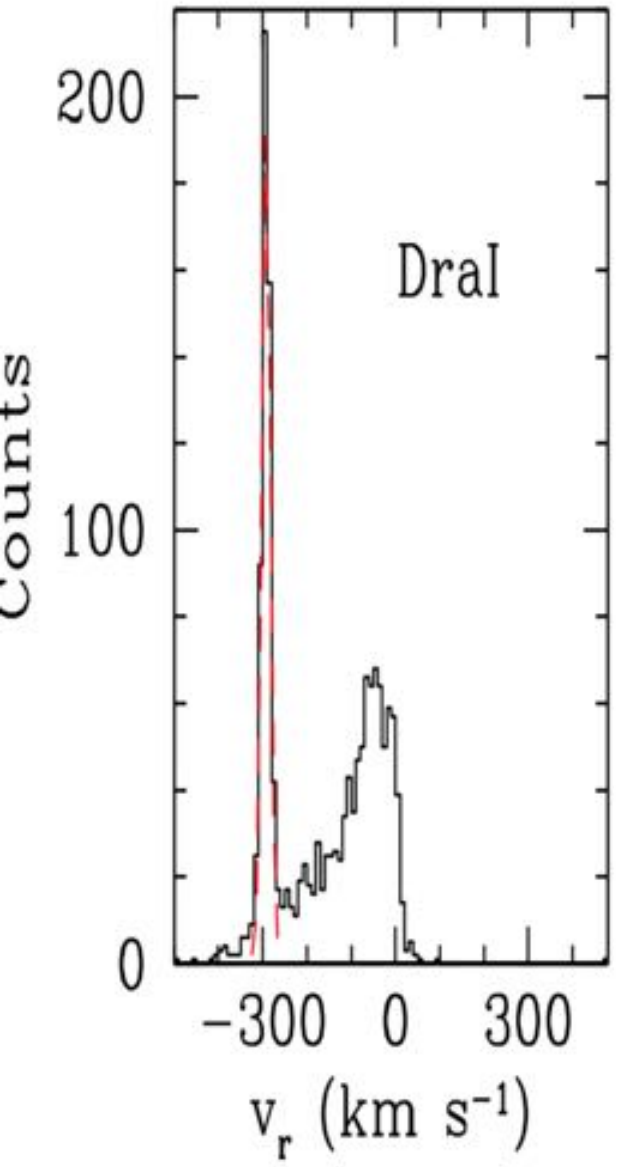


Need accurate J-factors!

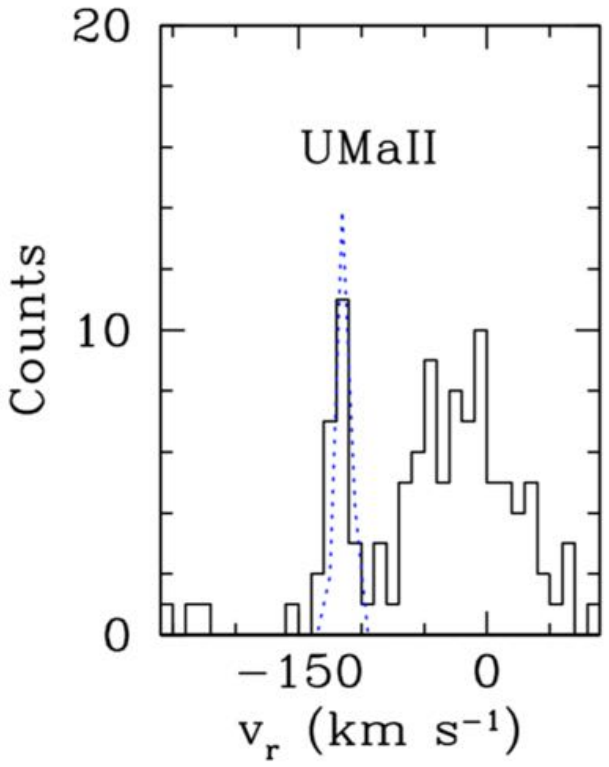


Bonnivard+ MNRAS 453 (2015) 849-867

Assessing J-factors

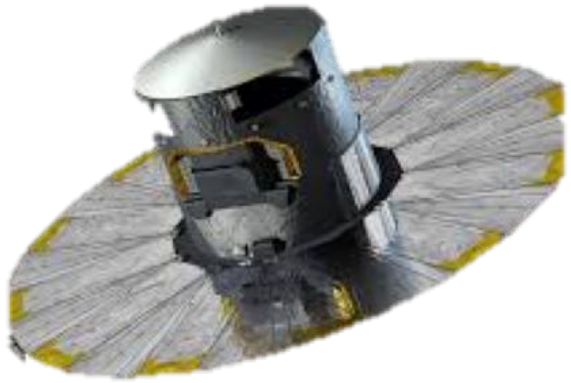


← ↓ F.G. Saturni



Advanced spectroscopy follow-ups of LSST targets→

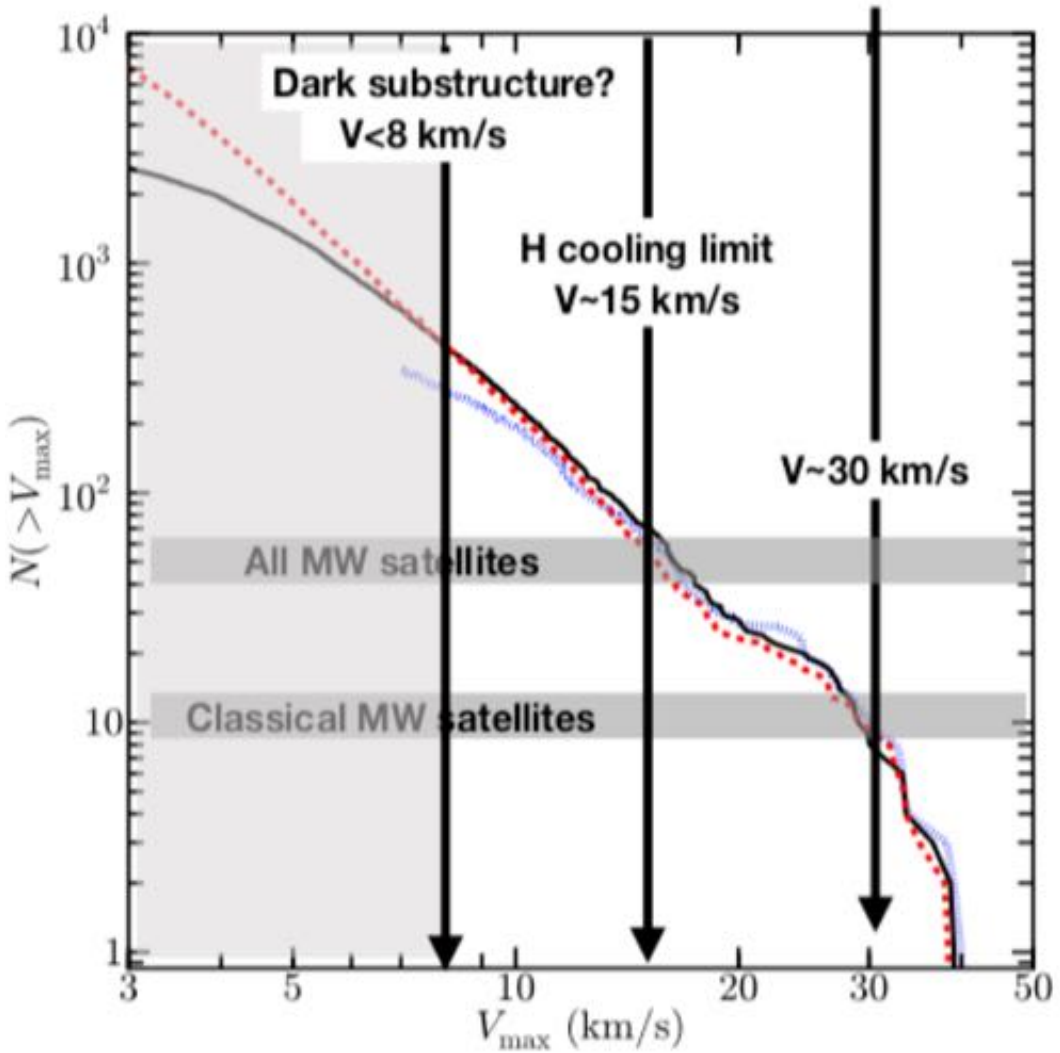
Remove foreground stars with GAIA→



Close interaction between communities needed!

Strategy #3: dark subhaloes?

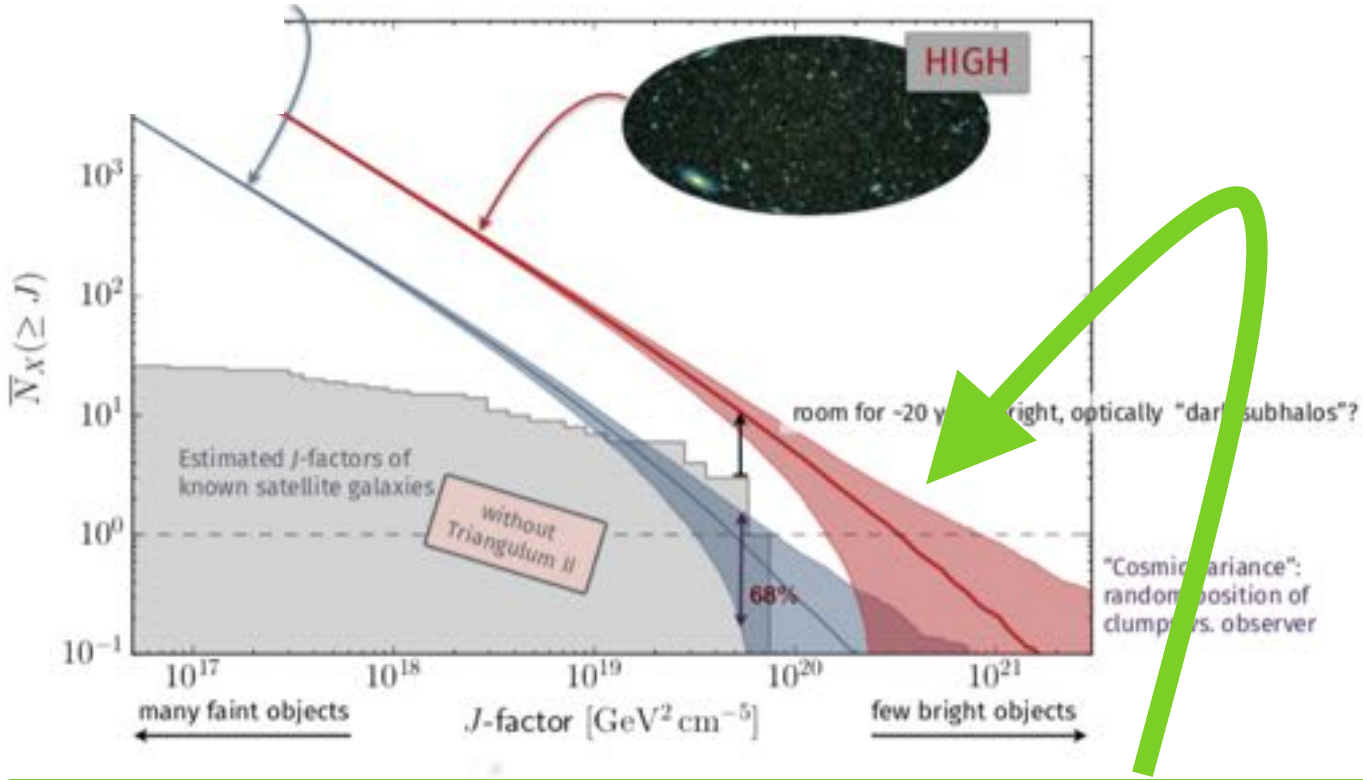
Moritz Hütten+ mhuetten@mpp.mpg.de



Garrison-Kimmel+2014

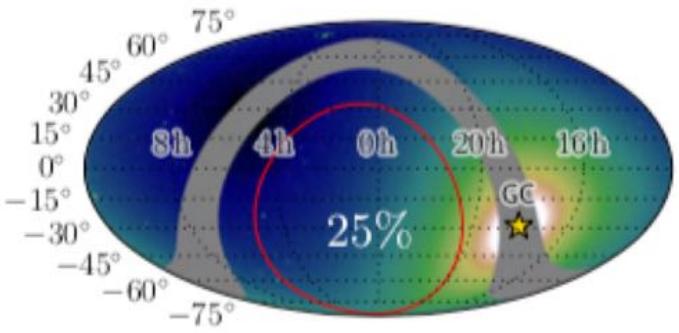
+ superclean targets
– unknown location
? Fluxes, uncertainty

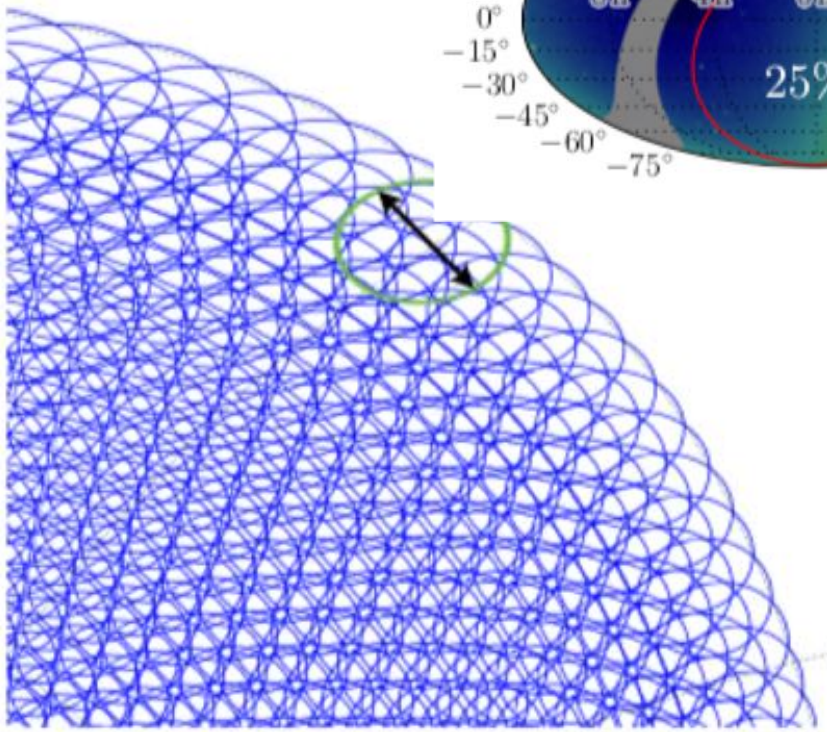
Lake (1990), … , Zechlin et al. (2012),
Schoonenberg et al. (2016), …
Hütten et al. (JCAP, 2016)



Room for 1-20 g-ray bright, optically dark subhalos!

Does CTA have a chance to find them?

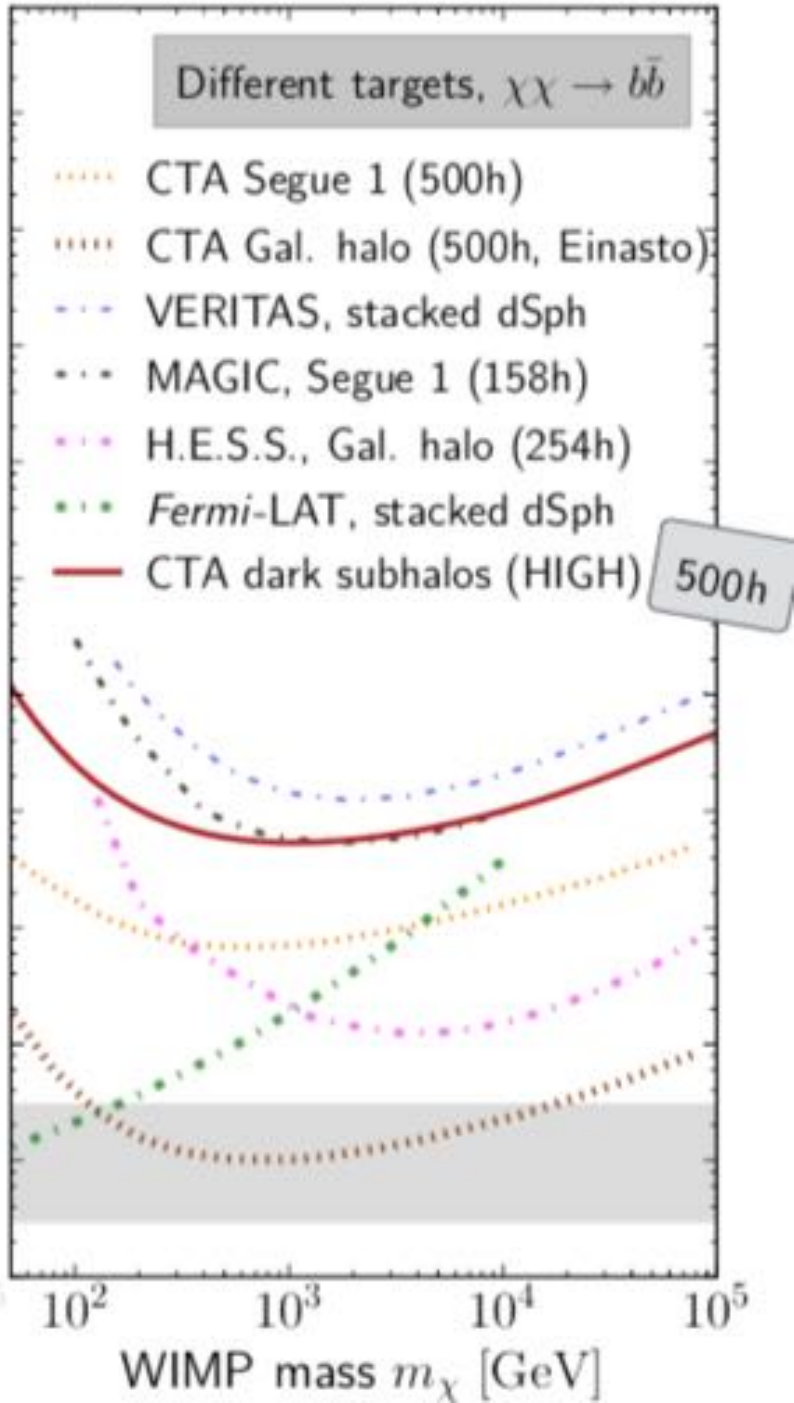


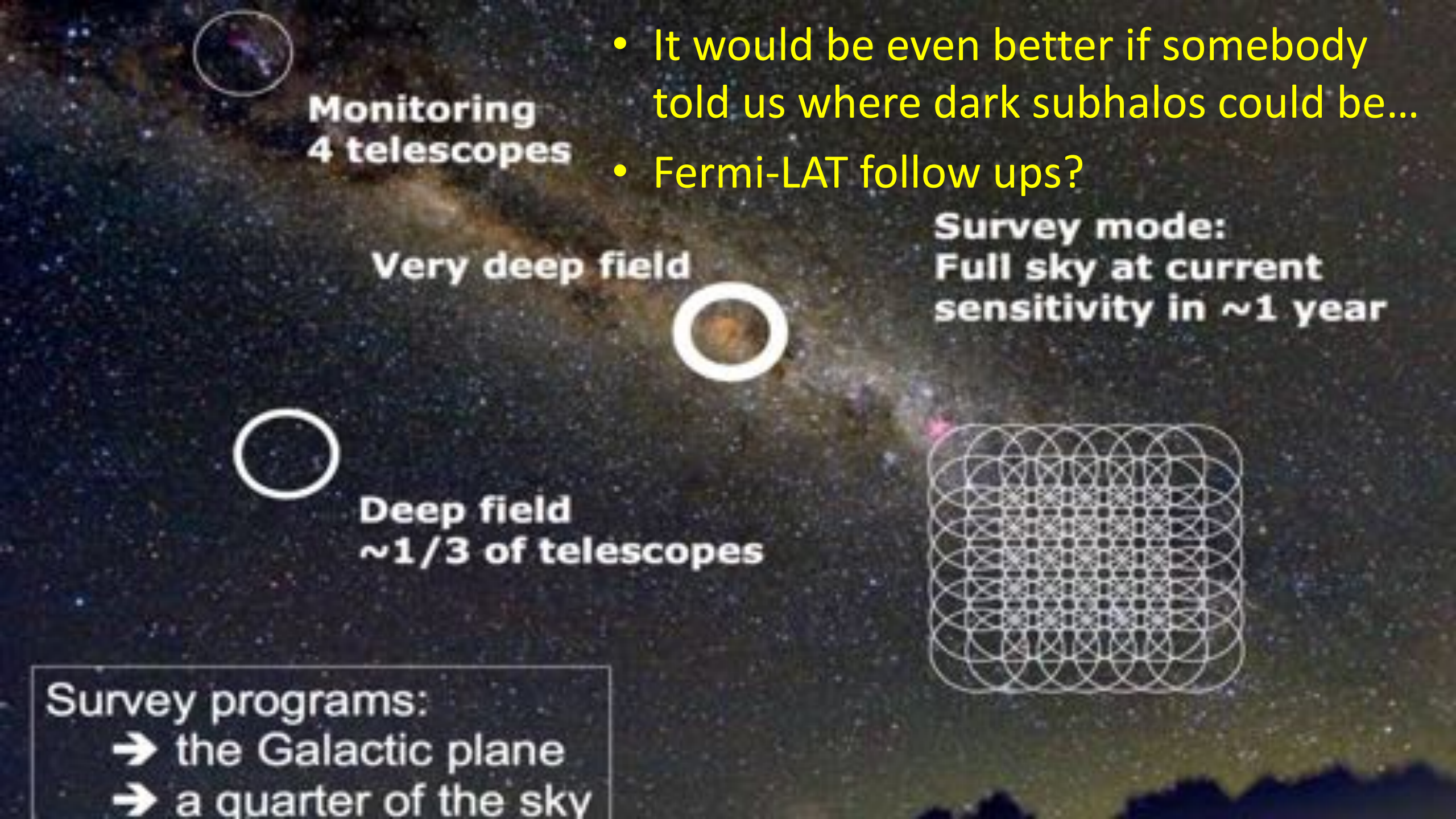


Example: 2880 observations à 10.4 min

Spacing $\Delta_{\rm fov} = 2°$

- The CTA extragalactic survey key science project: 1709.07997
- 25% of the sky over 10 yrs





- It would be even better if somebody told us where dark subhalos could be…
- Fermi-LAT follow ups?

As well as

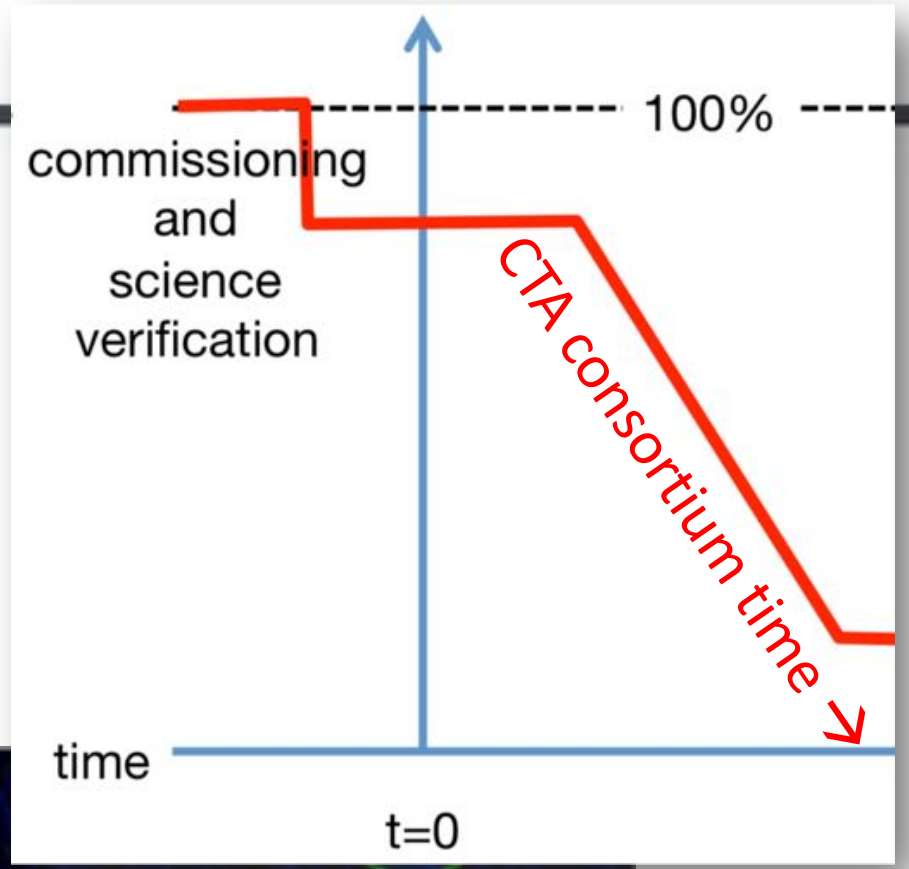
340h planned

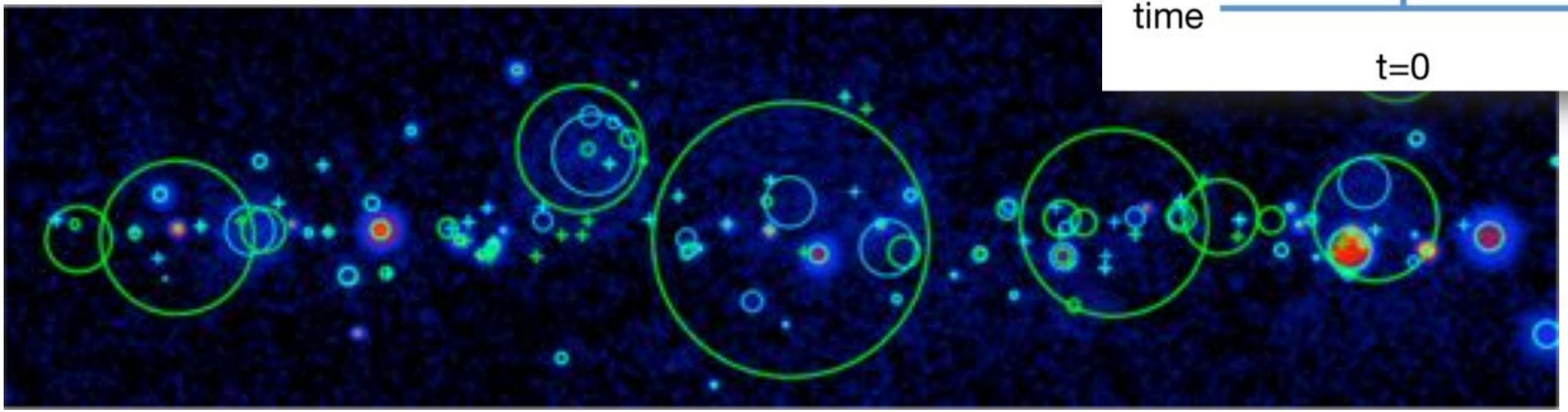
300h planned

Guest and pipelines program

- Guest observation time >50%

- Public photons and analysis pipeline!





Conclusions

Year	1	2	3	4	5	6	7	8	9	10
Galactic halo	175 h	175 h	175 h							
Best dSph	100 h	100 h	100 h							
in case of detection at GC, large σv										
Best dSph				150 h	150 h	150 h	150 h	150 h	150 h	150 h
Galactic halo				100 h	100 h	100 h	100 h	100 h	100 h	100 h
in case of detection at GC, small σv										
Galactic halo				100 h	100 h	100 h	100 h	100 h	100 h	100 h
in case of no detection at GC										
Best Target				100 h	100 h	100 h	100 h	100 h	100 h	100 h

- CTA will dedicate important fraction of time for dark matter searches
- Galactic center obvious target + extragalactic scan
- Where else to point? One or many dSphs? How to improve chances?

Thanks!