Radio Signals of Particle Dark Matter.

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Motivation

Is it possible to infer something “unknown”
(**non-gravitational signals of DM**)
by means of something “well-known”
(**radio-astronomy**)?

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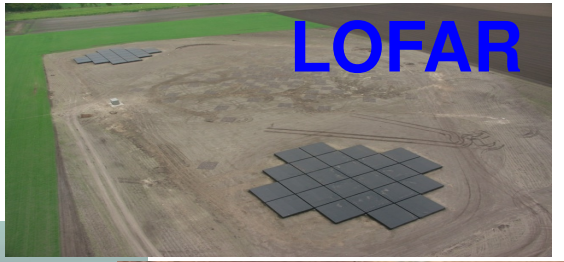
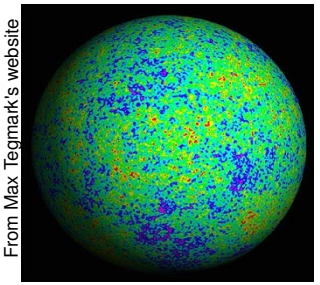
Maybe..

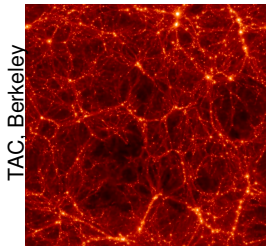
Artist's impression
Credit: SPDO/TDP/DRAO/Swinburne Astronomy Productions.



Gravitational evidences and DM properties

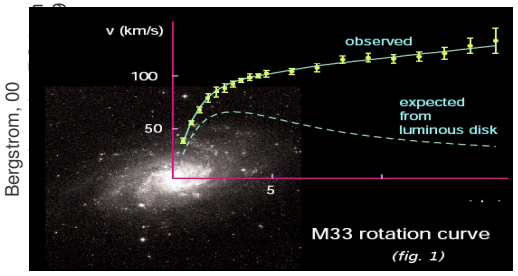


Cosmology { $\Omega_M \sim 6\,\Omega_b$ (DM relic density)
Stable
Thermally produced



Structure formation → Cold (bottom-up hierarchy)

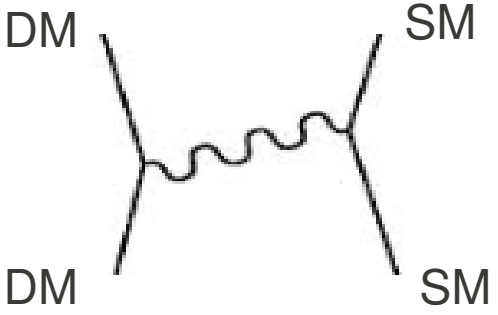
Cluster dynamics → Weak self-interactions



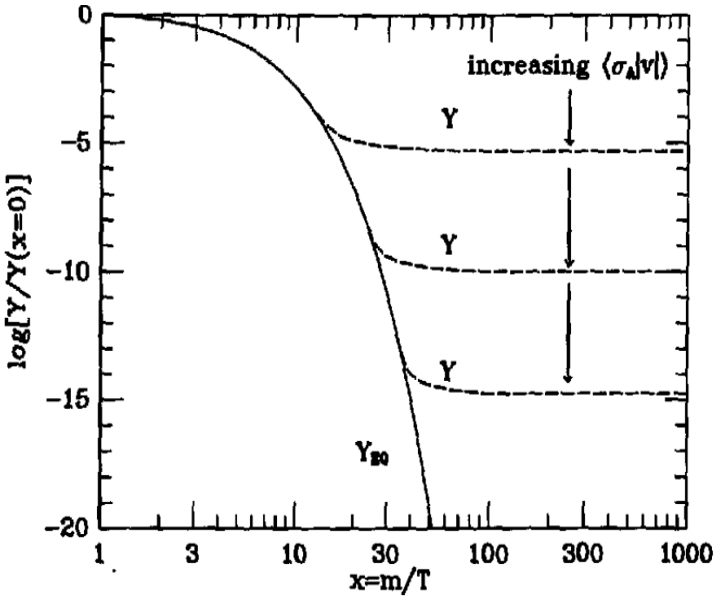
Galactic dynamics → Dissipationless

WIMP miracle

Assume DM in **thermal equilibrium** in the early Universe and **cold** at structure formation epoch



Relic density:



DM mass ~ GeV – tens of TeV

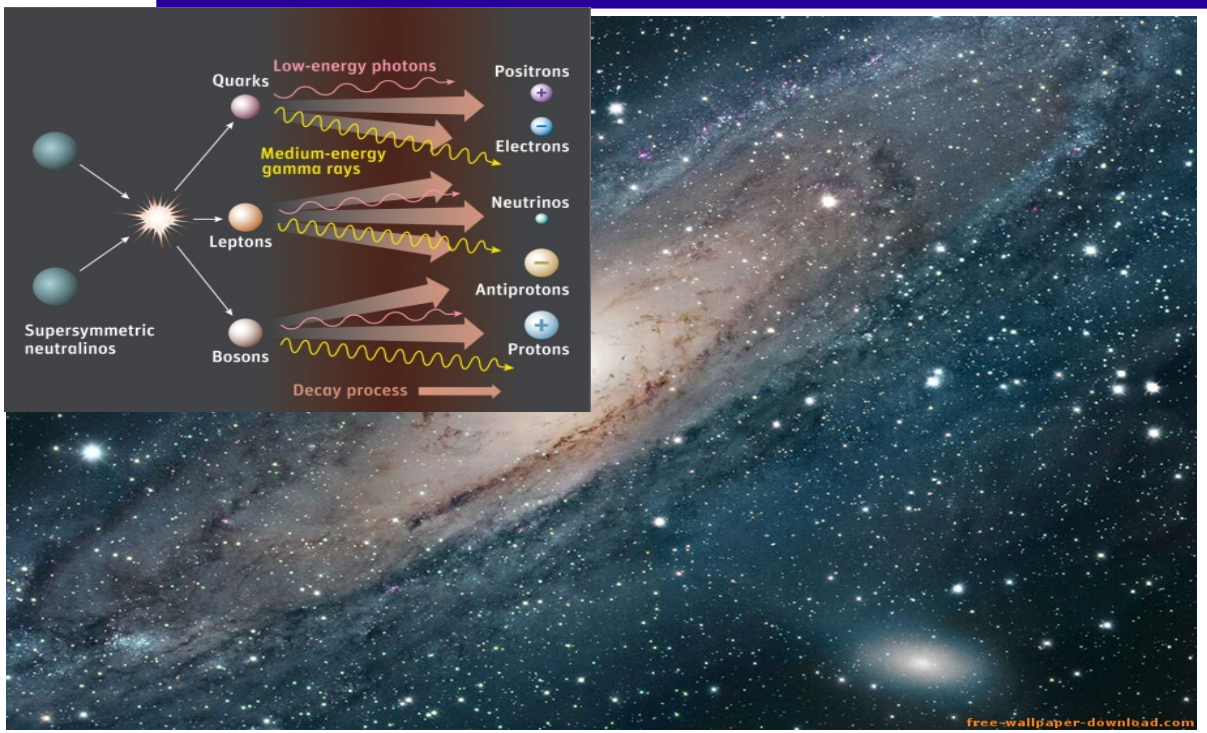
$$\Omega_\chi h^2 \approx \frac{3 \times 10^{-27} \mathrm{cm}^3 \mathrm{s}^{-1}}{\langle \sigma v \rangle}$$

The observed relic density **requires weak interactions**!

Physics beyond the standard model addresses EW symmetry breaking
→ **new particles are expected at ~ EW scale**

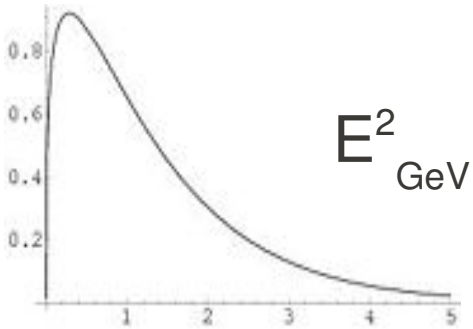
Examples: LSP in Supersymmetry, LKP in flat or warped extra-dimension models, LTP in Little-Higgs, ...

Radio emission from particle DM

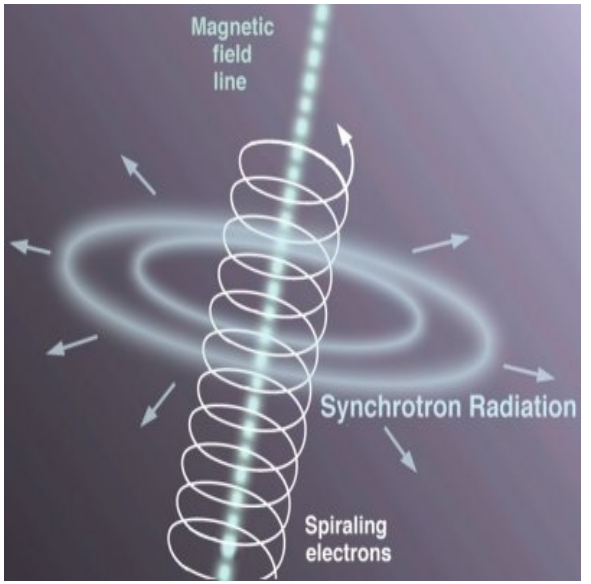


Annihilations (or decays) of DM particles inject relativistic electrons and positrons.

Emitted in a medium with **magnetic field**, they give raise to a radio continuum diffuse emission associated to **synchrotron radiation**.



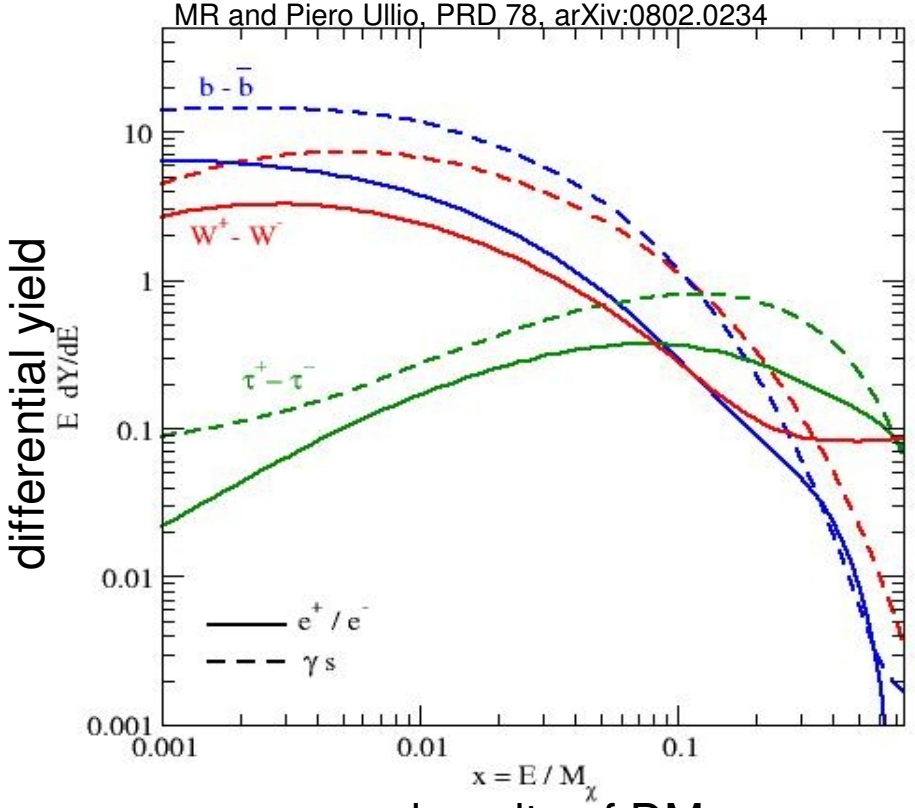
$$E^2_{GeV} \sim 200\ \nu_{GHz} / B_{\mu G}$$



Credit: Sky & Telescope / Gregg Dinderman

Electron/Positron yields

MR and Piero Ullio, PRD 78, arXiv:0802.0234



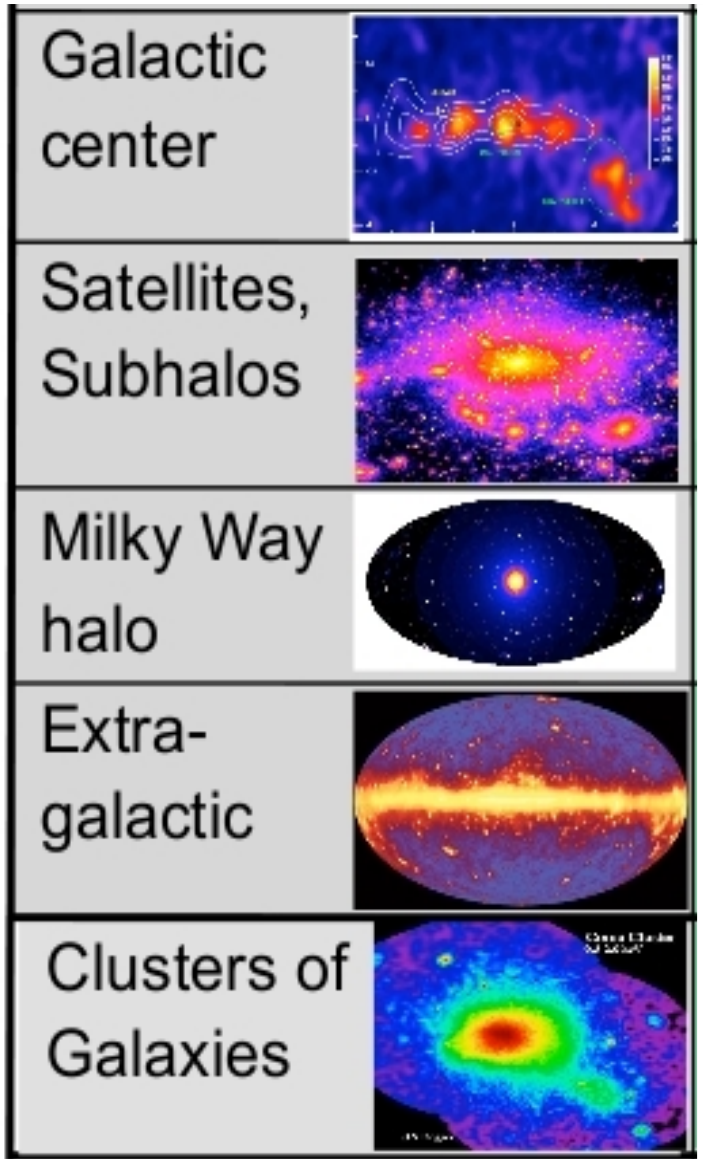
energy in units of DM mass

Whatever is the WIMP model, (namely the dominant annihilation channel, except for DM annihilating in neutrinos only), **DM injects sizable electron/positron yields**.

Comparable yields for γ-rays and electrons/positrons (MULTI-WAVELENGTH STRATEGY)

WHERE?

POSSIBLE TARGETS

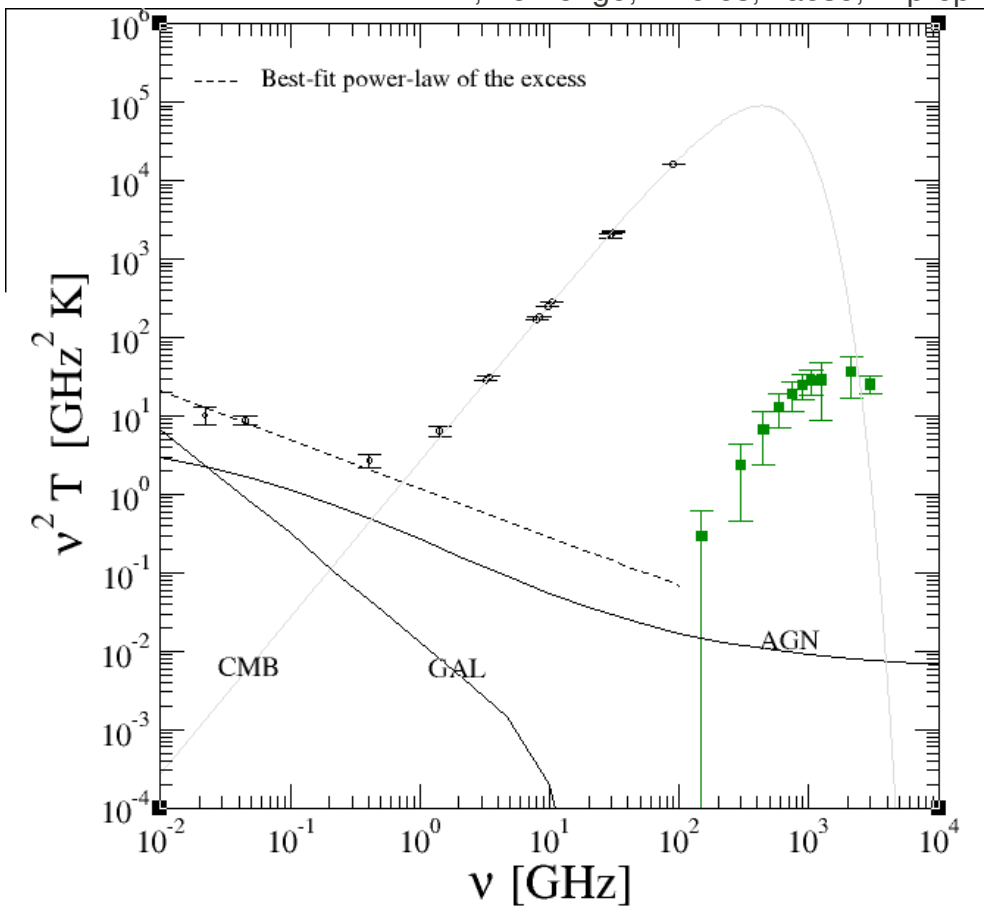


Images from Baltz et al., 2008 (S.Murgia talk)

Extragalactic / Isotropic

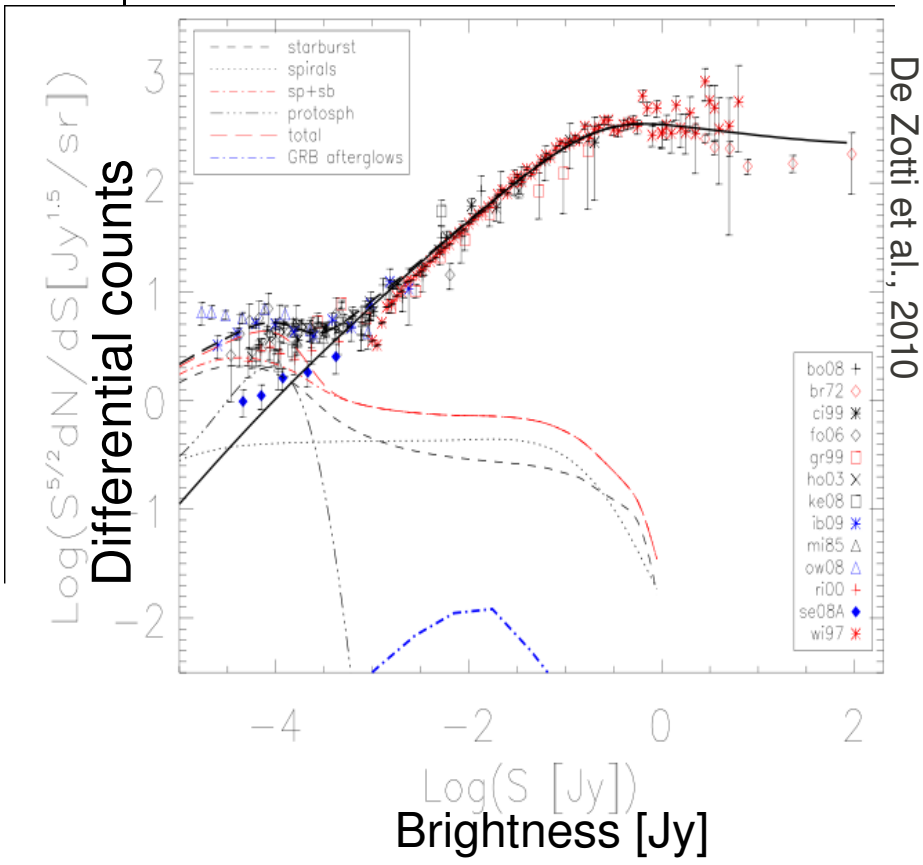
Recent measurements by the **ARCADE** collaboration (Fixsen at al., 2009)

MR, Fornengo, Lineros, Taoso, in prep.



Total intensity can be estimated through differential number counts:

$$I(\nu) = \int^{S_{\max}} \frac{dN}{dS}(\nu) \cdot S \; dS,$$



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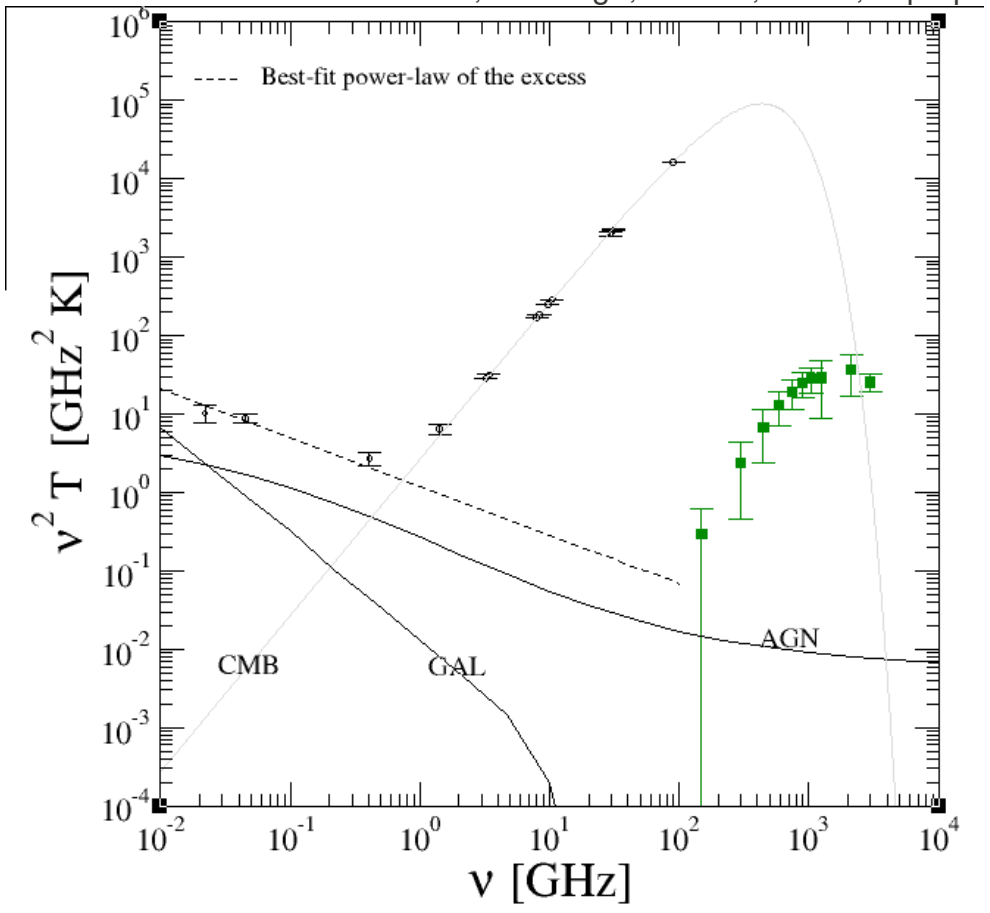

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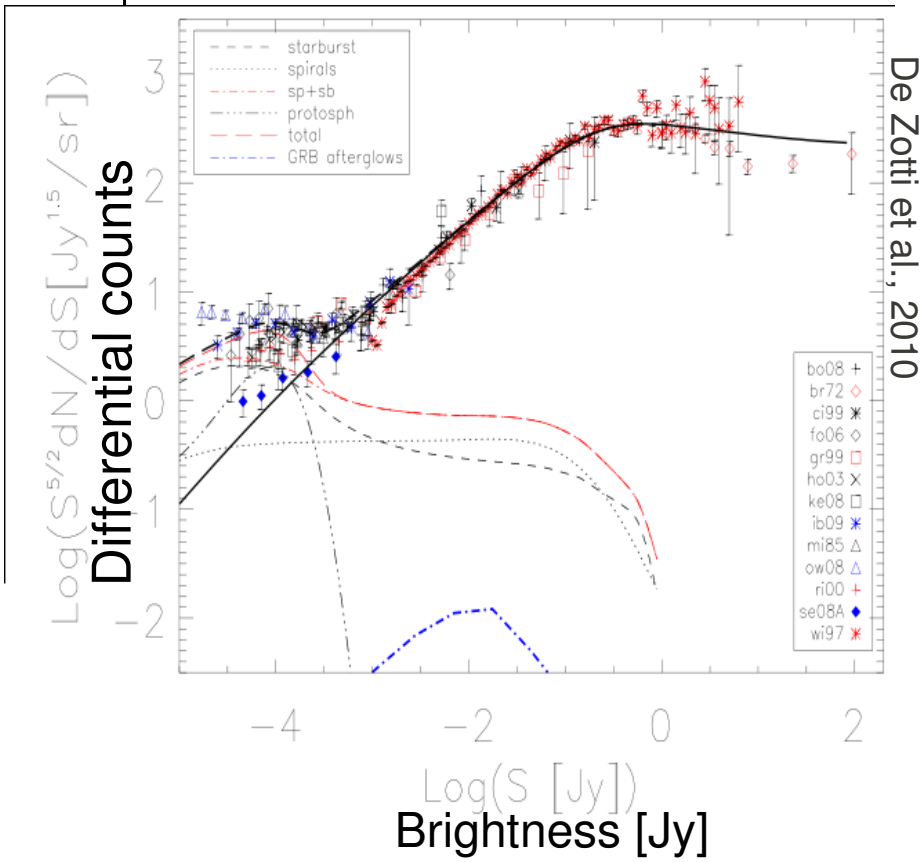

Extragalactic radio background extrapolated from number counts is a factor of 6 below the measured one.

Extragalactic / Isotropic

Simplest solution for ARCADE excess:

Radio background is produced by radio sources taking over at sub-μJy

(Singal et al, 2010)

DRAWBACK for "normal" astrophysical sources explanation:

- *ad hoc* evolutionary model (Singal et al, 2010, Ponente et al., 2011)
- constraints from gamma-rays (Lacki, 2010)

Extragalactic / Isotropic

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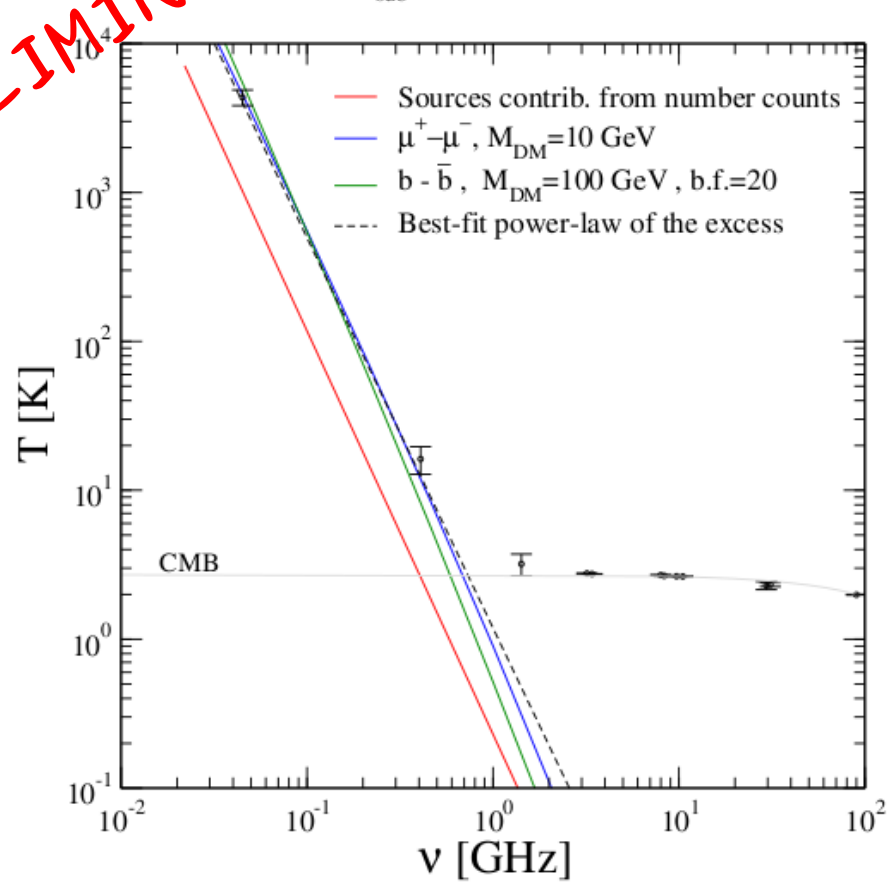
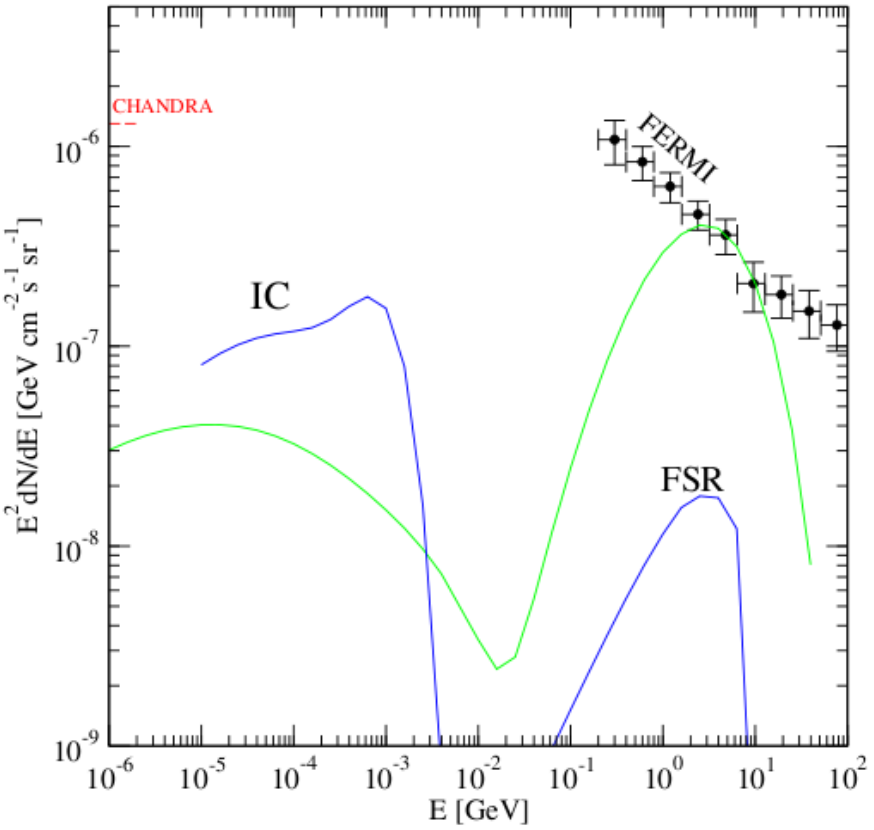


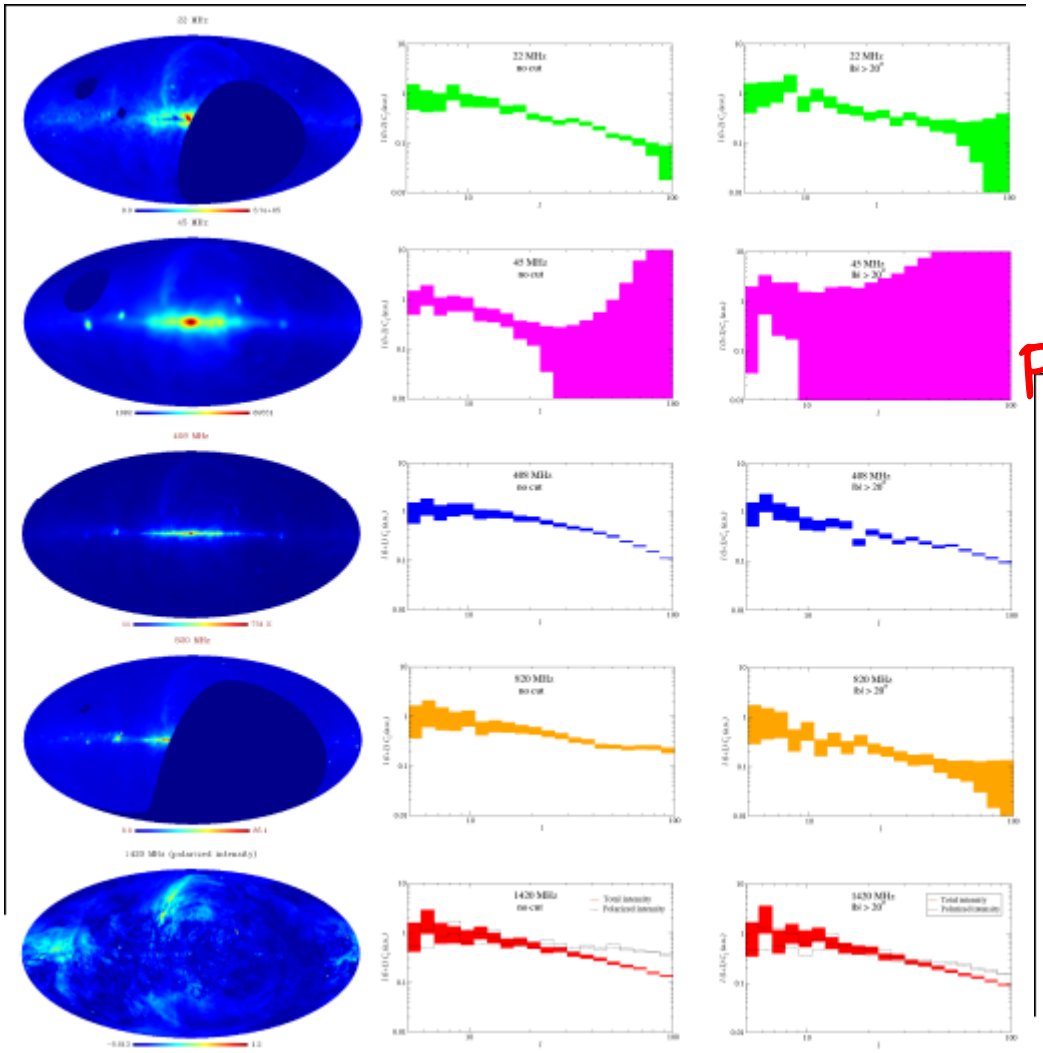


The DM source can fit the excess!

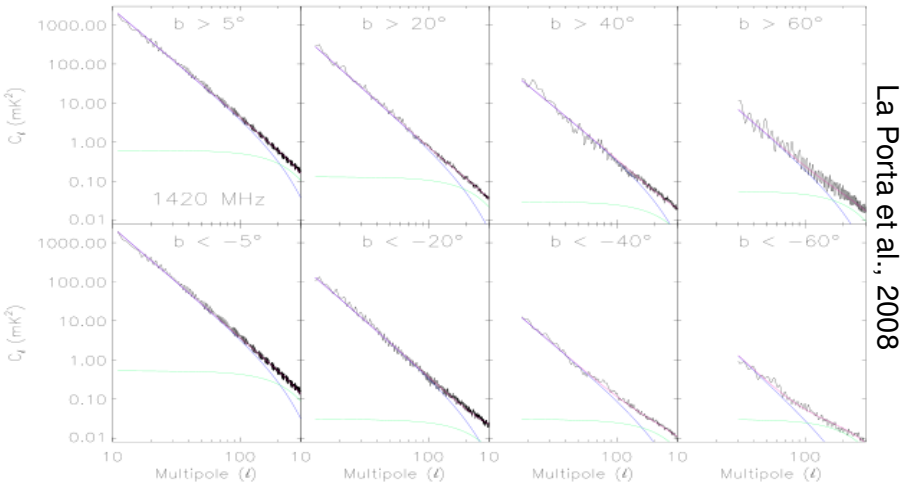
(MR, Fornengo, Lineros, Taoso, in prep.)

Extragalactic / Angular

Low multipoles dominated by Galactic foreground.



MR, Astropat. Phys. J. 2011 (arXiv:1101.5524)



La Porta et al., 2008

PRELIMINARY

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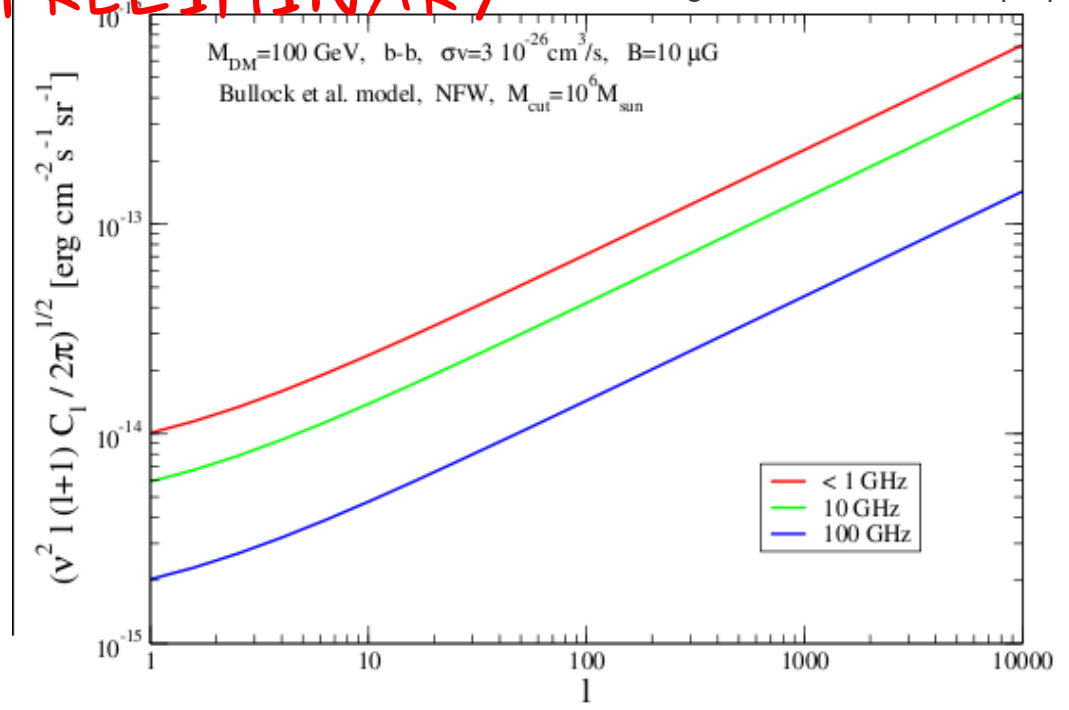

Extragalactic / Number counts

PRELIMINARY

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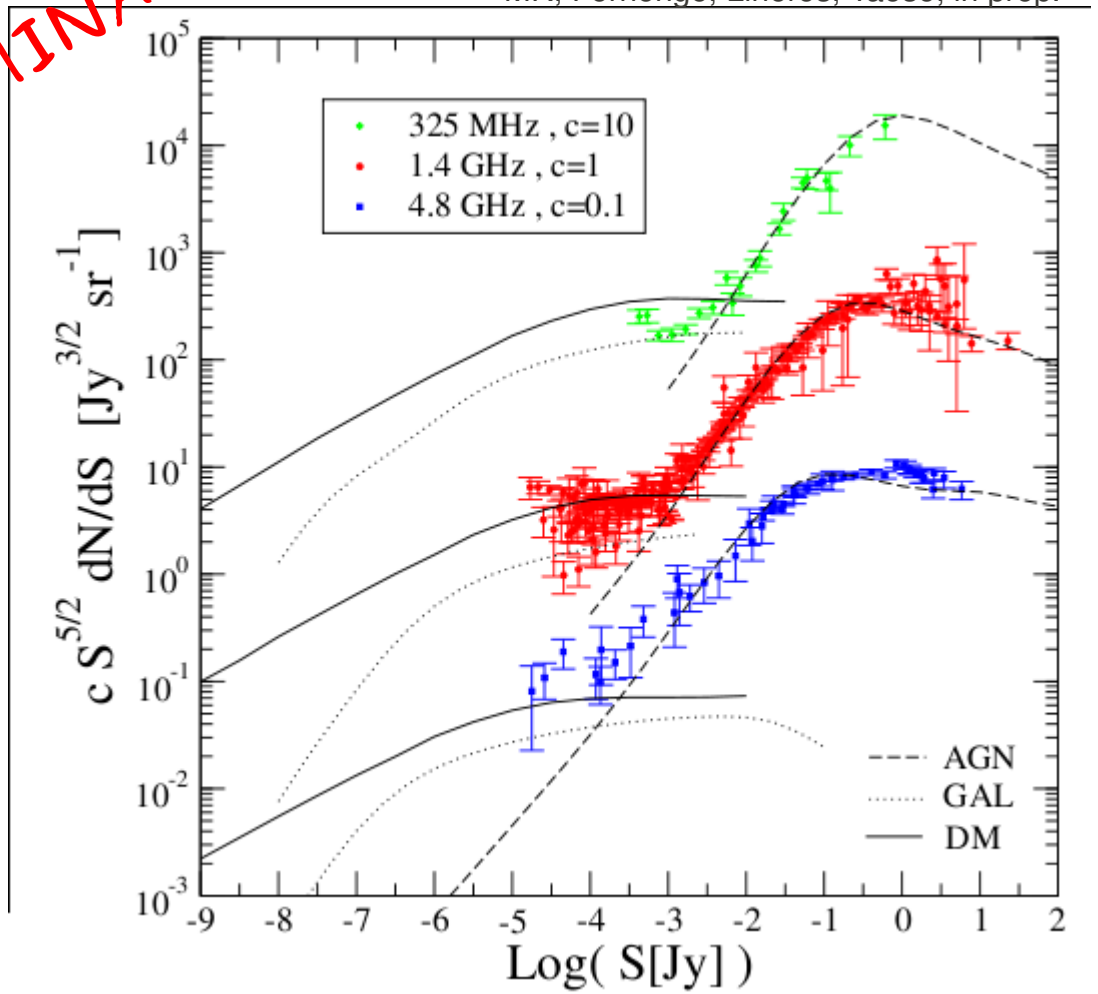


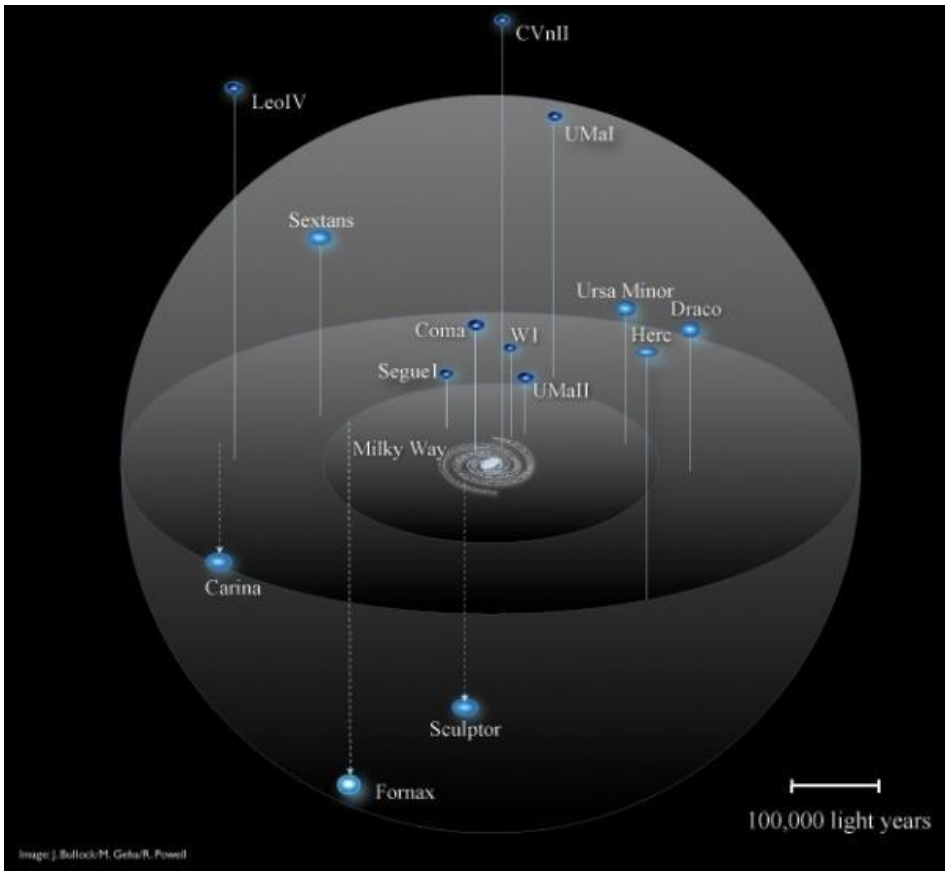
Number of DM sources at brightness < mJy is non-negligible.

Dwarf Spheroidal Galaxies

- **Closest DM dominated objects** other than the Galaxy (Flux~d^{-2}).

- Baryons highly subdominant: **low background** and more reliable **DM distribution** from simulations

- Recent discovery by **SDSS** of new ultra-faint satellites in the Local Group.

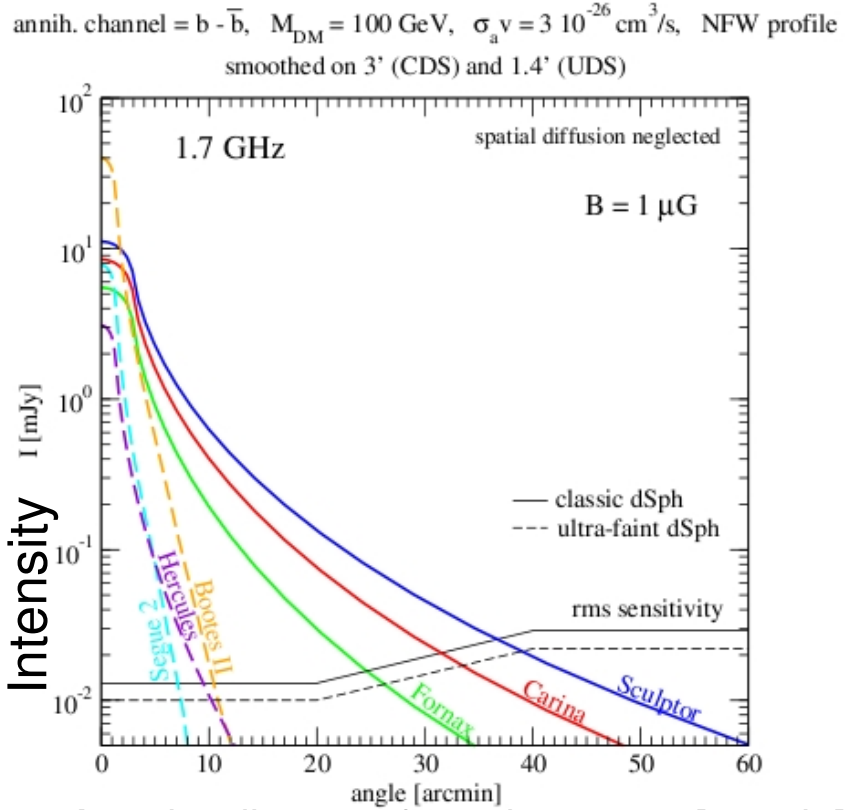


Dwarf Spheroidal Galaxies

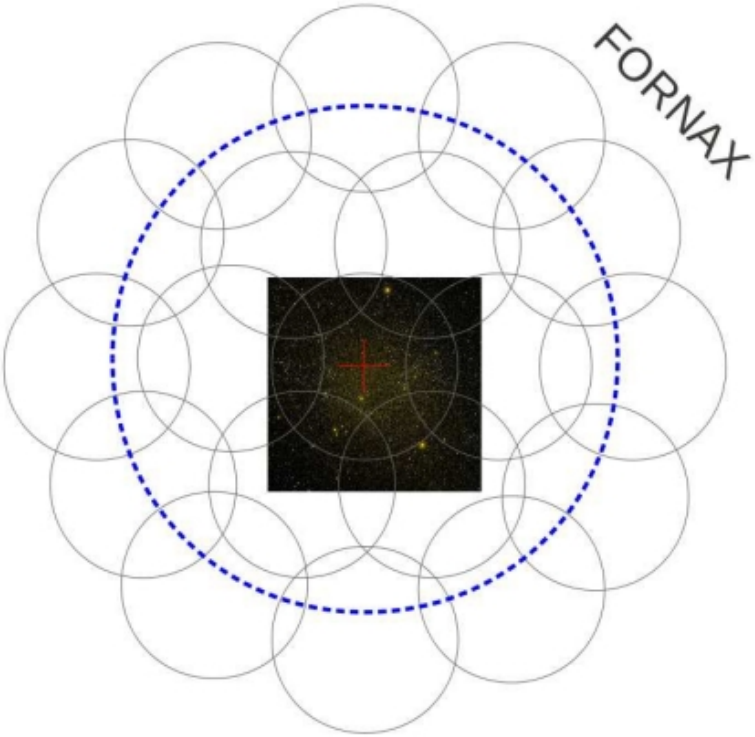
"Continuum and HI emissions from Local Group Dwarf Spheroidal Galaxies"

(MR, Colafrancesco, de Blok, Massardi, Profumo, Richter, Ullio)

Continuum rms sensitivity:10 μJy/beam (130 observing hours in July/August with ATCA)



Angular distance from the center [arcmin]



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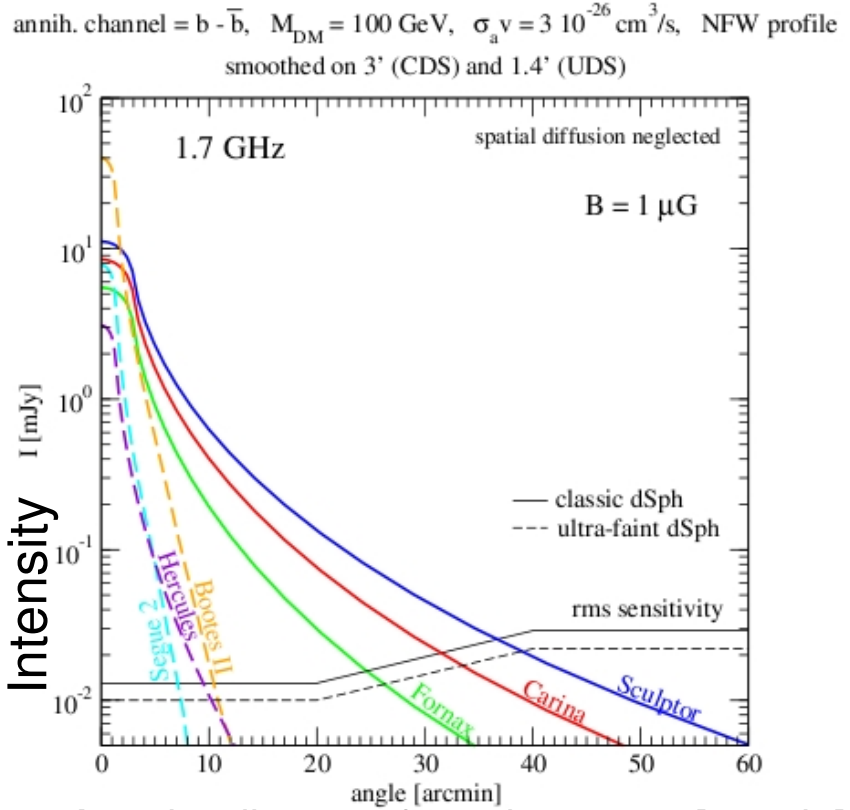

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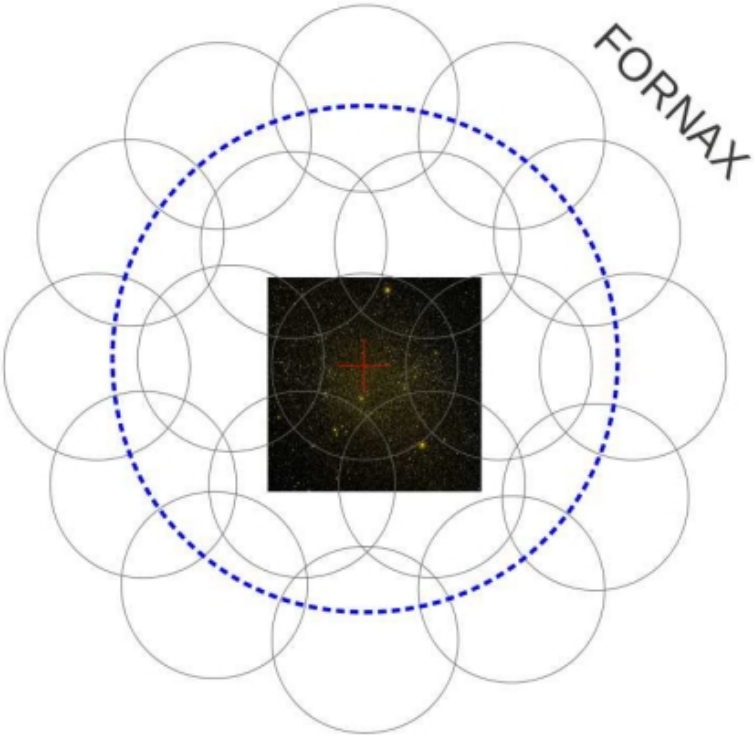

STAY TUNED!

Radio versus gamma

GOOD

Better angular resolution

Typically better sensitivity (signal to rms noise)

No contamination from Galactic foreground (for extra-galactic objects)

BAD

It's an indirect^2 method (additional unknowns)

Conclusions

Isolating a **DM signal** from astrophysical background through a **spectral analysis** only is rather **difficult**.
Mapping the spatial profile is essential and for this purpose **radio astronomy** is a superior tool among DM indirect searches.

Probably, radio signals **won't be the last word** on the DM nature, but they could be **one of the first evidences of non-gravitational DM interactions**.