Searching for WIMPs in the Large Magellanic Cloud

[based on MR, J. Reynoso-Cordova, M. Filipovic et al., arXiv:2106.08025]

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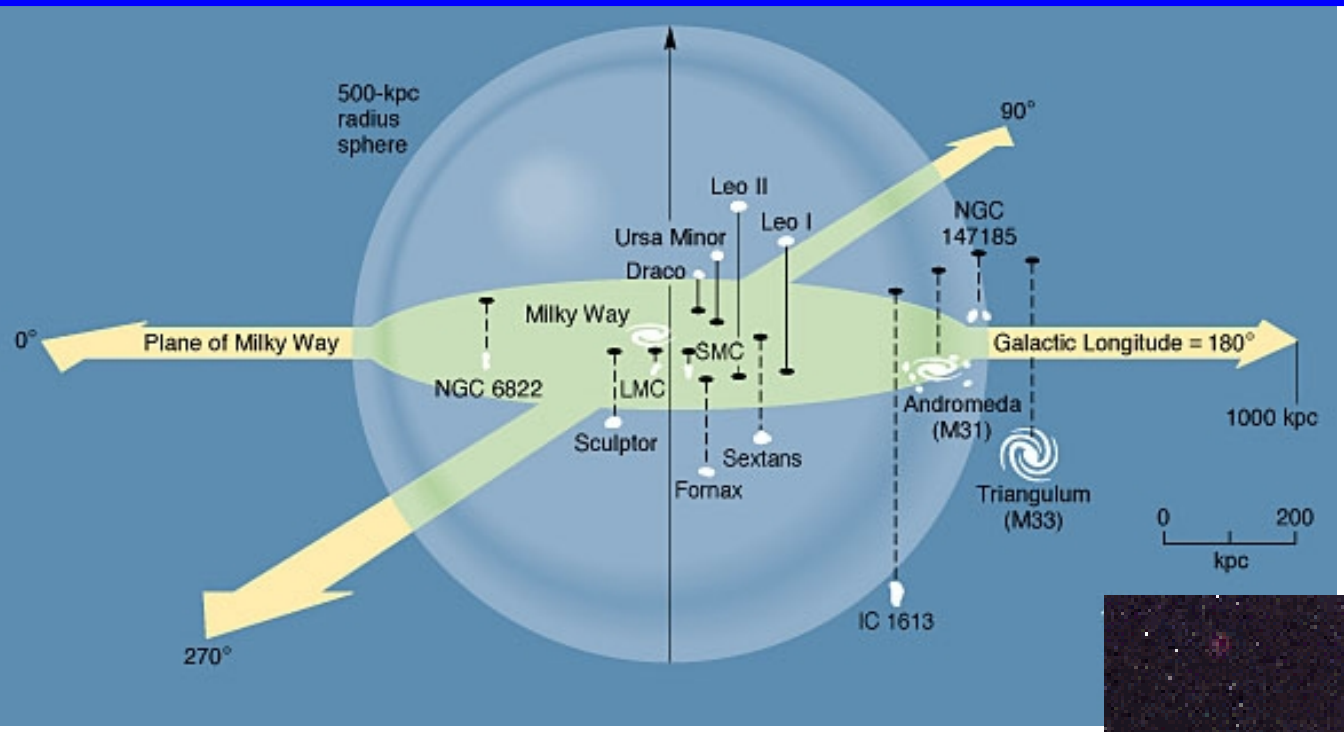
The Large Magellanic Cloud



Credit: David Darling

Large dark matter content
$M_{vir} \sim 10^{11} M_{Sun}$

Proximity to Earth
D ~ 50 kpc

ASKAP and EMU

Australian Square Kilometre Array Pathfinder

36 antennas, each 12 m in diameter
Commissioning and early science

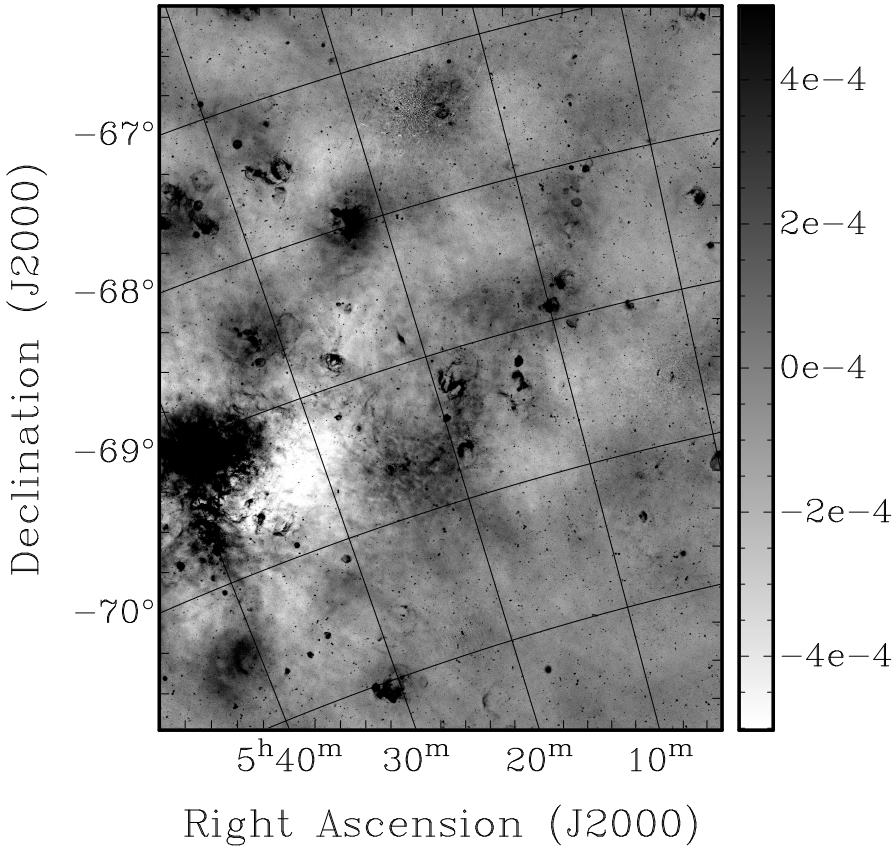
Credit: ATNF-CSIRO

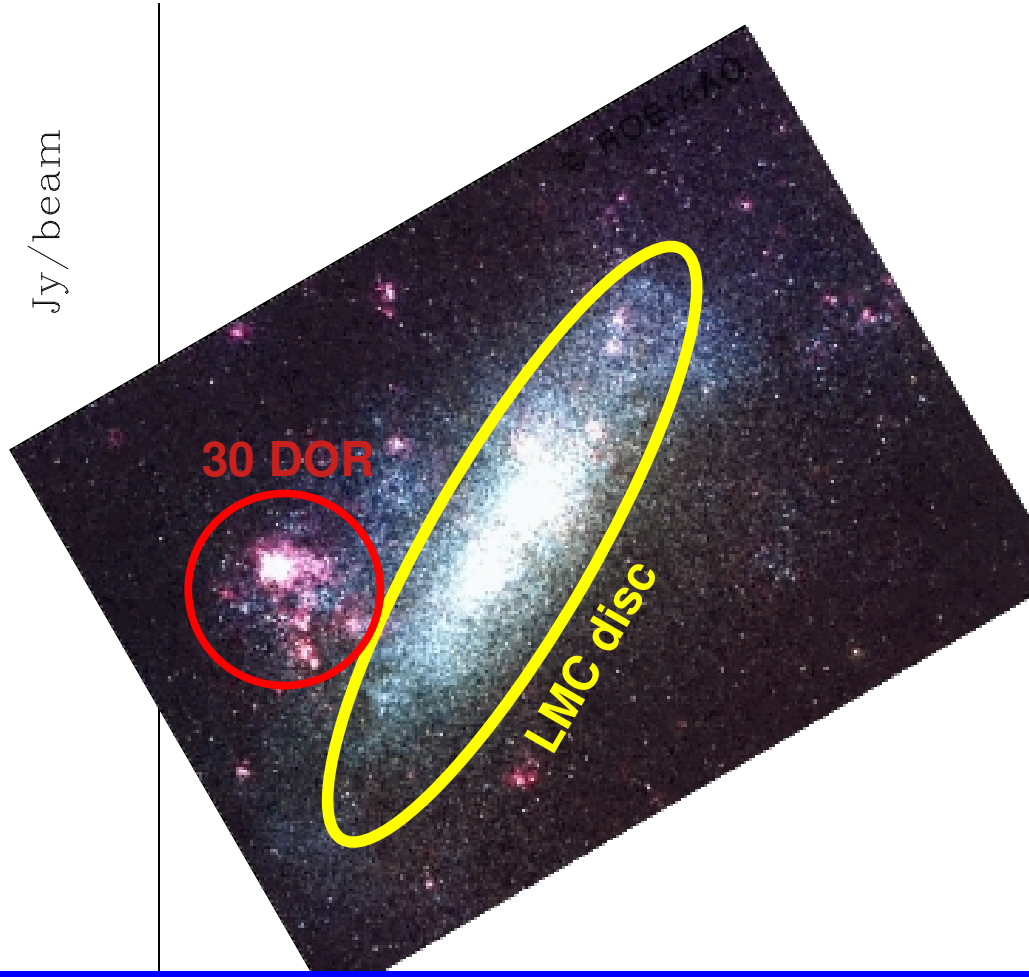
Evolutionary Map of the Universe

Survey of the Southern sky (3 x 10^4 deg^2)
at ~ 1 GHz with ~10'' resolution
and sensitivity of 30 μJy/beam

The ASKAP view of the LMC

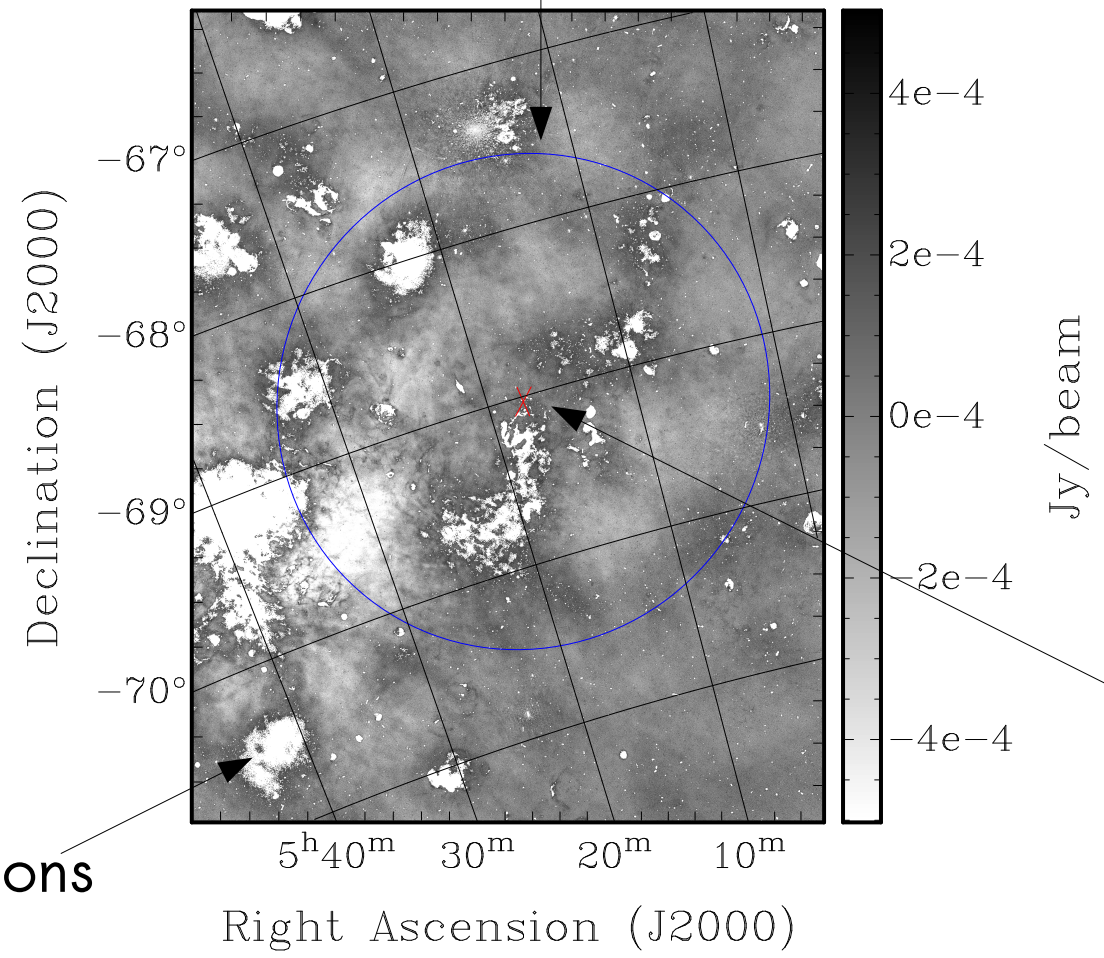
Total exposure time ~ 12h 40m
at 888 MHz with bandwidth 256 MHz
Angular resolution ~ 13''
RMS sensitivity ~ 58 μJy/beam





Data used in the analysis

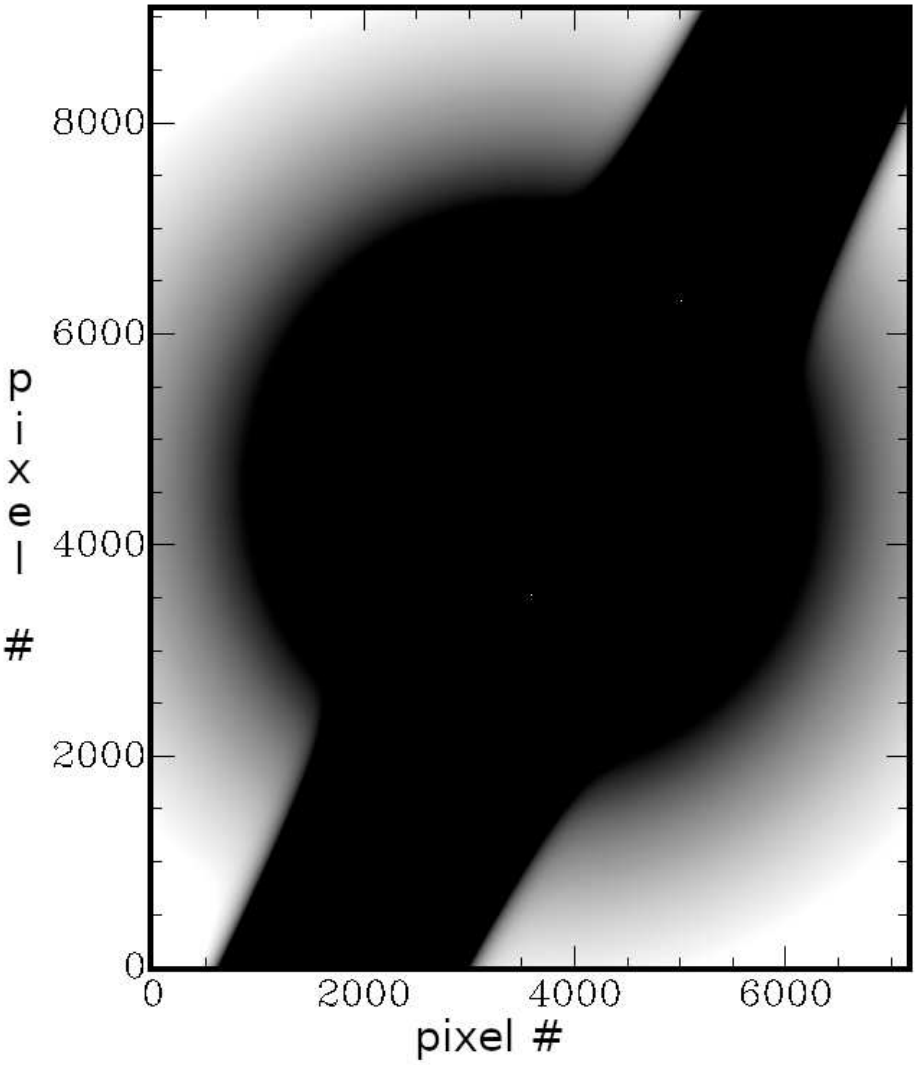
ROI = radius of 1.3 kpc
(1.5 deg in angular units)



Dynamical center

Masked regions

SIMPLE and CONSERVATIVE analysis



MODEL

$S_{meas} = S_{DM} + S_{disc} + S_{flat}$

S_{DM} = dark matter emission
S_{disc} = Gaussian disc
S_{flat} = spatially flat term

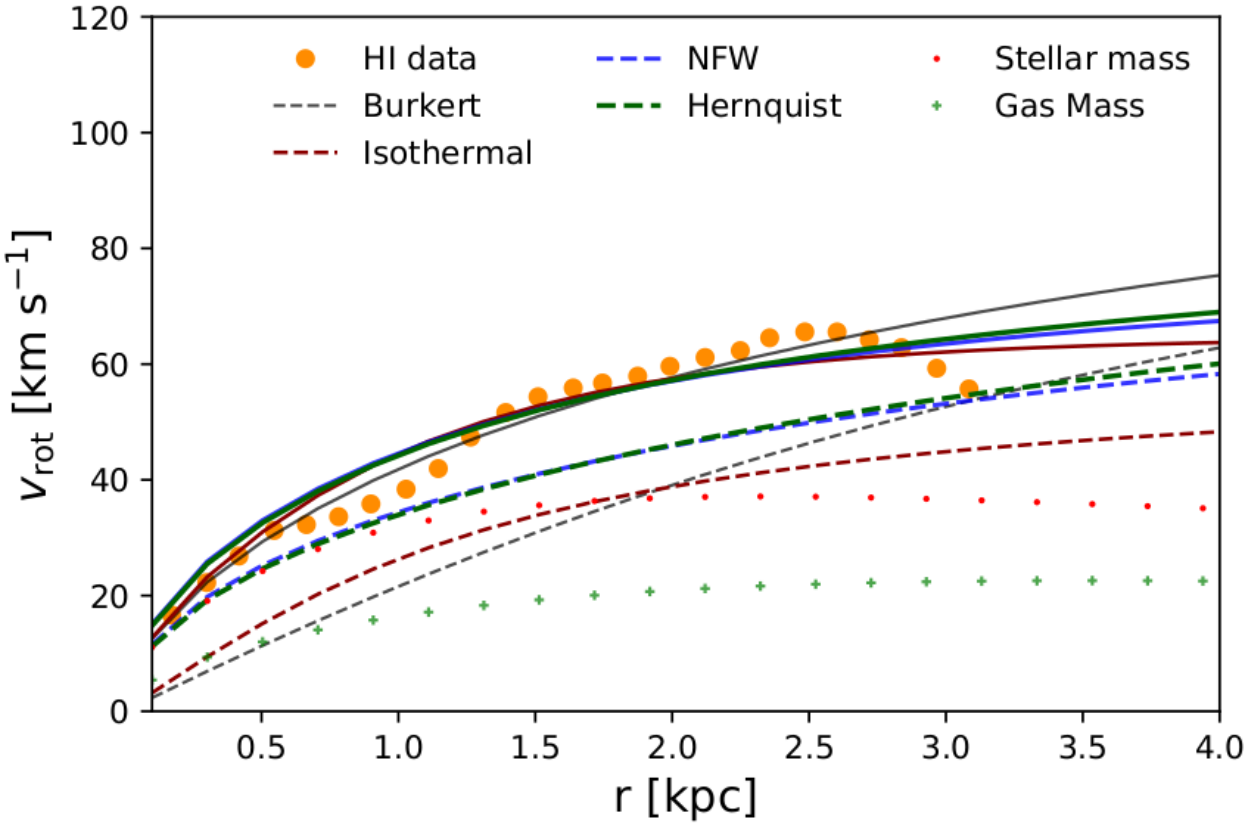
3 nuisance parameters:
$S_{0,disc}$, σ_{disc} , S_{flat}
2 DM parameters:
M_{DM}, $\langle \sigma_a v \rangle$

The DM profile

Fit to rotation curve

HI rotational data from Kim et al., ApJ 1998

$$v(r) = \sqrt{\frac{GM_{\rm tot}(r)}{r}}$$



$$M_{\rm tot} = M_{\rm DM} + M_{\rm star} + M_{\rm gas}$$

Stellar potential (Plummer-Kuzmin disk)

$$\phi_\star(r,z) = GM_\star \left[r^2 + \left(a_\star + \sqrt{z^2 + b_\star^2} \right)^2 \right]^{-1/2}$$

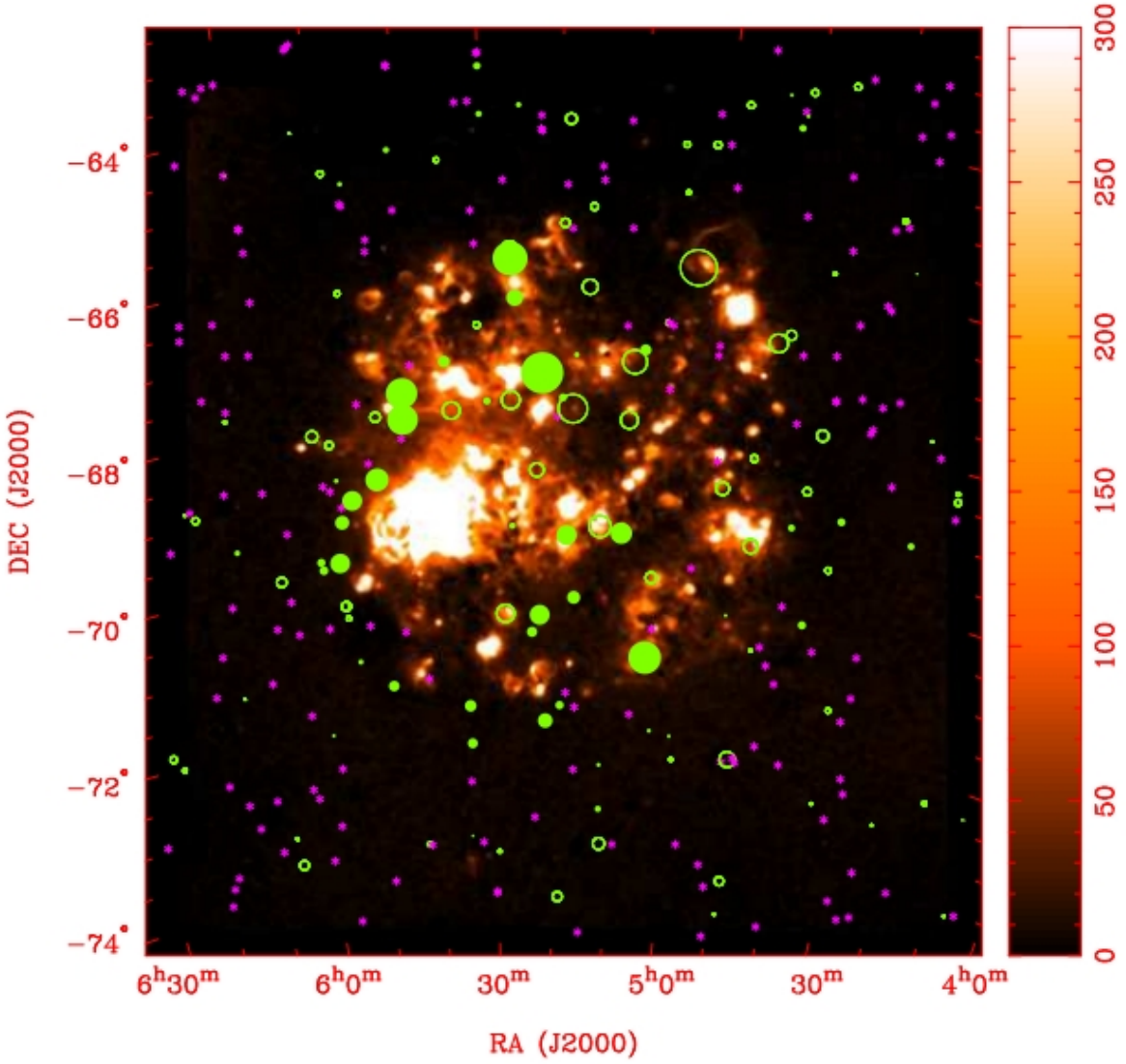
Gas density

$$\rho_g(r,z) = \frac{M_g}{2\pi a_g^2 b_g} 0.5^2 \,\mathrm{sech}\left(\frac{r}{a_g}\right) \mathrm{sech}\left(\frac{|z|}{b_g}\right)$$

→ J-factor ~ 10^{20} GeV^2/cm^5

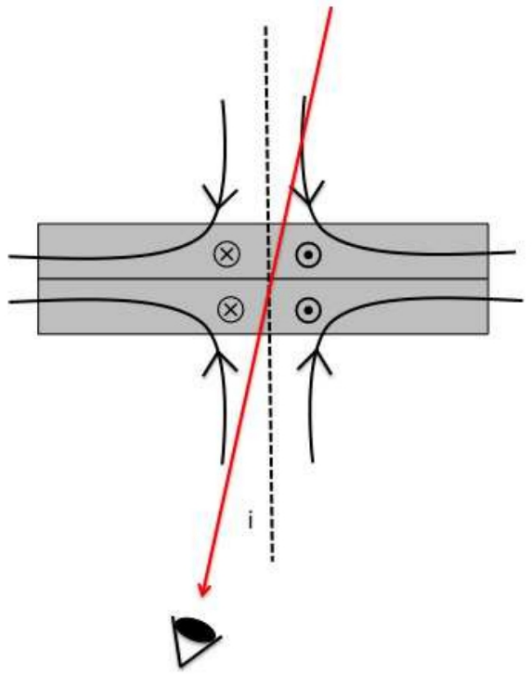
Magnetic field

Faraday rotation measure of polarized background sources
→ $B_{coher} > 1$ μG



Total magnetic field strength estimated as
4.3 μG
[Gaensler+, Science 2005]

Similar conclusion (+shape) from diffuse polarized data
[Mao+, ApJ 2012]

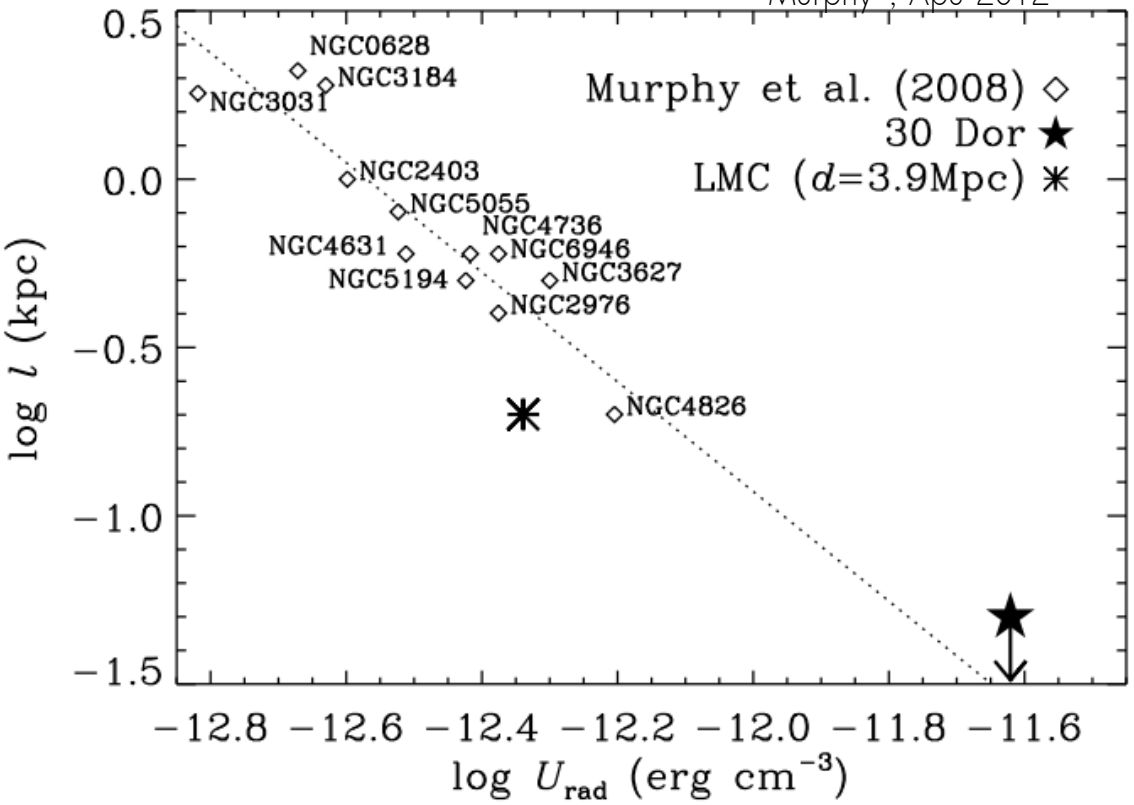


Spatial diffusion

Assuming diffusive propagation in a turbulent regime

$$D \simeq 3 \times 10^{27} \left(\frac{d_L}{\mathrm{kpc}}\right)^2 \left(\frac{10^{15}\,\mathrm{s}}{\tau}\right) \frac{\mathrm{cm}^2}{\mathrm{s}}$$

Murphy+, ApJ 2012



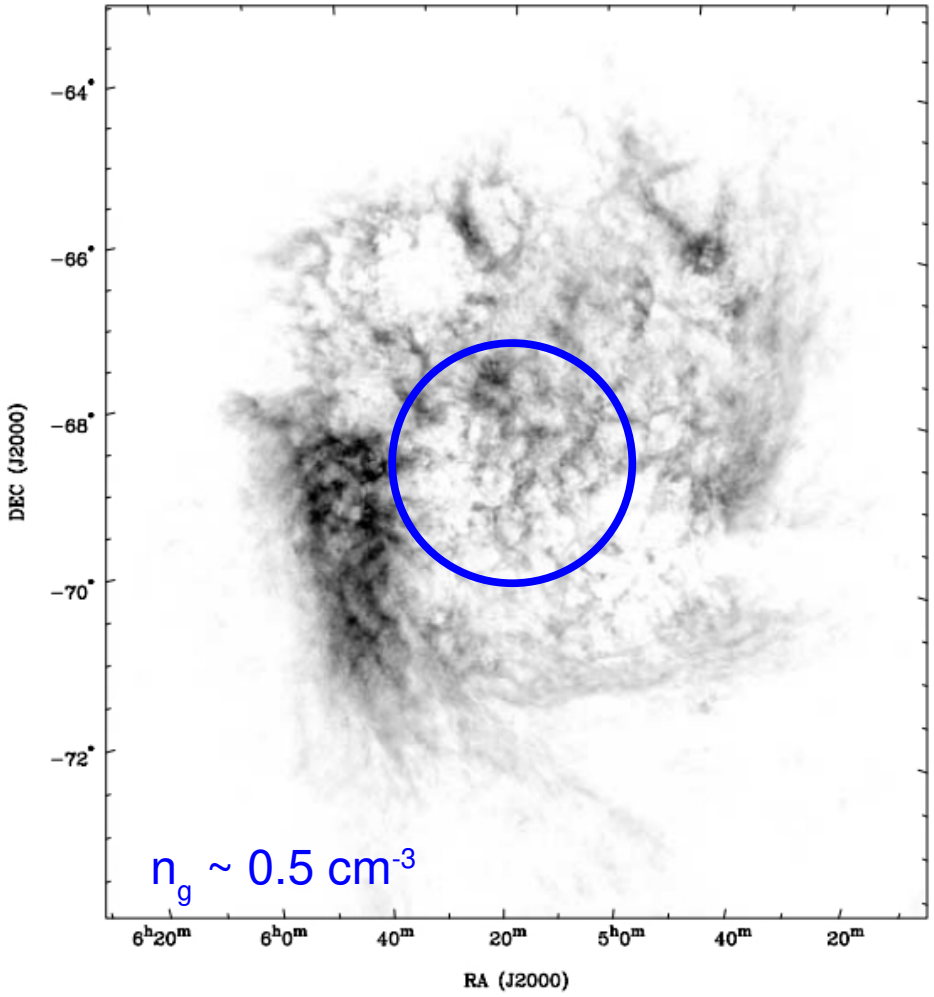
Supported by:

Large-scale diffuse emission
[Murphy+, ApJ 2012]

Data on supernovae remnants
[Bozzetto+, ApJS 2017]

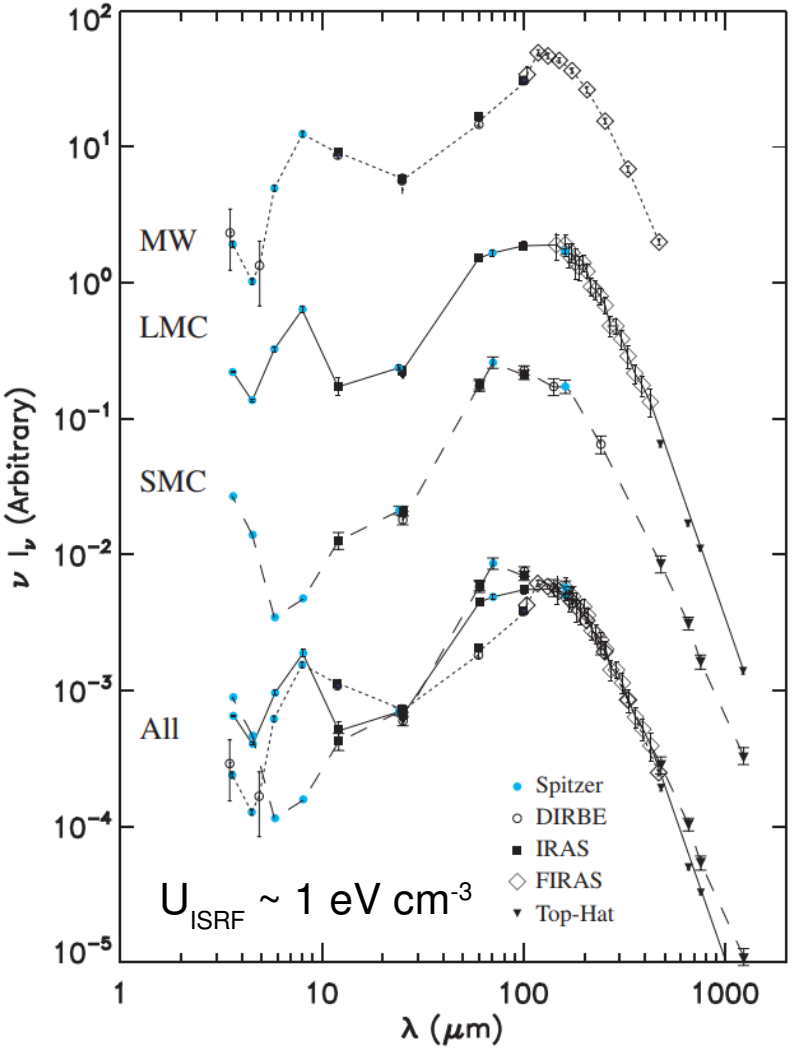
Gas and interstellar radiation fields

HI-gas column density
[Kim+, ApJS 2003]



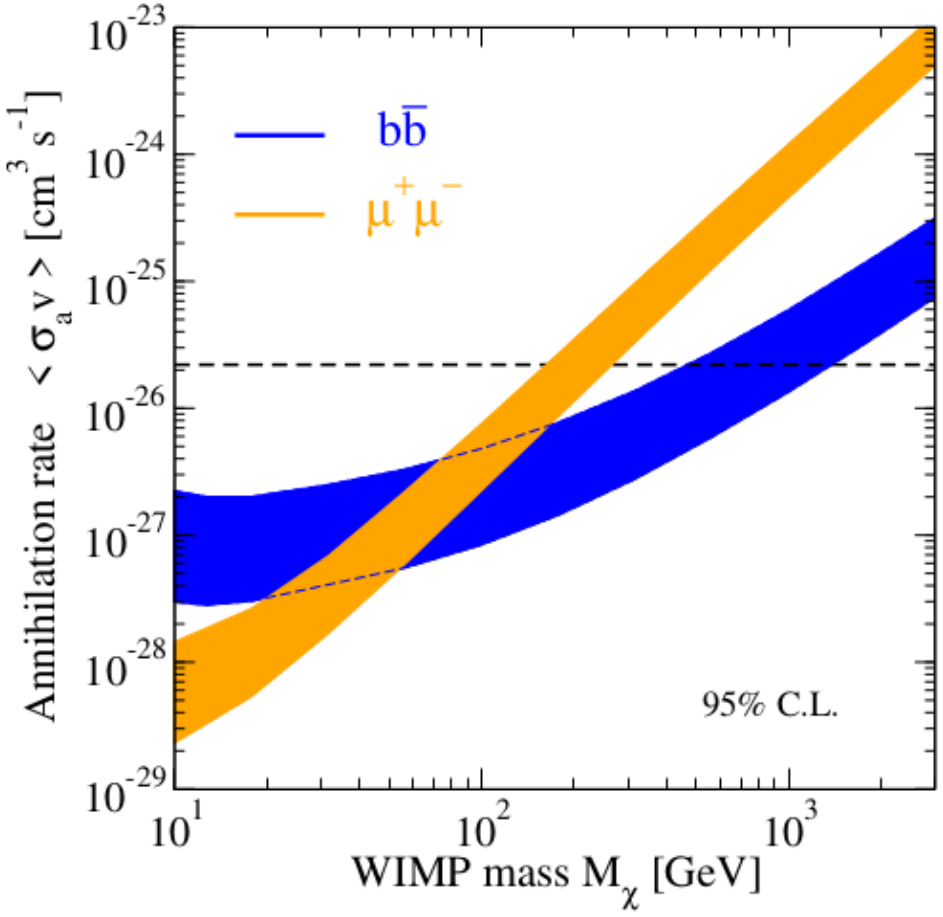
From mass estimates $n_g < 0.8$ cm^{-3}

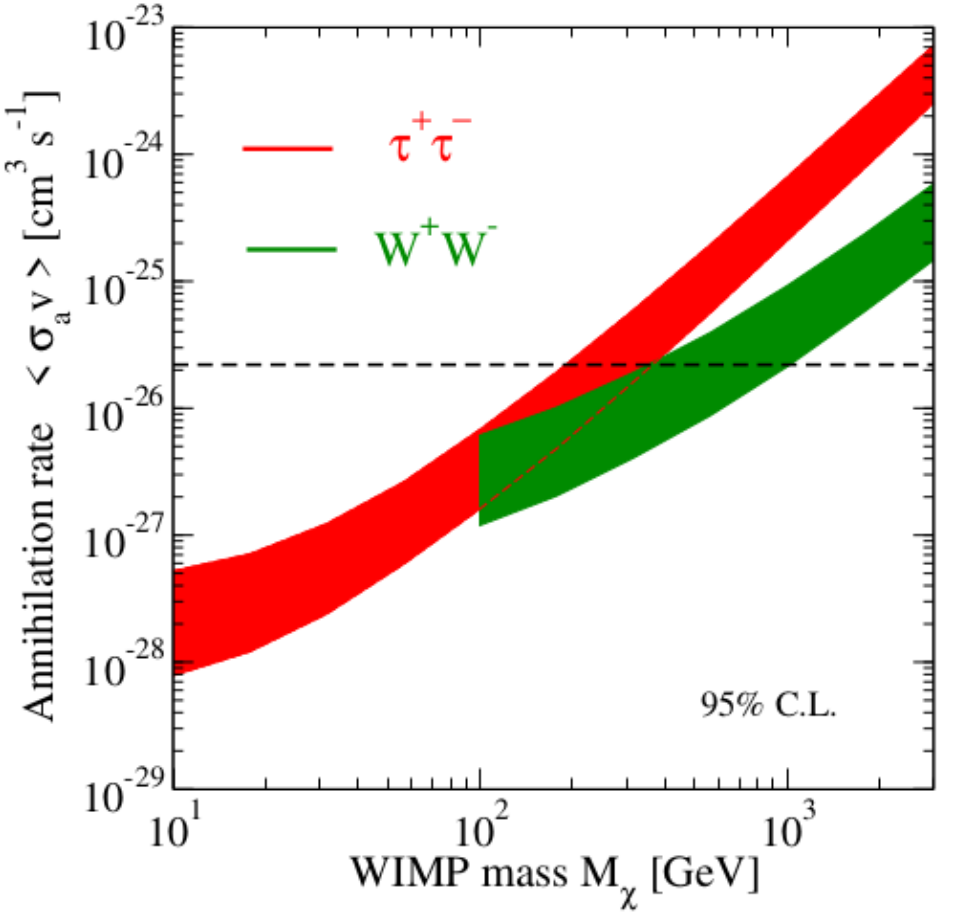
ISRF SED
[Bernard+, AJ 2008]



Bounds on annihilating DM

No preference for a diffuse emission from DM
→ **bounds**

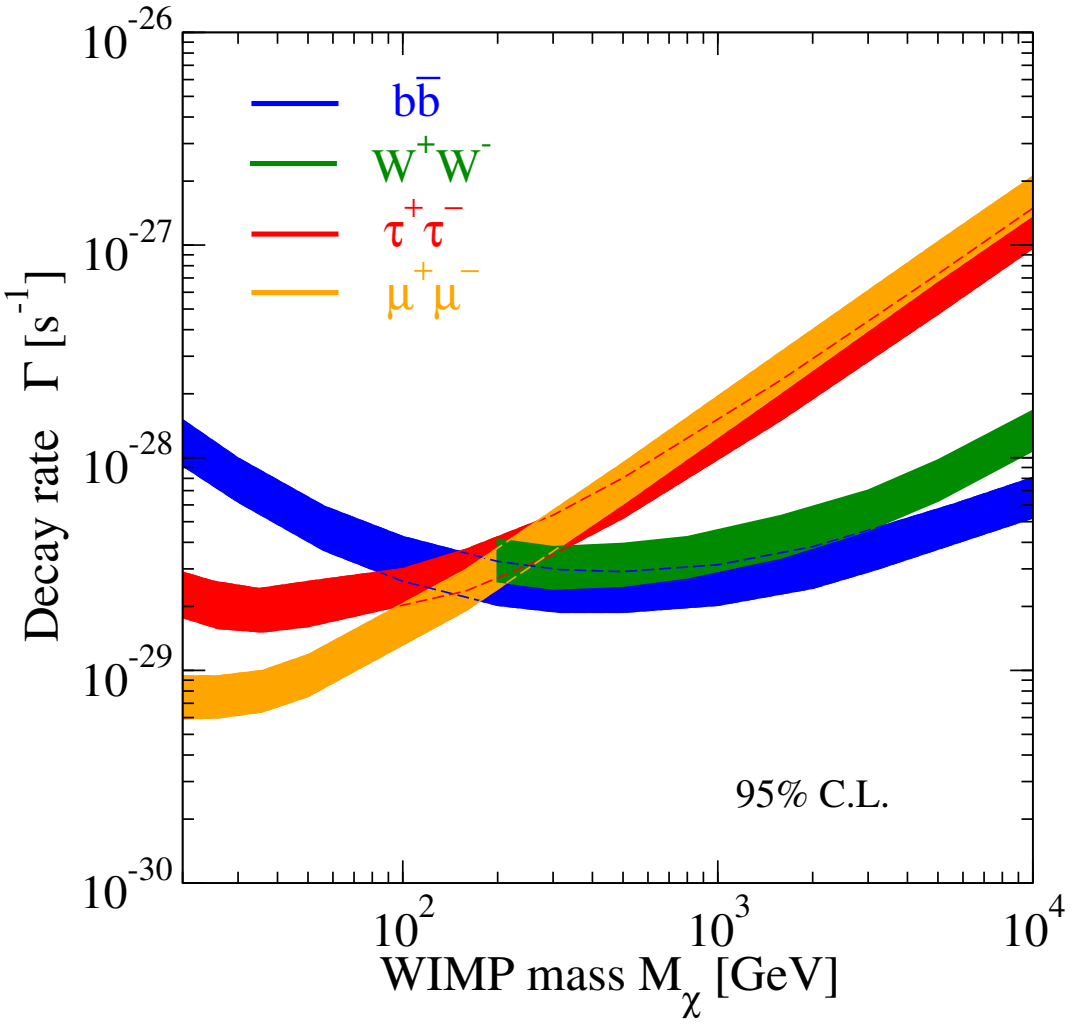




Bounds on decaying DM

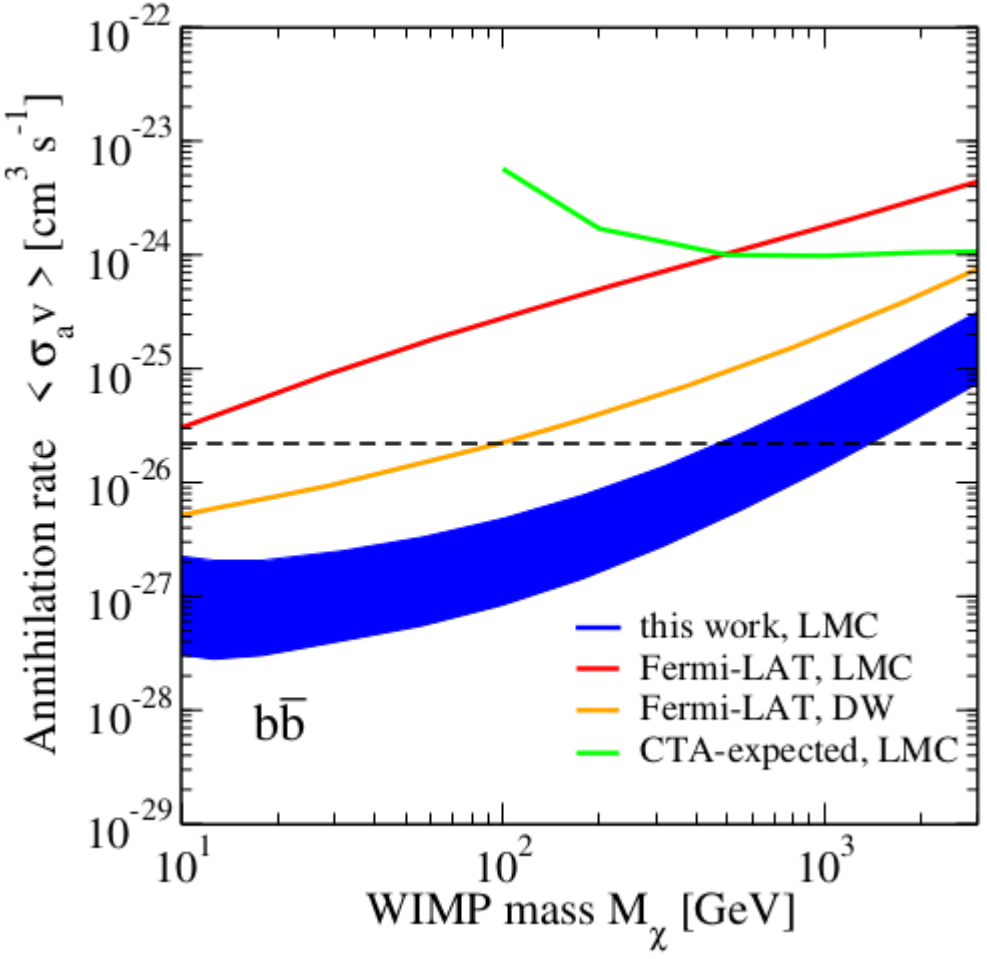
LMC is the most massive satellite of the Galaxy

→ very competitive bounds



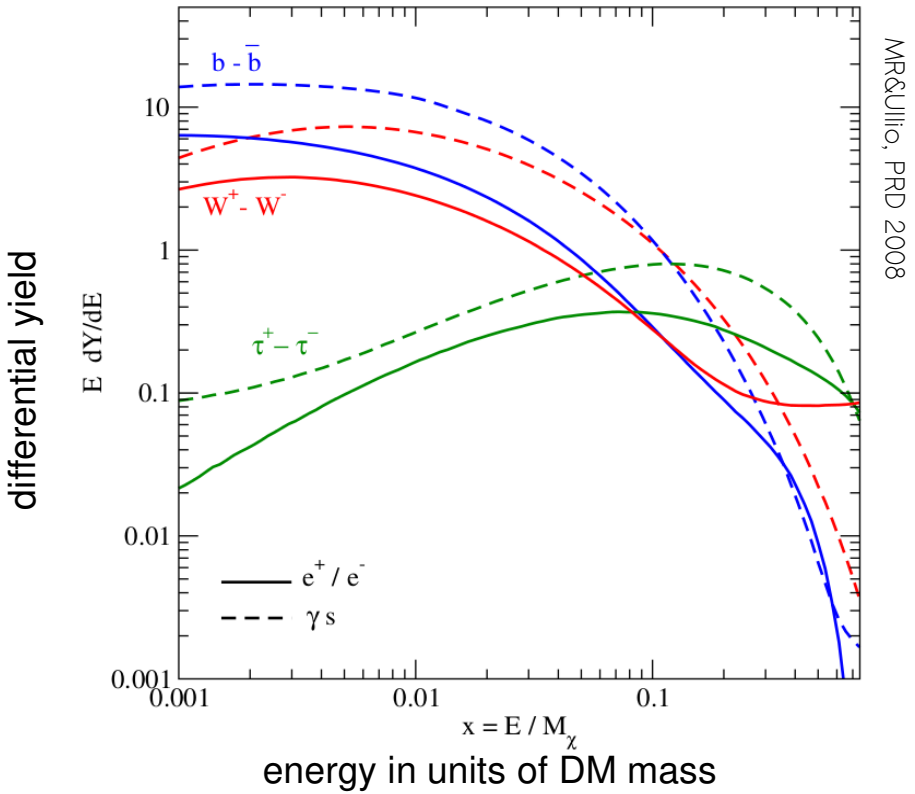
Comparison with gamma-rays

Comparison restricted to searches in
LMC and **dwarf spheroidal galaxies**



Comparison with gamma-rays

Spectrum of injection from WIMPs



If the ambient **magnetic field** is **significant**, WIMP models generically induce **comparable luminosity** in the gamma-ray and radio bands

Deeper characterization from radio observations than from gamma-rays

→ stronger bounds from radio data

Summarizing

LMC properties:

Large J-factor (and solid determination)
Magnetic field strength > μG

→ stringent bounds from radio observations

With ATCA/EMU observations

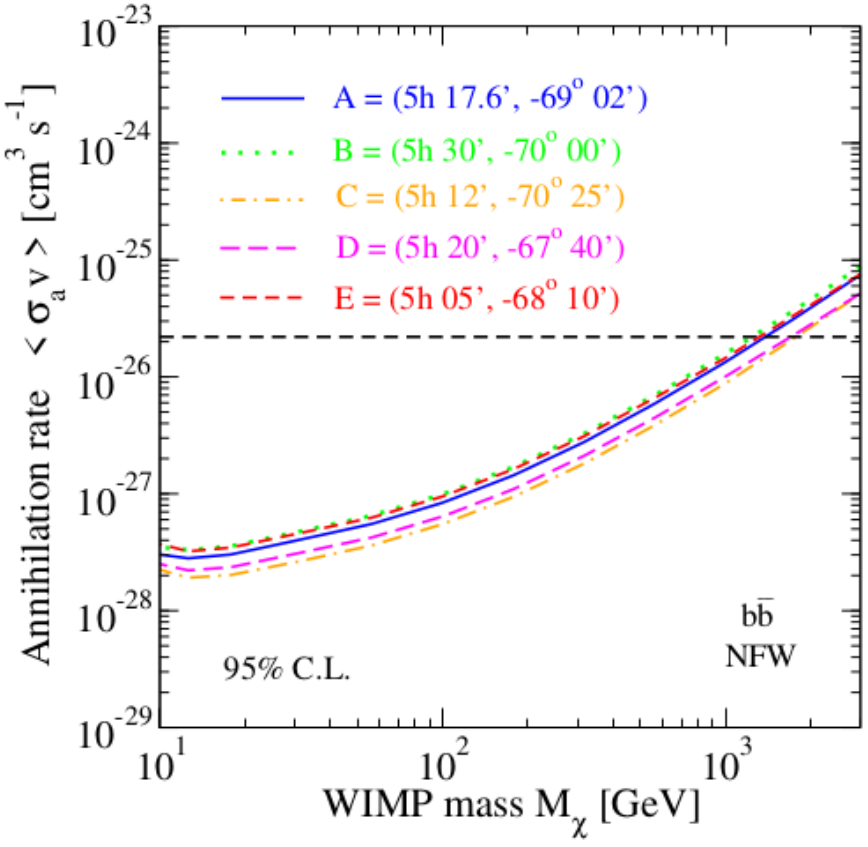
→ Thermal cross-section excluded for DM masses below

480 GeV ($b\bar{b}$)	358 GeV (W^+W^-)
192 GeV ($\tau^+\tau^-$)	164 GeV ($\mu^+\mu^-$)

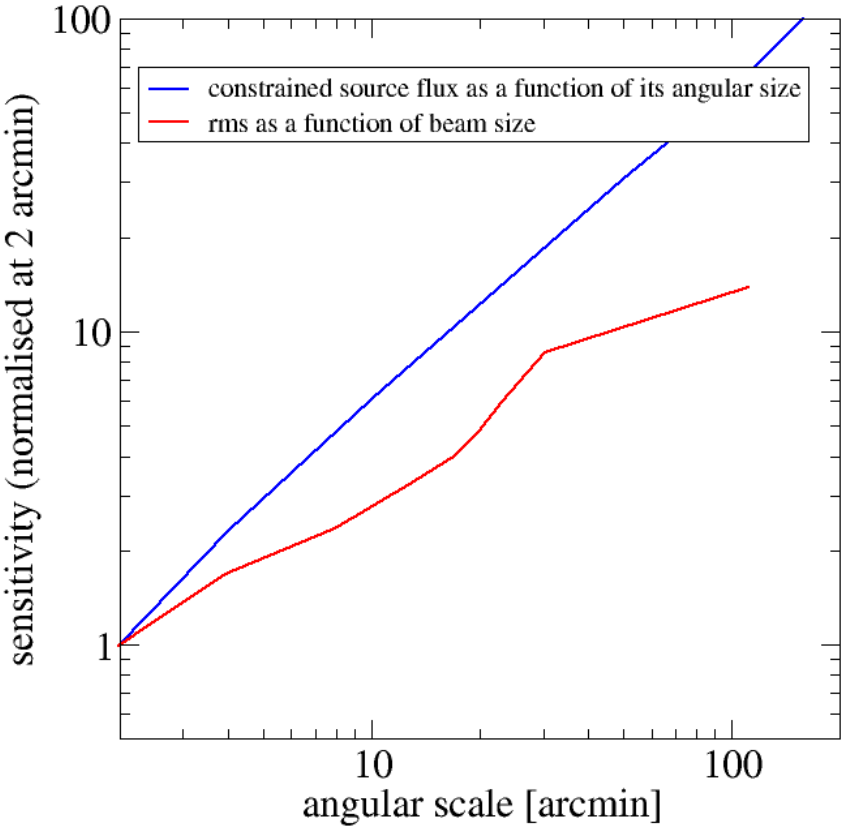
Next months/years: more observations and extended foreground modeling

Backup / Checks and sensitivity

Bounds obtained centering the DM distribution on different positions across the map

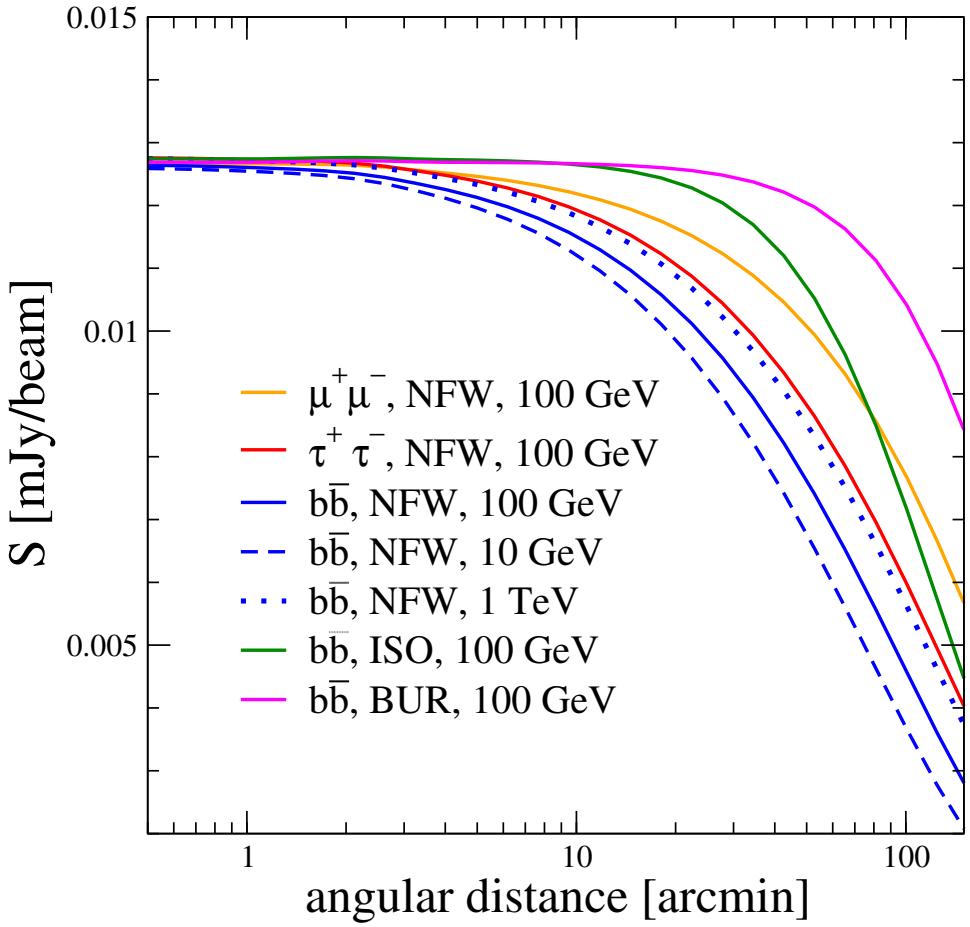


Assumed sensitivity versus simulations



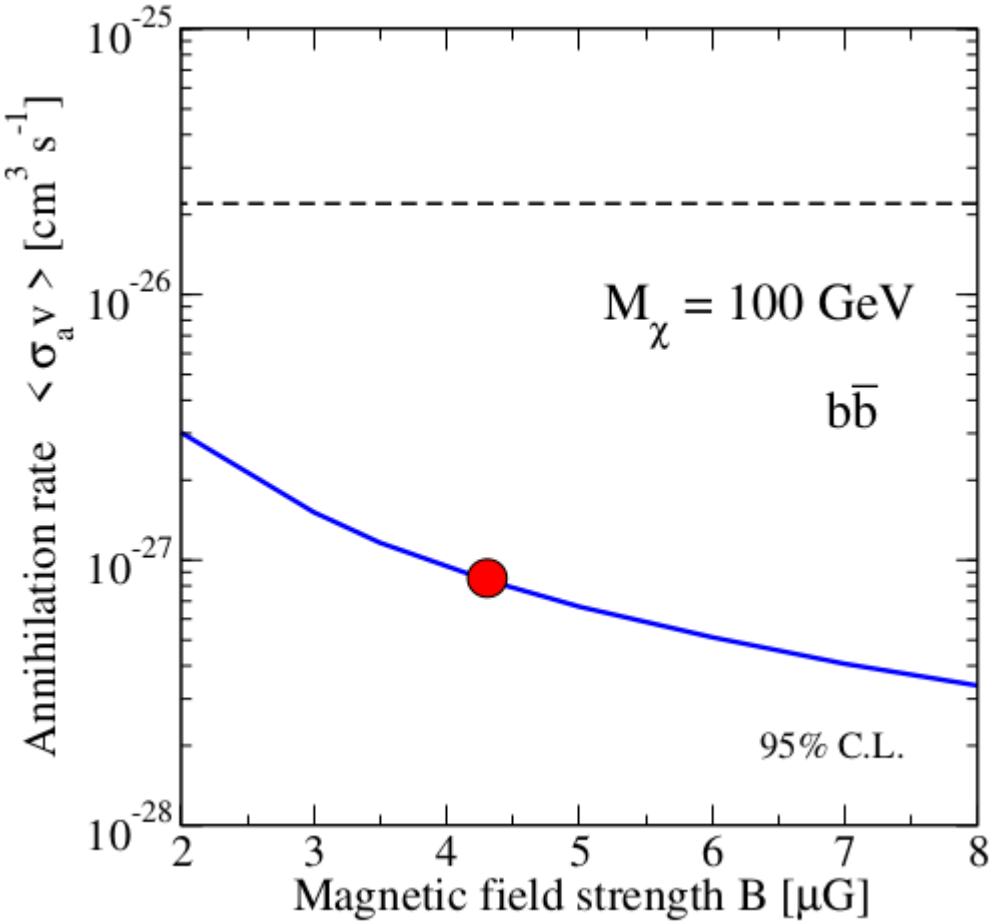
Backup / Shape of the signal

WIMP emission profile as a function of the angular distance from the LMC center, for different models.



Backup / Dependence on the B-strength

Impact of the **magnetic field strength** on the bound



Backup / Comparison with other radio-analyses

Comparison with bounds from **radio** searches in **dwarf spheroidal galaxies** and in the **LMC**