Istituto Nazionale di Fisica Nucleare

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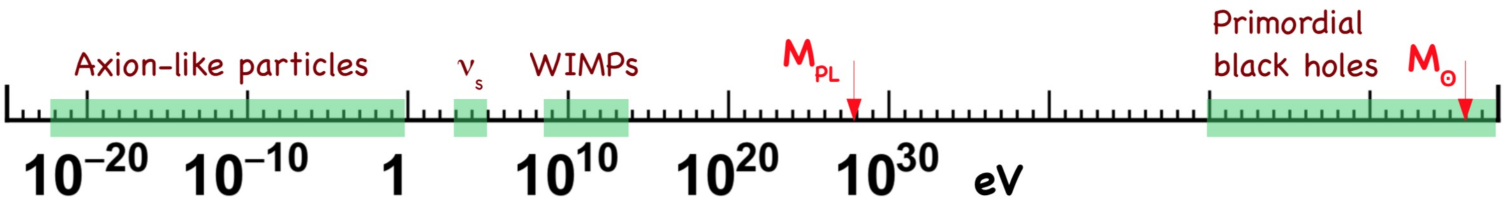
Status of indirect Dark Matter searches

IFAE 2019
Napoli, 8-10 April 2019

The dark matter landscape



Overwhelming evidence for dark matter at many scales but its properties are largely unconstrained

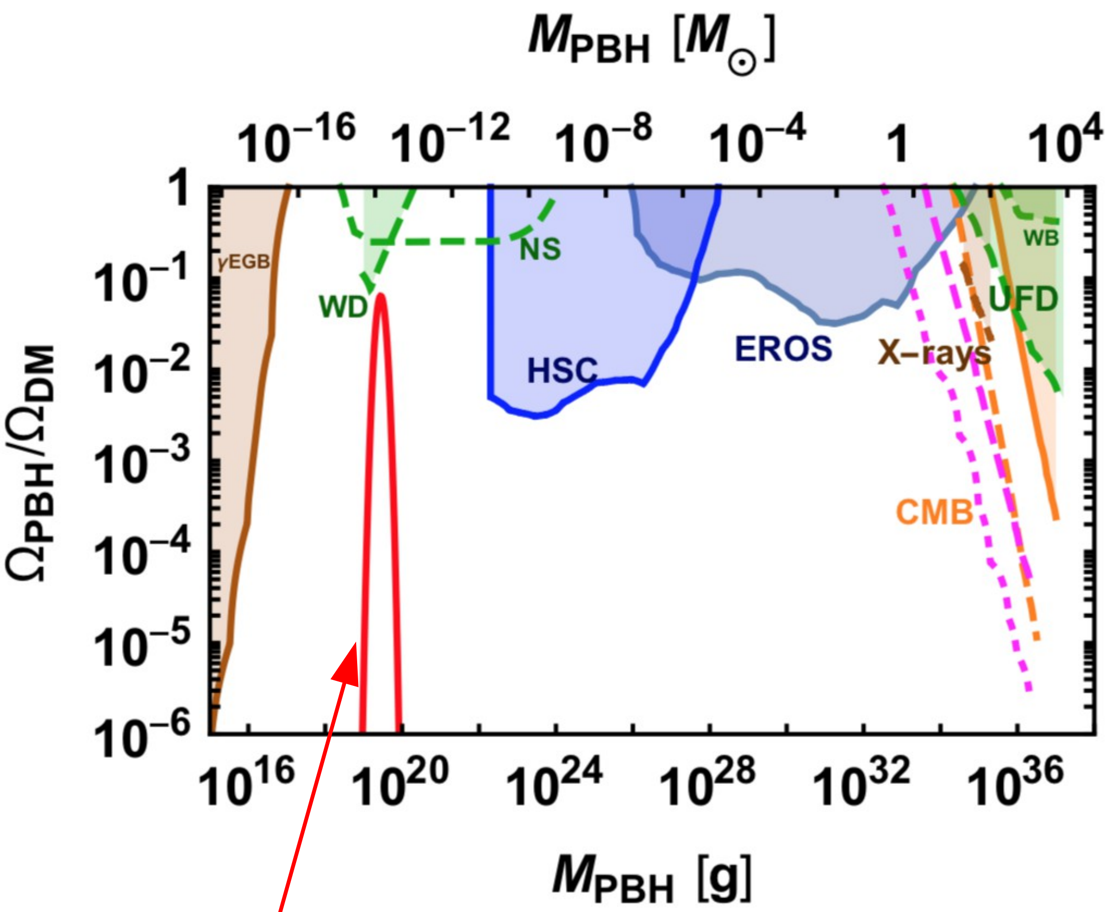
In this talk: brief review of the status of indirect searches.

Credit: S.Gariazzo

Primordial black-holes

- **PBHs** can be produced in the early Universe   Hawking (1971), Zeldovich,Novikov (1966), Hawking Carr (1974)

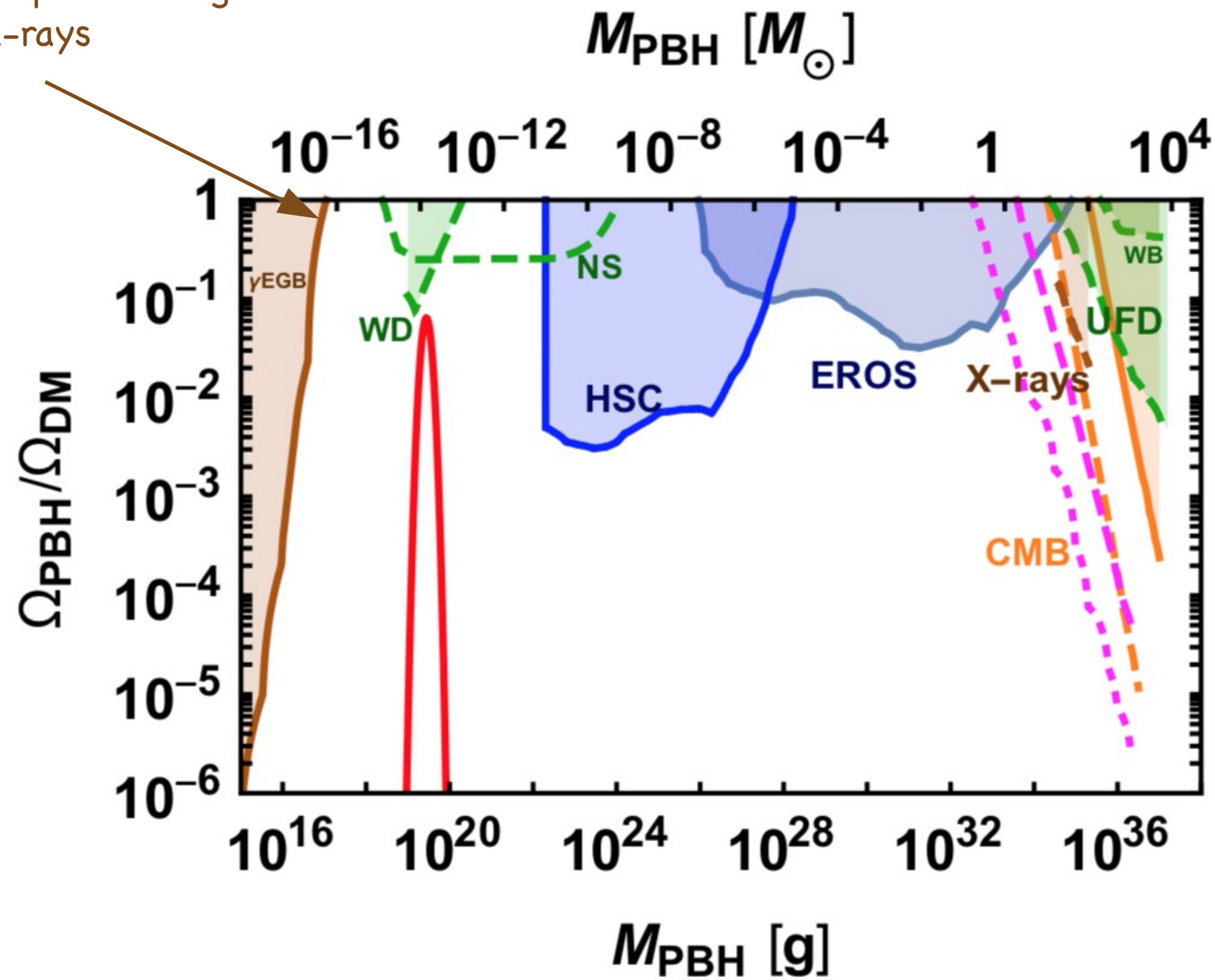
- Mechanism: collapse of primordial inhomogeneities from inflation or of topological defects or from phase-transitions



As an example: mass function from inflationary model in Ballesteros, M.T. 2018
PBHs mass function can be very different in other models!

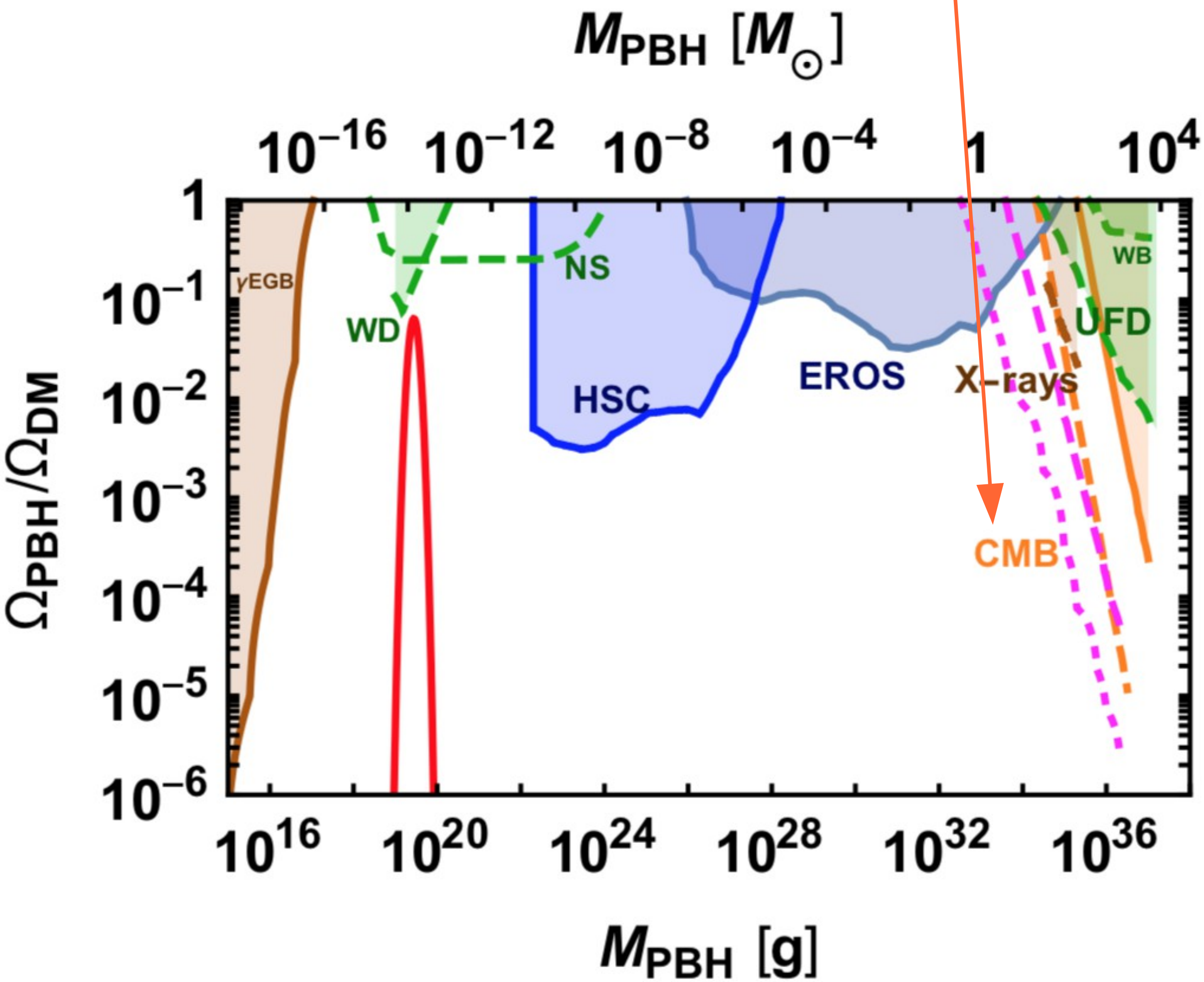
Constraints

Light PBHs have already evaporated
Bounds on evaporation signals
from gamma-rays



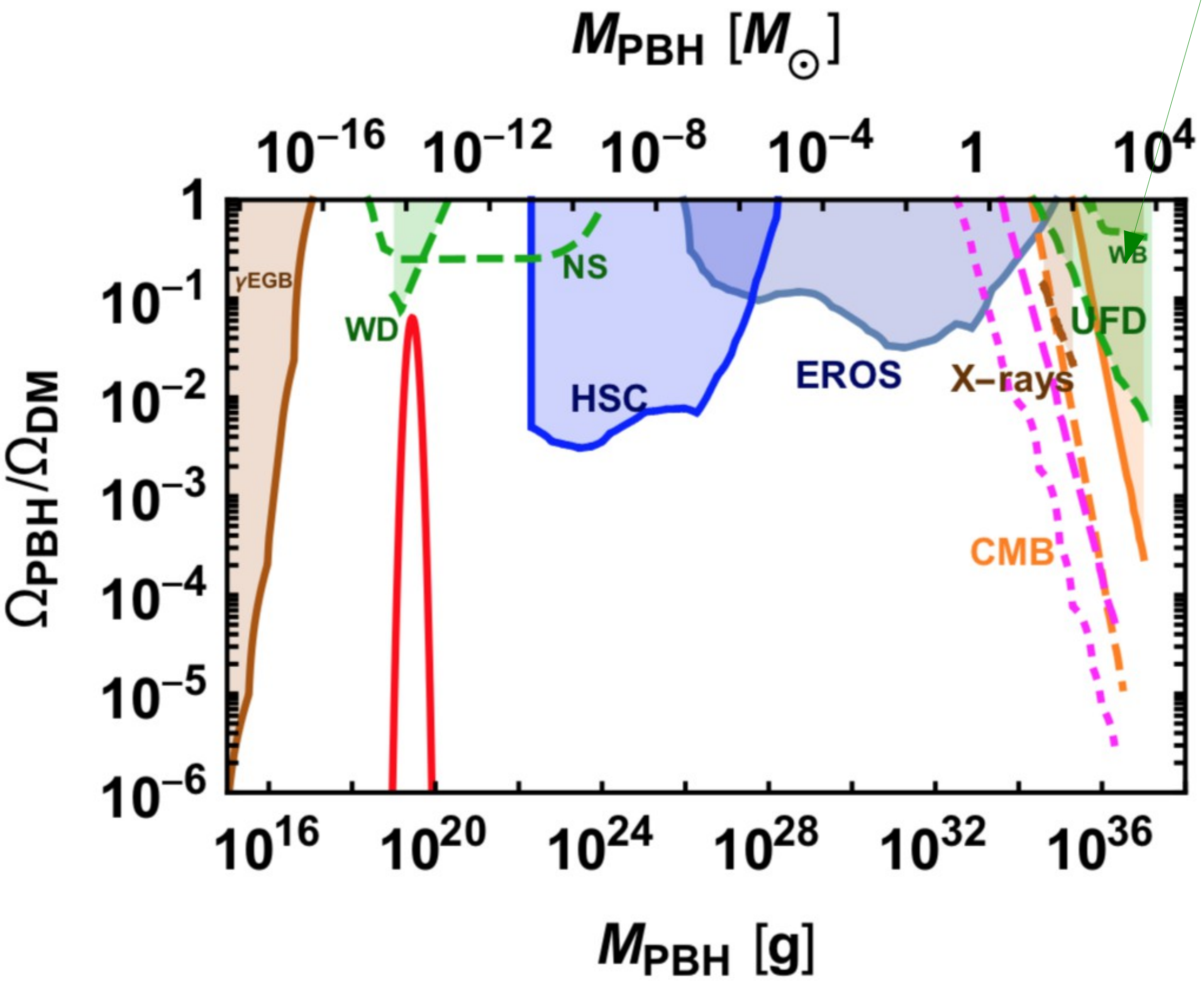
Constraints

Accretion of matter around PBHs can alter the ionization history of the Universe.
Strong bounds from CMB anisotropies.



Constraints

Dynamical constraints:
wide binaries, ultra-faint dwarfs

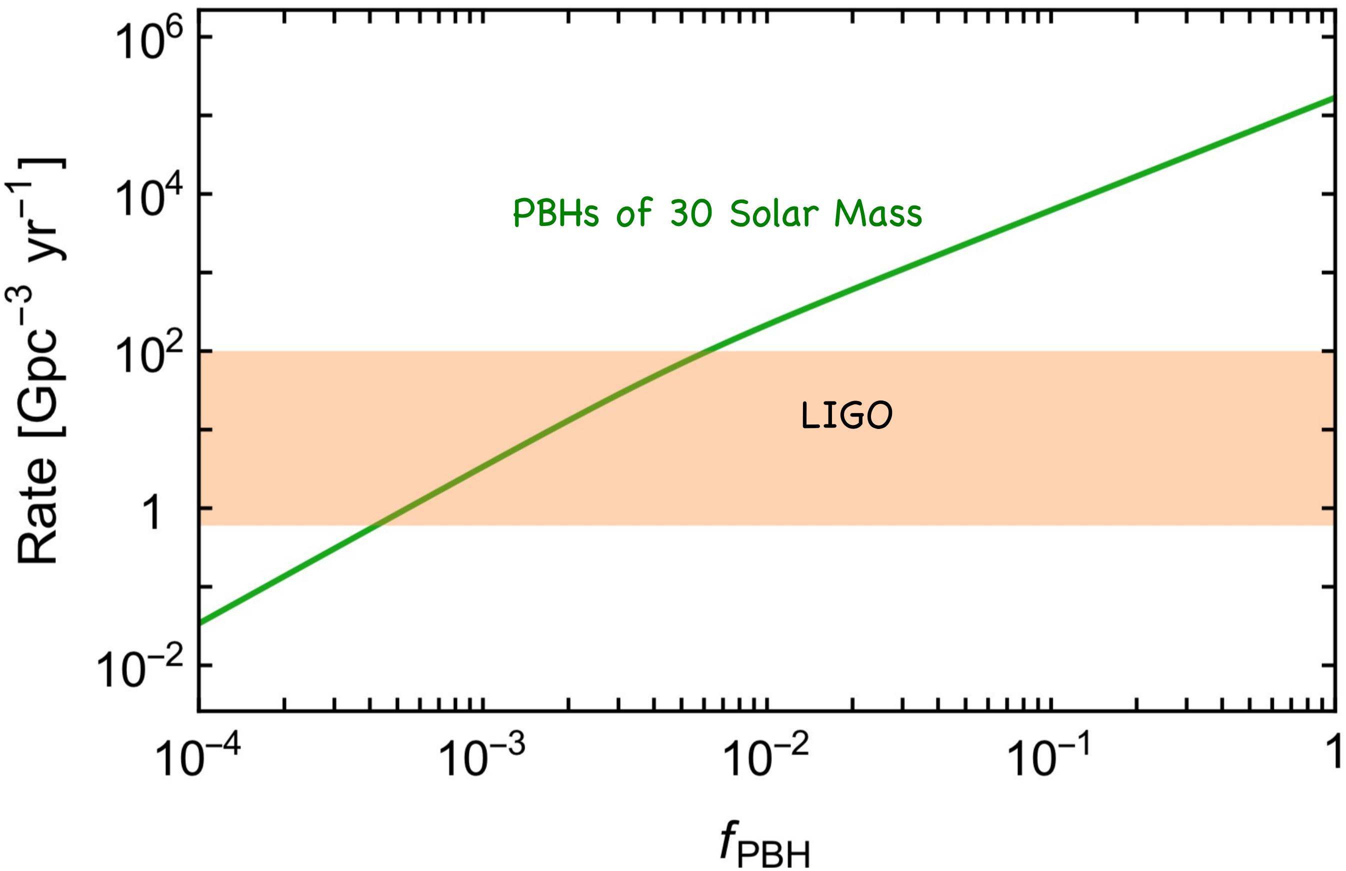


LIGO and PBHs

Interactions of 3 or more PBHs lead to the formation of binaries, which can merge much later

Nakamura et al. 1997, Kinugawa et al. 2014

Given the LIGO merger rate PBHs of O(10) $M_\odot$ can only be subdominant DM



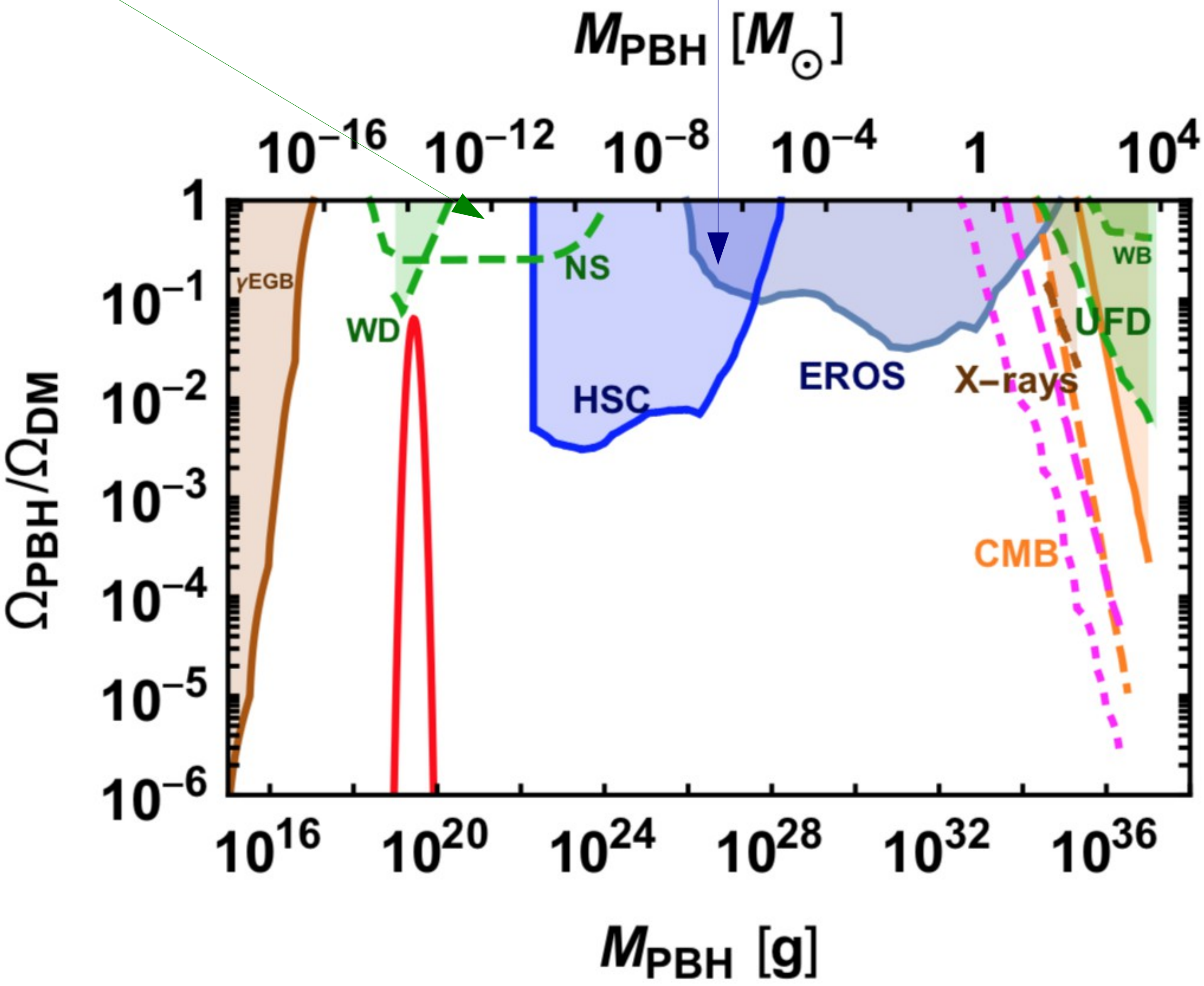
Recent computations of merger rate: Sasaki et al. 2017, Ali-Haimoud et al. 2017, Kavanagh et al. 2018, Chen et al. 2018, Raidal et al. 2019

For the role of the clustering on the merger rate see Desjacques, Riotto 2018; Ballesteros, Serpico, M.T. 2018

Constraints

White dwarf explosion
Neutron stars capture

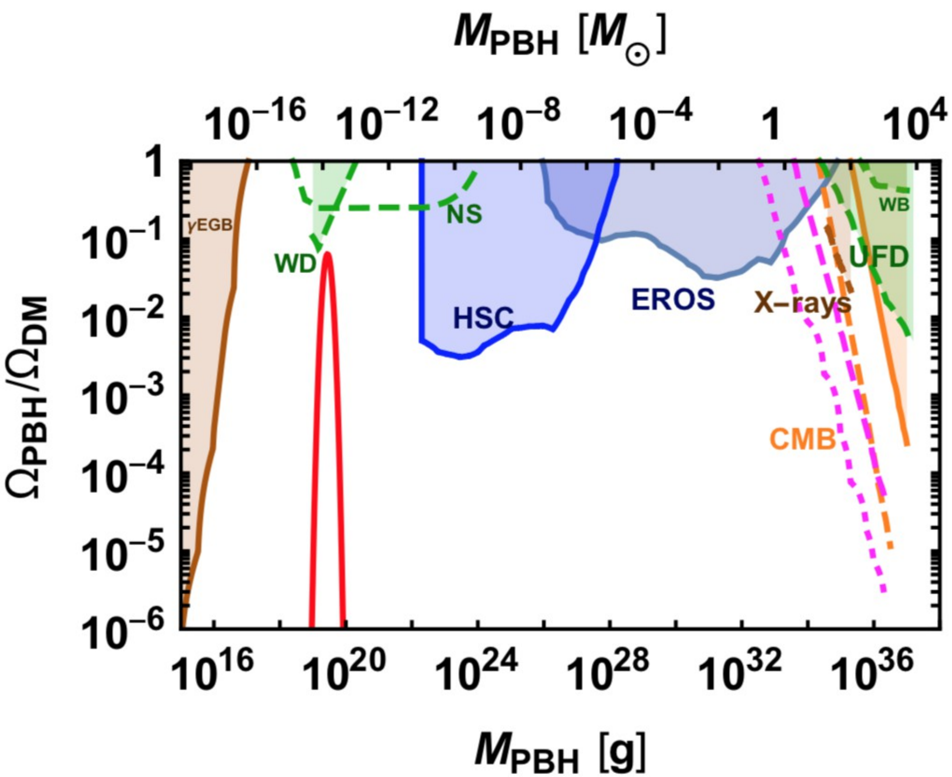
Microlensing constraints



Future prospects

Future prospects includes

For PBHs in the 1-100 $M_\odot$ range see
Astro2020 White Paper 1903.04424



Gravitational Waves Talk by Drago

Exp: LIGO, VIRGO, LISA, Einstein Telescope

- Golden channel: detection of BHs below the Chandrasekhar mass
- BHs mergers at high z
- Indirect probe: stochastic GW back associated with formation of PBHs

Microlensing

Exp: WFIRST, JWST, Euclid

Pulsar Timing array

Exp: SKA
Detect background of GWs and transient sources

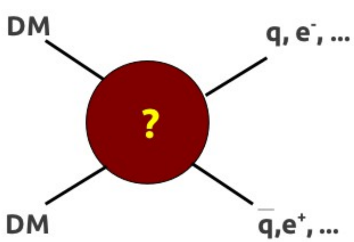
How to probe window at 10^{-16}-10^{-11} $M_\odot$?

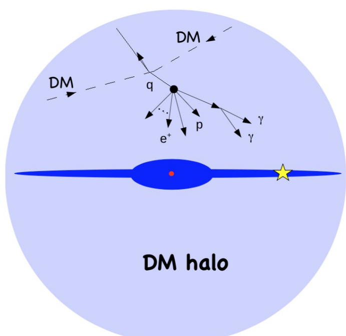
Femtolensing Katz et al. 2018
GW background with LISA (indirect way) e.g. Cai et al. 2018, Bartolo et al.2018
Microlensing with X-ray pulsars Bai et al. 2018
Other ideas?

Particle dark matter: astrophysical signals

Signals

Search for DM annihilations or decays products:
photons, neutrinos, anti-protons, positrons
anti-nuclei

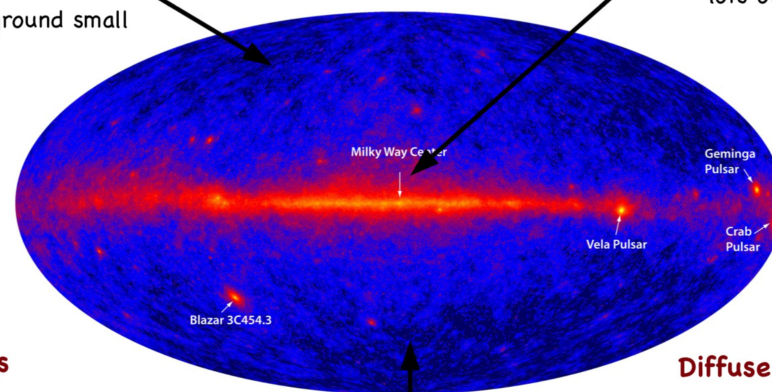




Targets

Dwarf galaxies
Large Mass/Luminosity ratio
Nearby
Astro background small

Galactic center
+ Large DM density
- lots of sources, large bkg



DM clumps

Diffuse galactic halo

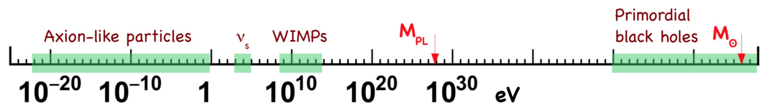
Clusters of galaxies

Extragalactic diffuse emission

In this talk: focus on photon signals from G<u>alactic Center and dwarfs</u>

Other interesting searches in this Conference with
charged cosmic-rays: talk by Donnini + Serini, Nadir, Dimiccili, Catanzari
21 cm searches talk by Mitridate

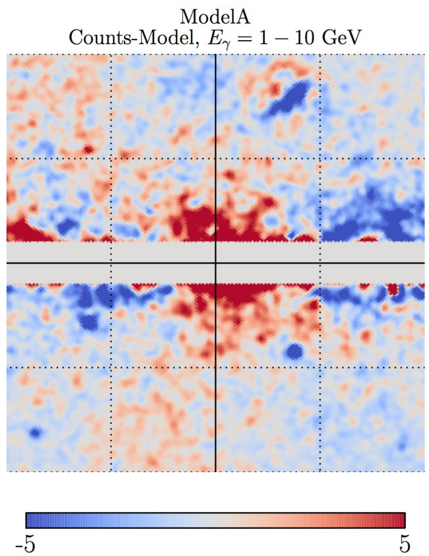
The Galactic Center GeV excess



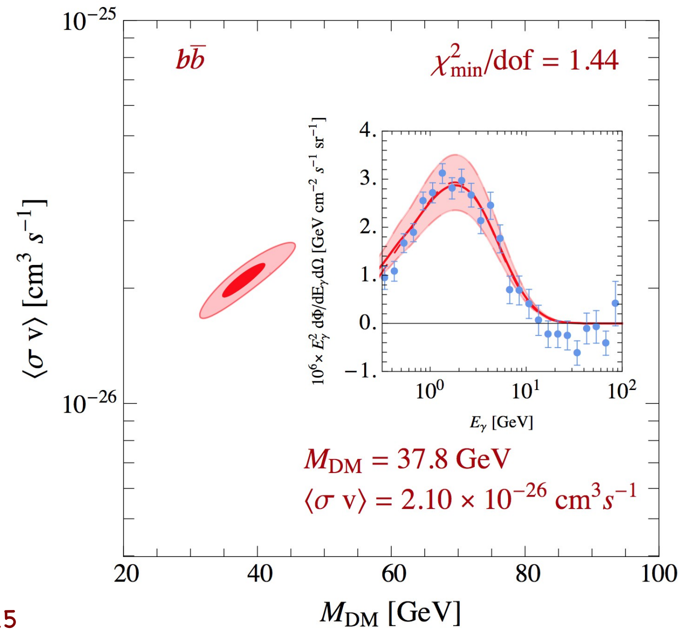
Signal and properties

Excess of GeV photons from inner galaxy (up to 10 degrees)
Almost spherically symmetric
Peaked at few GeVs

Vitale and Morsell 2009, Godenough, Hooper 2009; Hooper, Linden 2011; Abazajian Kaplinghat 2012; Hooper, Slatyer 2013; Gordon, Macias 2013; Huang,Urbano,Xue 2013; Abazajian et al. 2014; Daylan et al. 2014;Calore et al. 2014; Calore,Cholis,Weniger 2014; Zhou et al. 2015; Fermi Collaboration 2017, + …



Gaggero, MT, Urbano, Valli, Ullio 2015



Cirelli, Gaggero, Giesen, MT, Urbano 2014

Interpretations

Diffuse emission electrons at the GC:
Burst-like injections
Enhanced SFR

Population of unresolved milli-second pulsars

DM annihilations

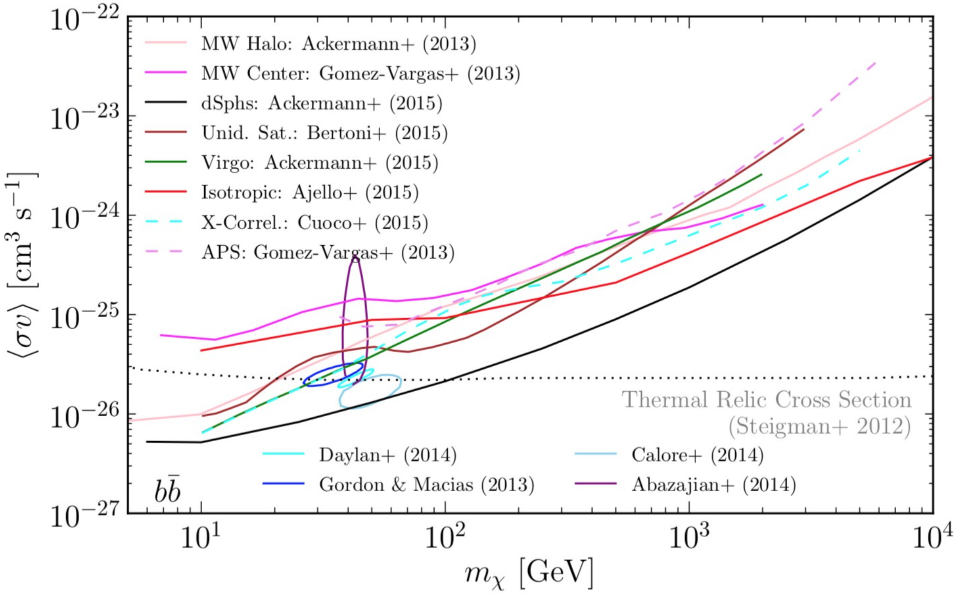
Dwarf spheroidal galaxies

Main uncertainties:
- J-factors
- background mis-modeling

Impact on the limits around factor 2-3

Bonnivard et al. 2015, Geringer-Sammeth et al. 2015,
Hayashi 2016, Klop 2017
Calore et al. 2018

Charles et al. 2016



Support for milli-second pulsar hypothesis

Fluctuations analysis Bartels et al. 2015, Lee et al. 2015

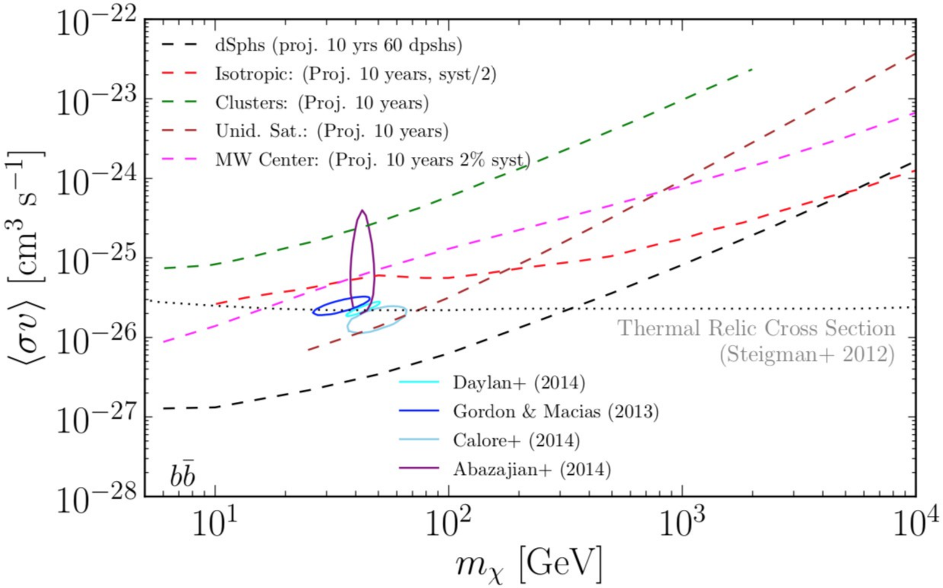
Evidence for an emission profile tracing the stellar mass in nuclear buldge

Bartels et al. 2018, Macias et al. 2018

Future prospects

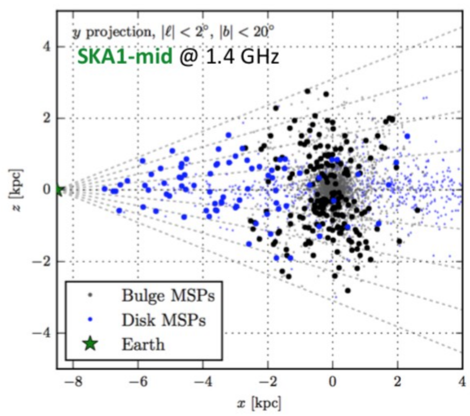
Limits from dwarfs: factor few improvements
Better statistic, new dwarfs discovered with
SDSS, DES, LSST,...

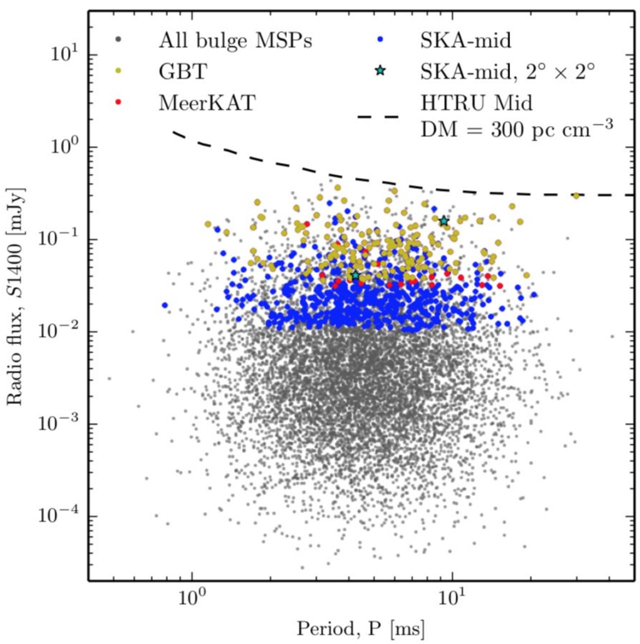
Charles et al. 2016



MSPs can be discovered with radio observations
tens of sources detectable with MeerKAT

Calore et al. 2016

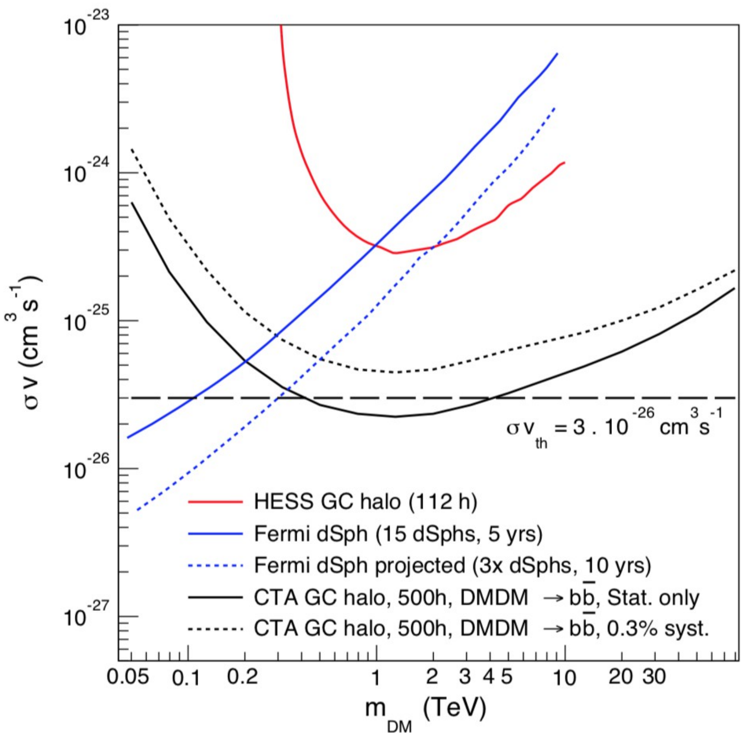




Future directions with gamma-rays

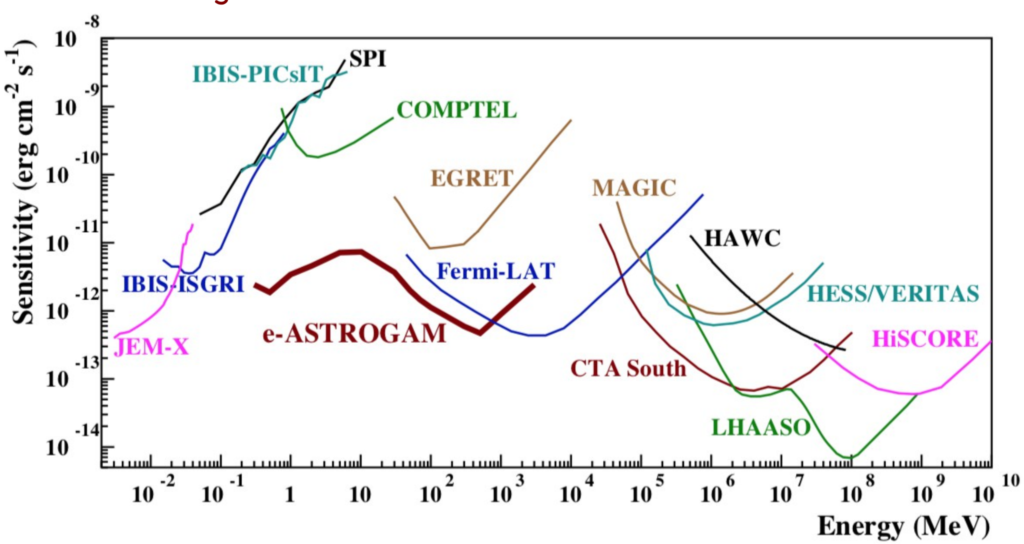
In the E > TeV domain limits from HESS, MAGIC, VERITAS and more recently HAWC

Significant improvement (around factor 10) with CTA in the near future (2022-2025)

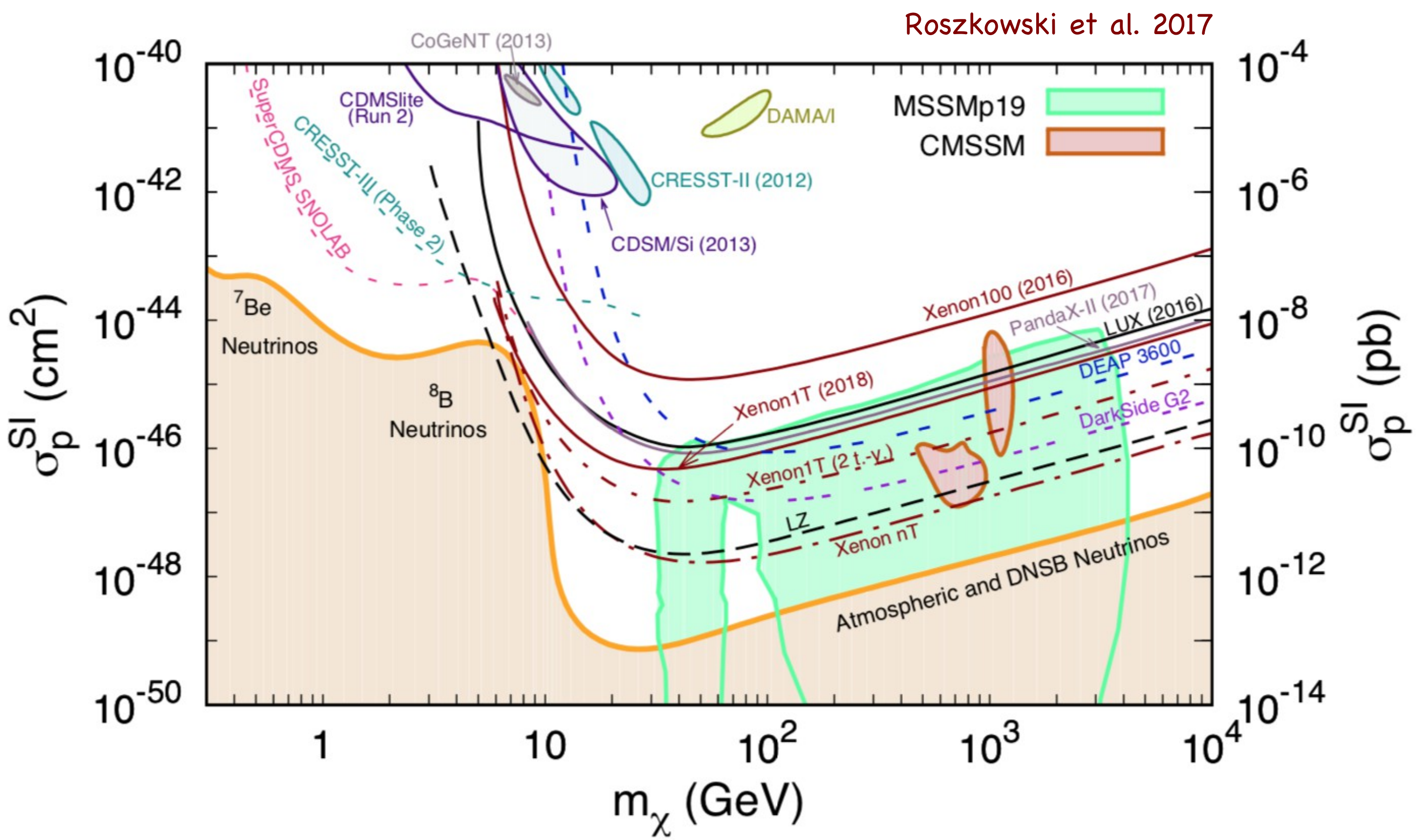


Lefranc et al. 2015
See also Silverwood et al. 2015, Carr et al. 2015

De Angelis et al. 2017

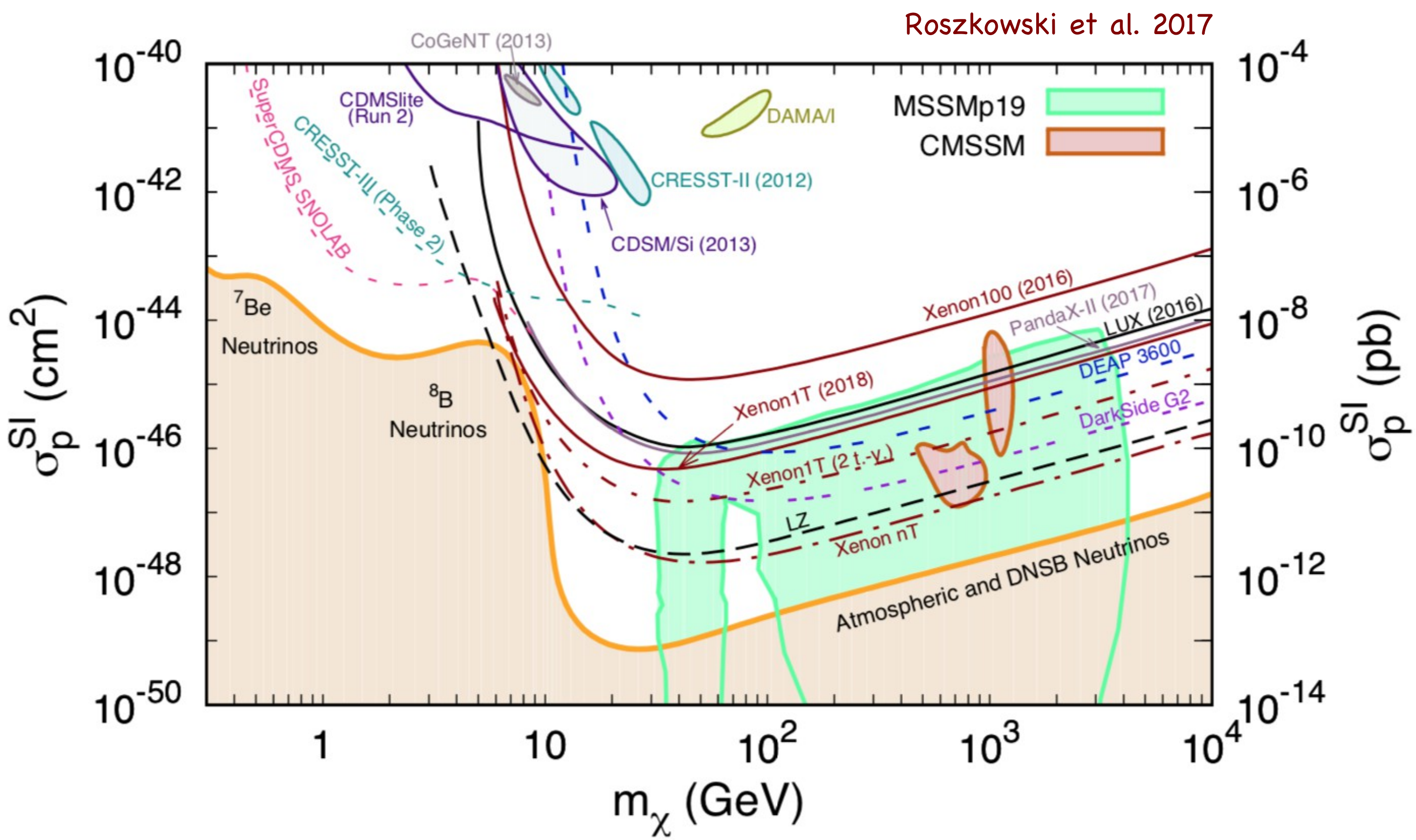


Direct detection



In this Conference with charged cosmic-rays: see talk by Picciau, Cappella, Di Gangi + Alexandrov, Di Lorenzo, Pinci

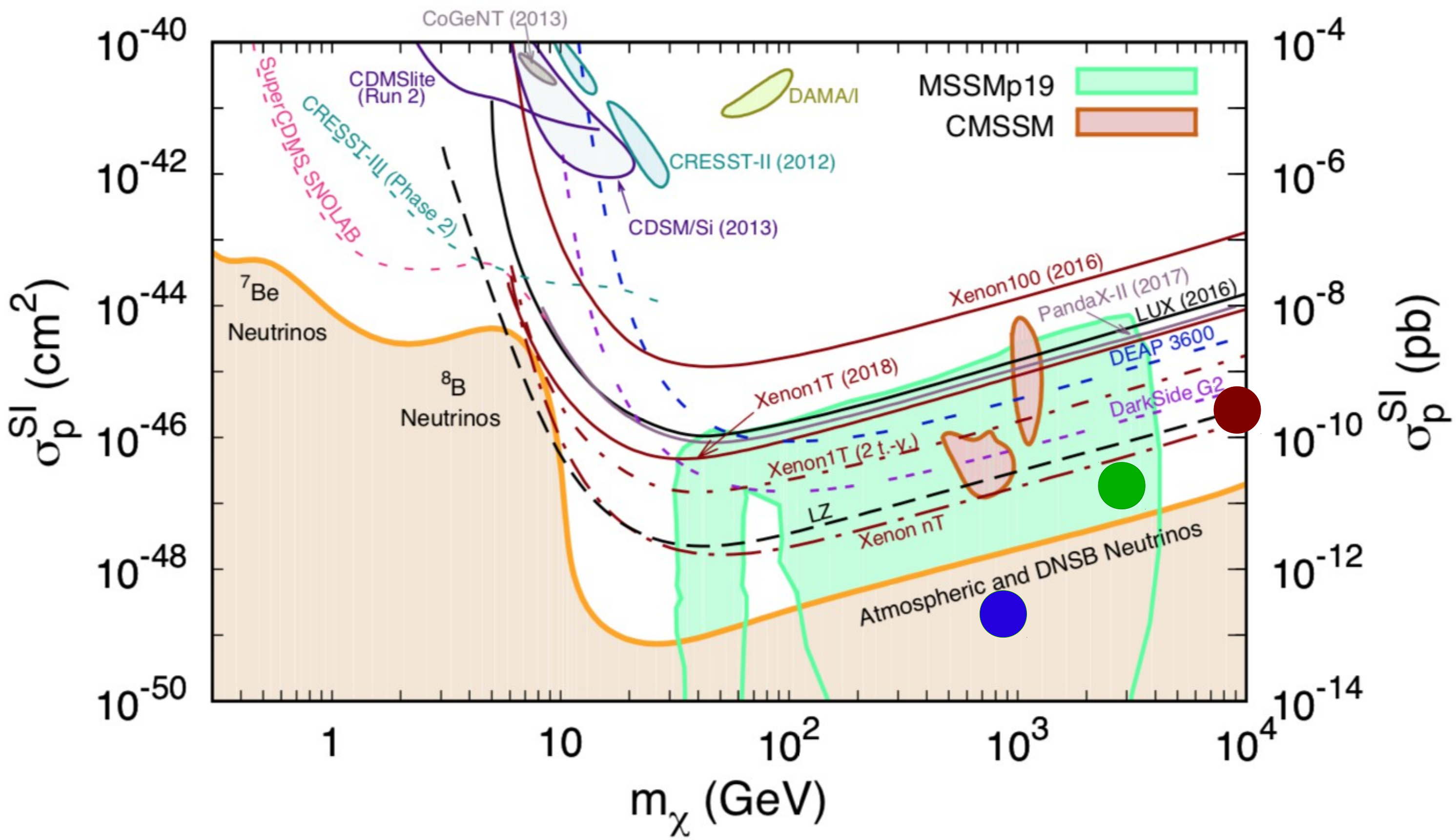
Direct detection



New ideas to extend the reach in the sub-GeV range, e.g.

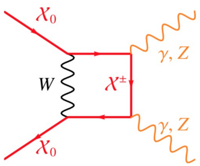
Superconductors (Hochberg et al. 2016) Superfluid He (Knapen et al. 2017) Graphene (Hochberg 2016) Crystal defects (Kadribasic et al. 2017)...

Direct detection

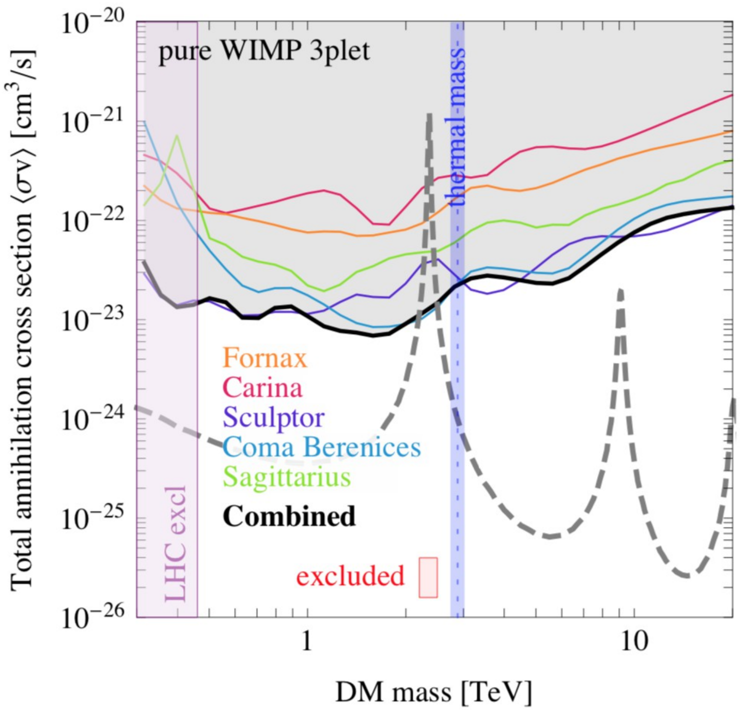


Example of complementarity DD & ID for wimps: pure EW multiplet DM
Higgsino, **Wino**, **Minimal DM**

TeV gamma-ray lines

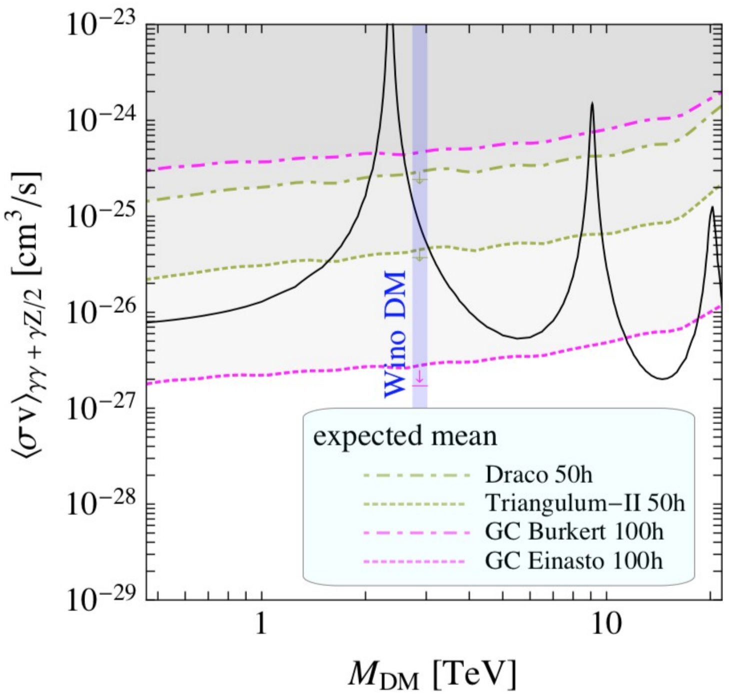


Current bounds from HESS obs of dwarfs not yet competitive
GC constraints potentially much stronger but dependent on the DM density profile



Cirelli, Panci, MT, Sala, Silk + HESS coll 2018

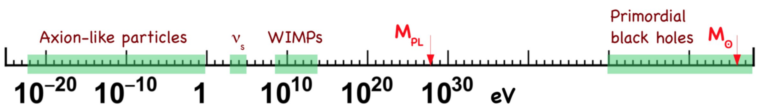
Future with CTA



Lefranc et al. 2016

keV dark matter

In this Conference talk by Saviano



3.5 keV line detected in multiple targets (clusters, M31, GC) and with different instruments (XMM-Newton, Chandra, Suzaku) consistent with DM decay, e.g. sterile neutrino

Bulbul et al. 2014, Boyarsky et al. 2014, Urban et al. 2014, Cappelluti et al. 2017, ...

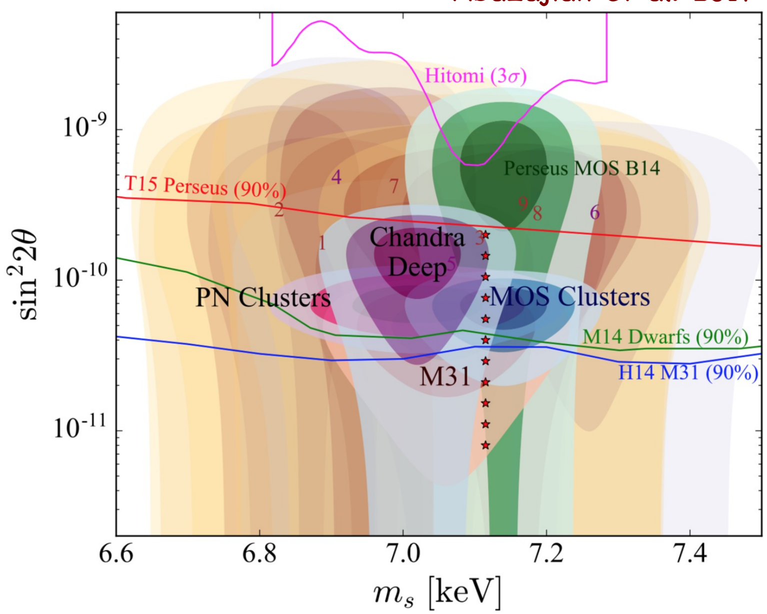
Also null detections from various targets. Recently strong constraints from null detection in XMM-Newton blank sky observations

Dessert et al. 2018

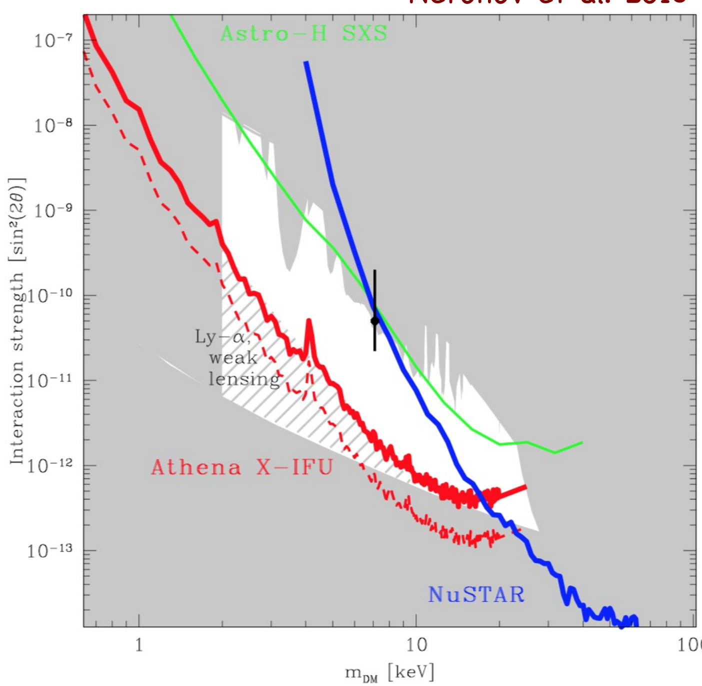
Future tests:

Micro-X
X-RISM (2021)
Athena (2028)

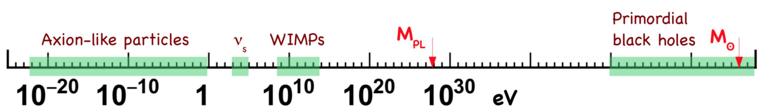
Abazajian et al. 2017



Neronov et al. 2016

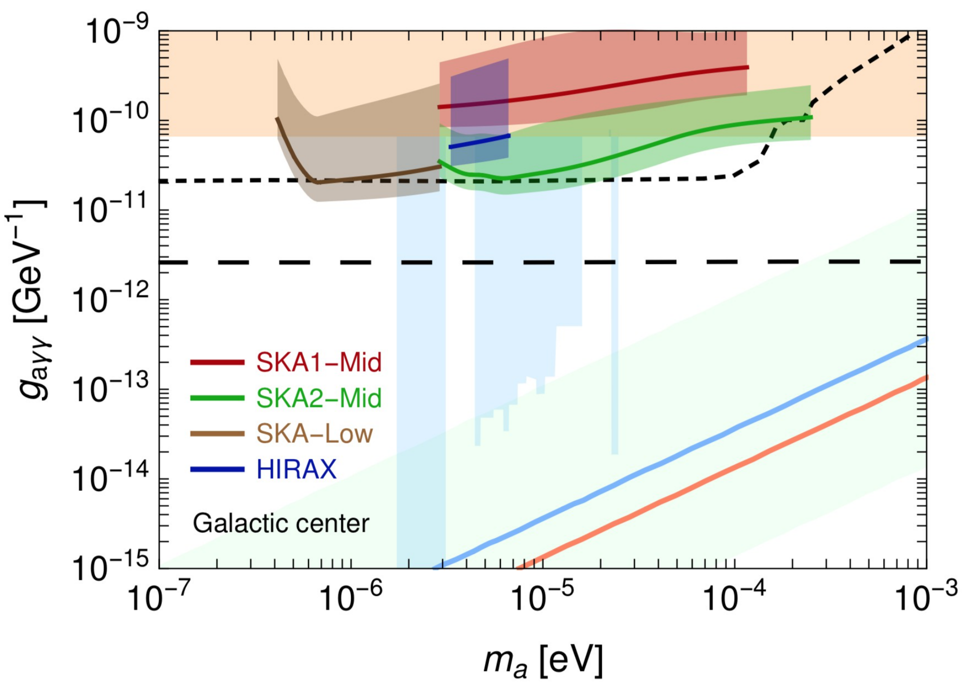


ALP

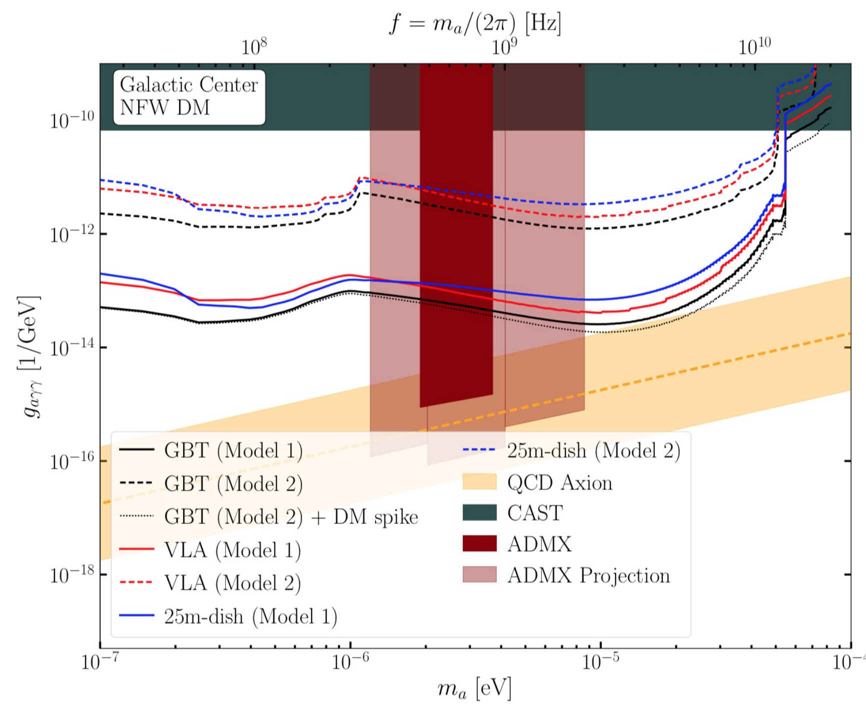


In this Conference talk by Di Luzio + Rettorali

Sensitivity of future radio surveys to decays of ALP and conversion inside astrophysical objects



Caputo, Regis, MT, Witte 2018



Safdi, Sun, Chen 2018

Conclusions

Huge range of possibilities for dark matter

Different methods and energy ranges to explore the landscape of DM candidates

DM signals are faint but many opportunities exist!

THANKS