Enrico Borriello
Università degli Studi di Napoli "Federico II"

Dark Matter Constraints
from galactic radio observations

In collaboration with:

- G. Miele – University of Naples "Federico II" & INFN section of Naples
- A. Cuoco – The Oskar Klein Centre for Cosmo Particle Physics, AlbaNova, Stockholm, Sweden
- G. Longo, M. Paolillo & B.B. Siffert – University of Naples "Federico II"
- R. Beck & F. Tabatabaei – Max-Planck Institut fur Radioastronomie, Bonn, Germany

Summary

- **Part I:** Constraints from our Galaxy (GC excluded)

  Based on: E. Borriello, A. Cuoco & G. Miele, Phys. Rev. D 79 (2009) 023518
  E. Borriello, A. Cuoco & G. Miele, ApJ 699 (2009) L59

- **Part II:** Constraints from external galaxies (M33 & LMC)

  Based on: E. Borriello. et al., ApJ 709 (2010) L32
  B. B. Siffert et al., in preparation

Part I

Constraints from our Galaxy (GC excluded)

- We perform an **all-sky analysis**, covering the 15°x15° region surrounding the GC.
- We calculate the continuum radio emission due to DM annihilation as the sum of the **halo + clumps** components.

DM annihilation

$$\chi+\chi \longrightarrow q+\bar{q} \longrightarrow \pi^- + \dots$$

$$\pi^- \longrightarrow \nu_\mu + \mu^-$$

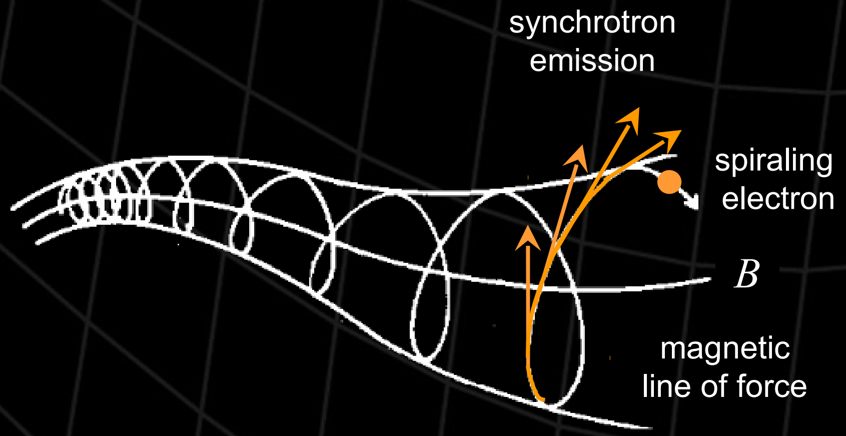
$$\mu^- \longrightarrow \nu_e + \nu_\mu + e^-$$

$$\chi+\chi \longrightarrow \mu^+ + \mu^-$$

$$\mu^- \longrightarrow \nu_\mu + \bar{\nu}_e + e^-$$

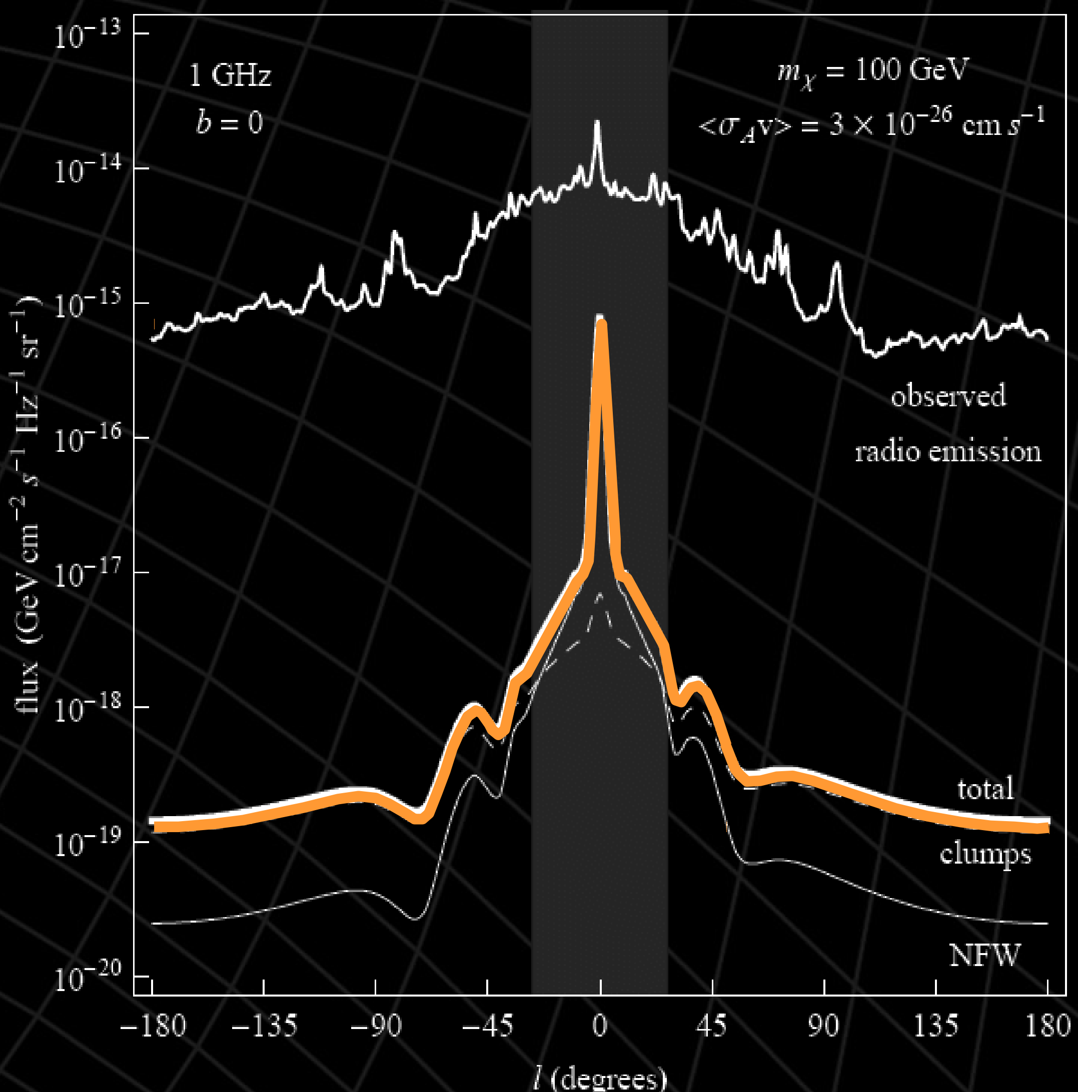
$$\mu^+ \longrightarrow \bar{\nu}_\mu + \nu_e + e^+$$

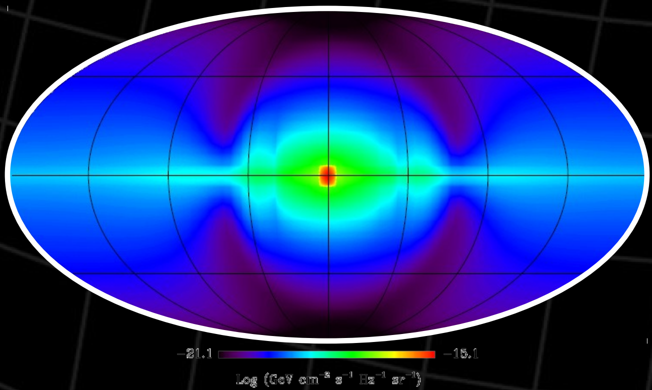
We are interested here in electrons and positrons that, spiraling through the galactic magnetic field, emit synchrotron radiation that contributes to the galactic radio emission.



Dark Matter Synchrotron Signal

E.Borriello, A.Cuoco & G.Miele, Phys.Dev.D 79 (2009) 023518





The signal from **single bright clumps** offers only poor sensitivities because of diffusion effects which spread the electrons over large areas diluting the radio signal.

The **diffuse signal** from the halo and the unresolved clumps is instead relevant and can be compared to the radio astrophysical background to derive constraints on the DM mass and annihilation cross section.

Radio Foreground

Constraints on the DM emission are obtained comparing the expected diffuse emission from the "smooth halo" and the unresolved population of "clumps" with **all sky observation** in the radio band. In the frequency range between 100 MHz–100 GHz where the DM synchrotron signal is expected.

Contributions:

- **CMB** that, thanks to the very sensitive multi-frequency survey by the WMAP (22.8, 33.0, 40.7, 60.8 and 93.5 GHz), can be modeled and removed from the observed radio galactic emission. Gold et al., arXiV:1001.4555

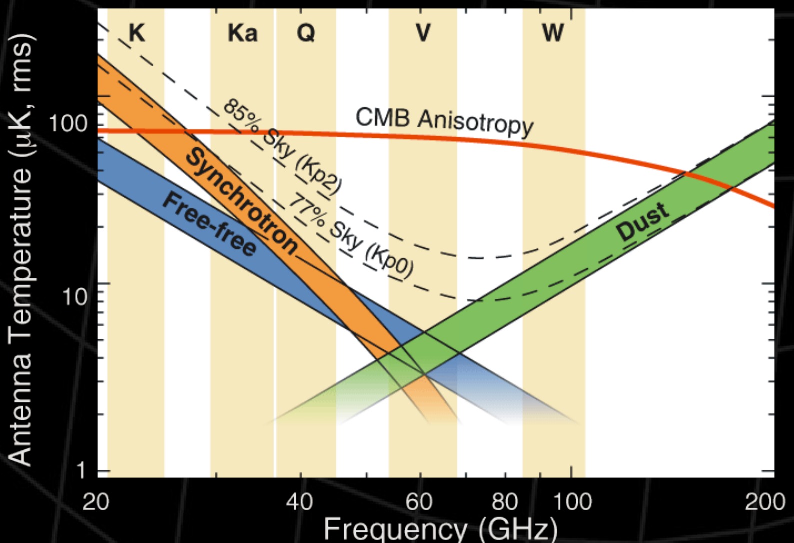
- **Synchrotron** emission from relativistic electrons spiraling through the GMF.

  Template: C.G.T. Haslam et al., A&A **100** (1981) 209.

- **Free-free** emission: Thermal bremsstrahlung of non relativistic electrons on the galactic ionized gas. Template: D.P. Finkbeiner, ApJS **146** (2003) 407.

- Emission from vibrational modes of thermal **dust** grains.

  Template: D.P. Finkbeineret al., ApJ **524** (1999) 867.

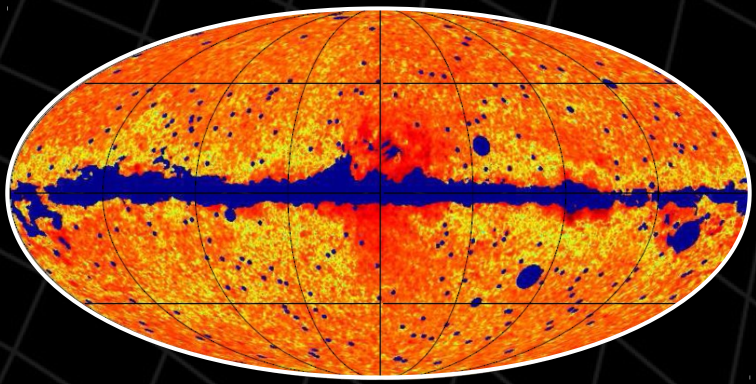


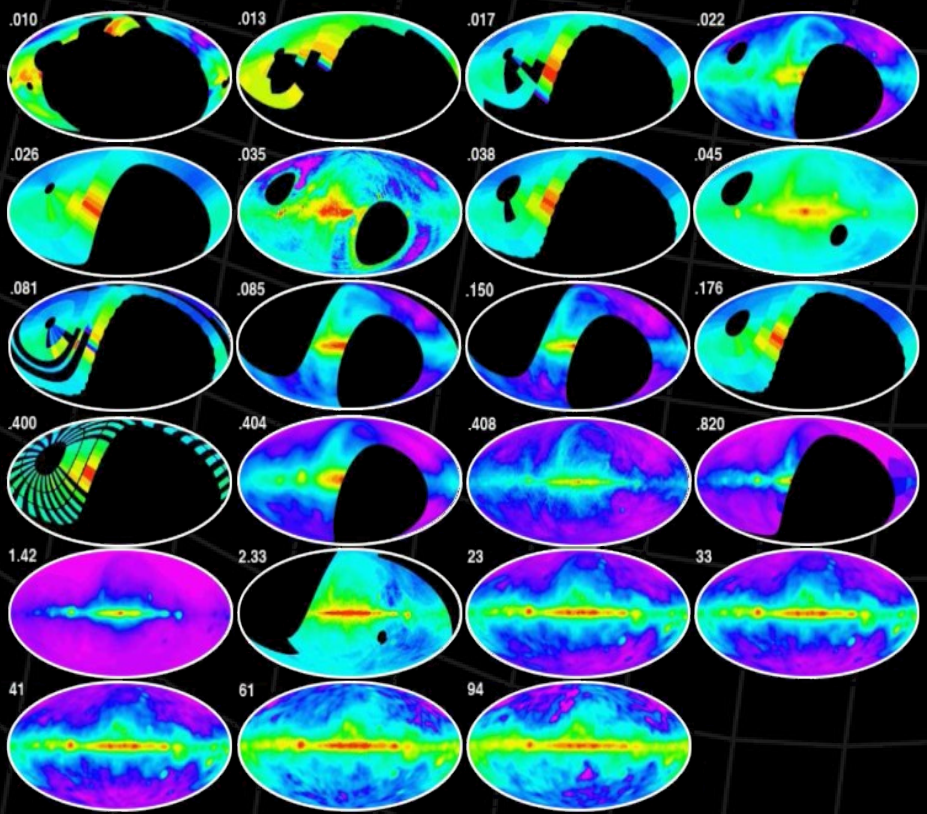
Radio Foreground

Model dependent approach:

One can try to remove the foreground (WMAP Haze)

D.P. Finkbainer, arXiv:astro-ph/0409027
D. Hooper et al., Phys. Rev. D **76** (2007) 083012





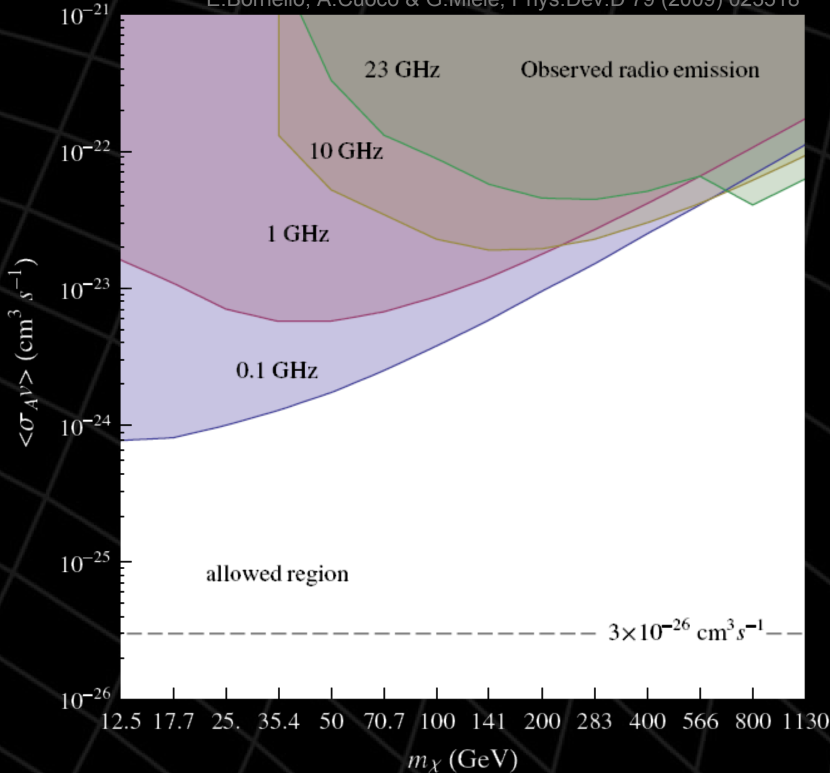
Our approach (conservative):

One can compare the DM signal with the observed radio emission where only the CMB is removed. We use the code of De Olivera Costa et al., where most of the radio survey observations in the range 10 MHz–100 GHz are collected and interpolated.

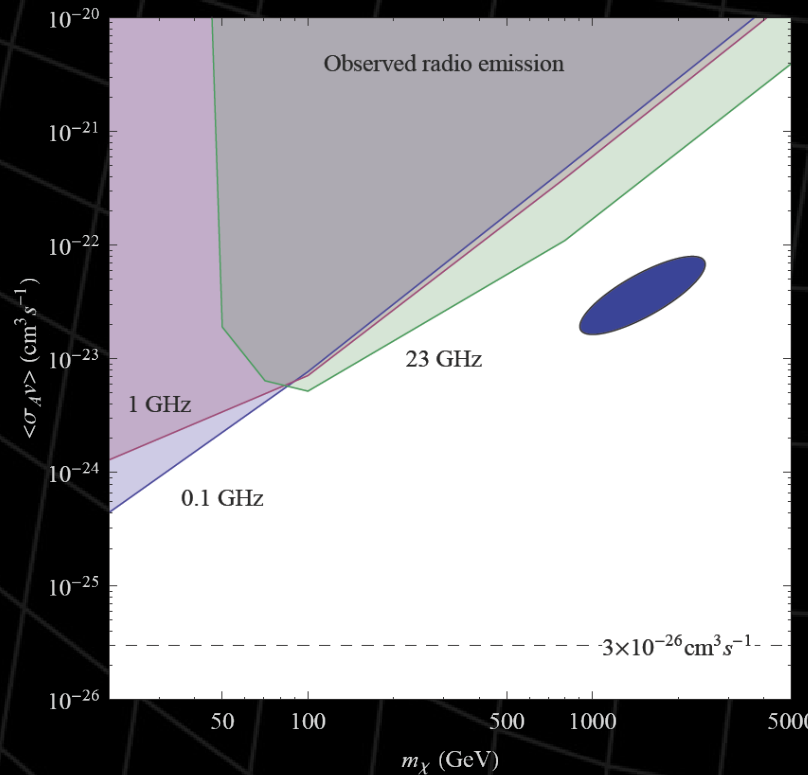
De Olivera Costa et al., arXiv:0802.1525 [astro-ph]

DM Annihilation Constraints

E.Borriello, A.Cuoco & G.Miele, Phys.Dev.D 79 (2009) 023518

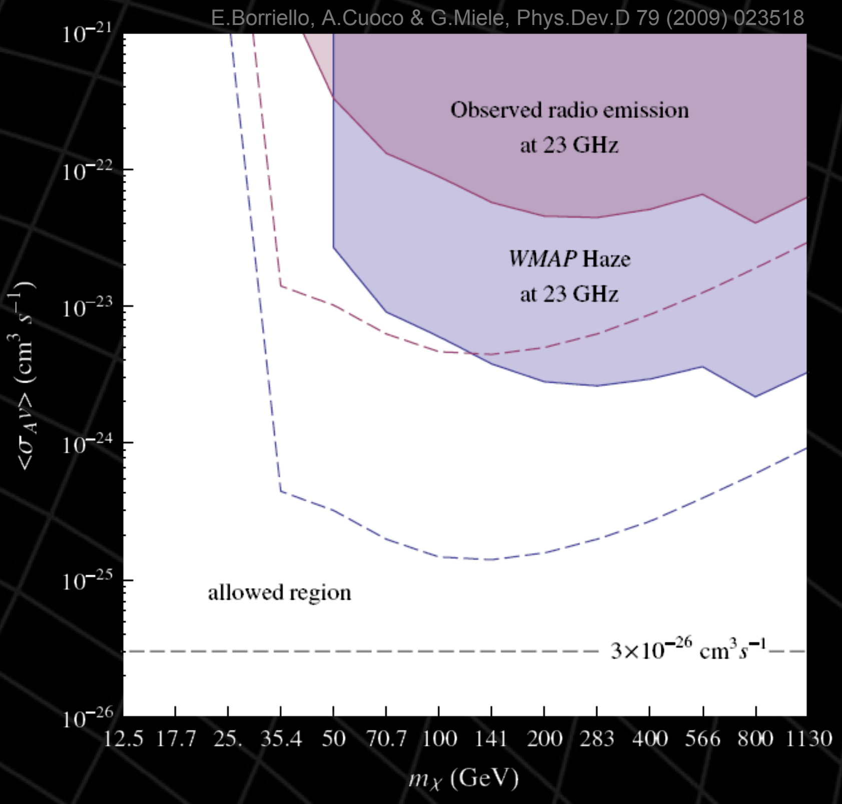


$\chi\,\chi \to q\,\bar{q}$



$\chi\,\chi \to \mu^+\mu^-$

DM Annihilation Constraints



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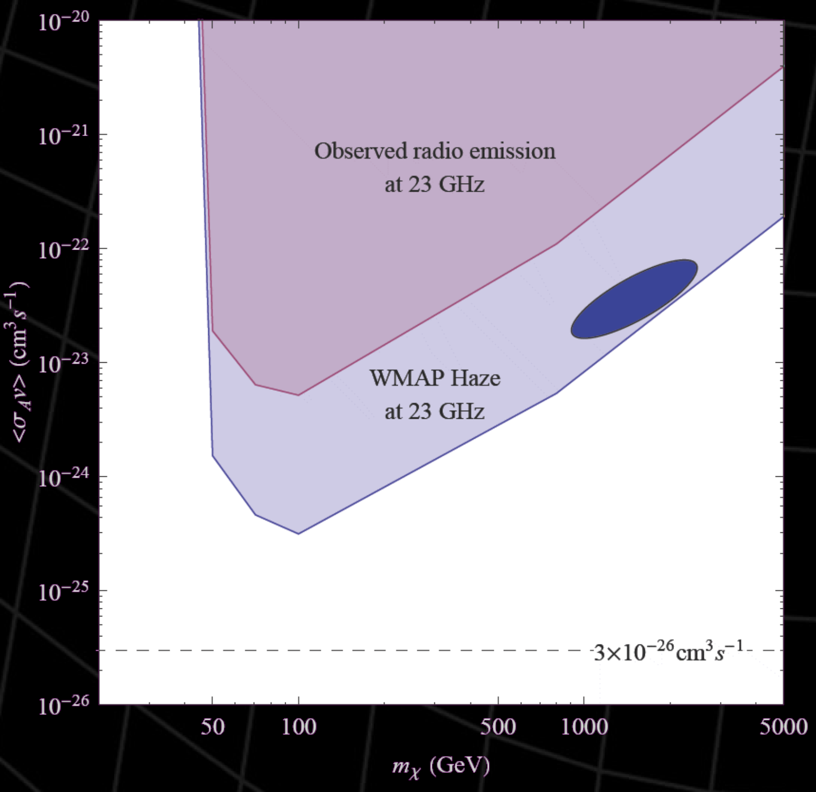


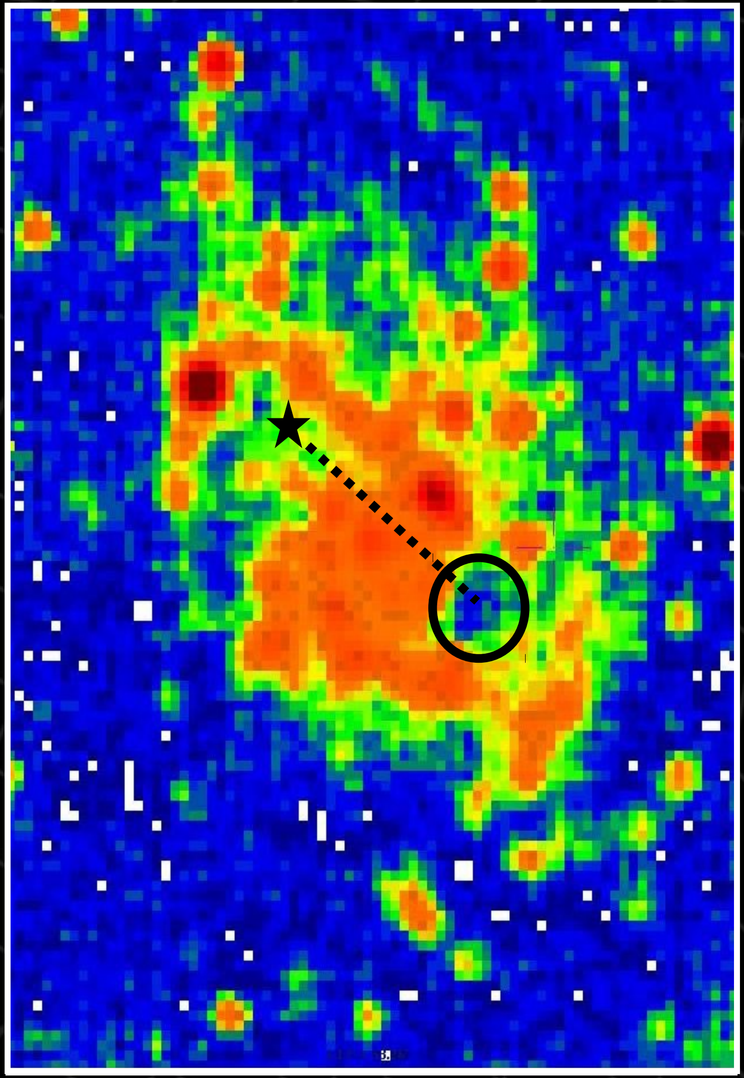
$$\chi\,\chi \rightarrow \mu^+\mu^-$$

Constraints from external galaxies

- Instead of calculating the integrated radio flux coming from the entire galaxy (a lot of uncertainties would be propagated on the final results) we could focus our attention on a small region, for this could be well known from an astrophysical point of view.

- Our aim is to reduce the best we can the foreground contamination to the observed flux.

Radio cavities in external galaxies



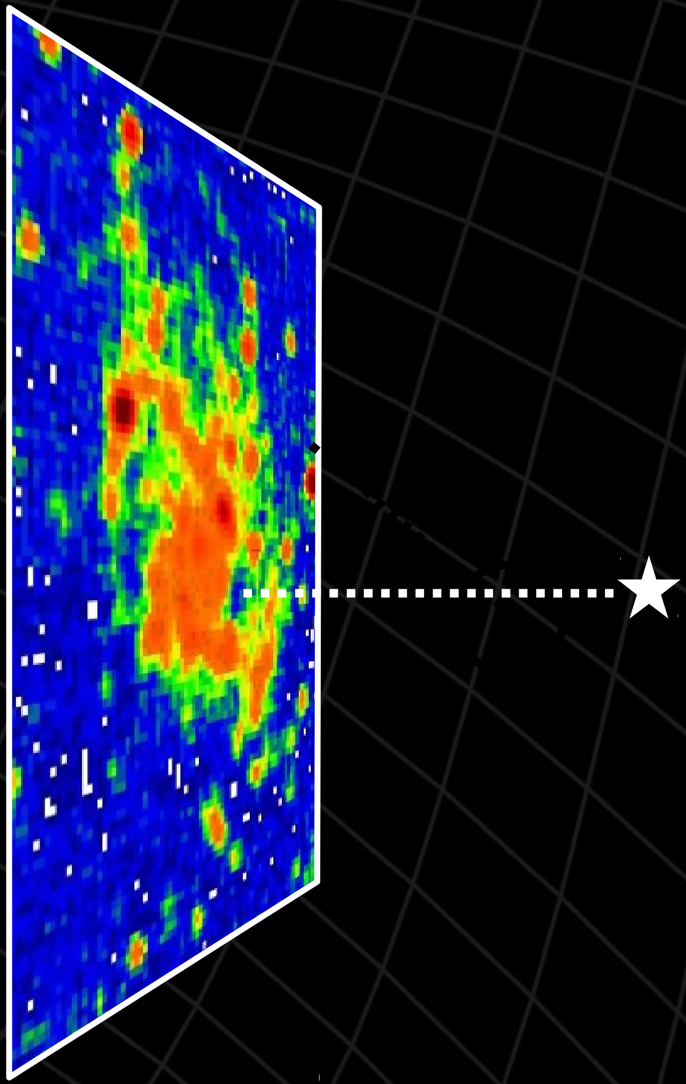
The presence of strong inhomogeneities in radio maps of galaxies is a common feature.

We expect them in the MW, too. We cannot see them because we share their position in the disc of the Galaxy.

The situation changes completely if we, instead, belong to a different galaxy, particularly if the external galaxy is placed **"face-on"** with respect to us.

This way we obtain the **lowest** possible value of **foreground contamination** on our results.

Radio cavities in extenal galaxies



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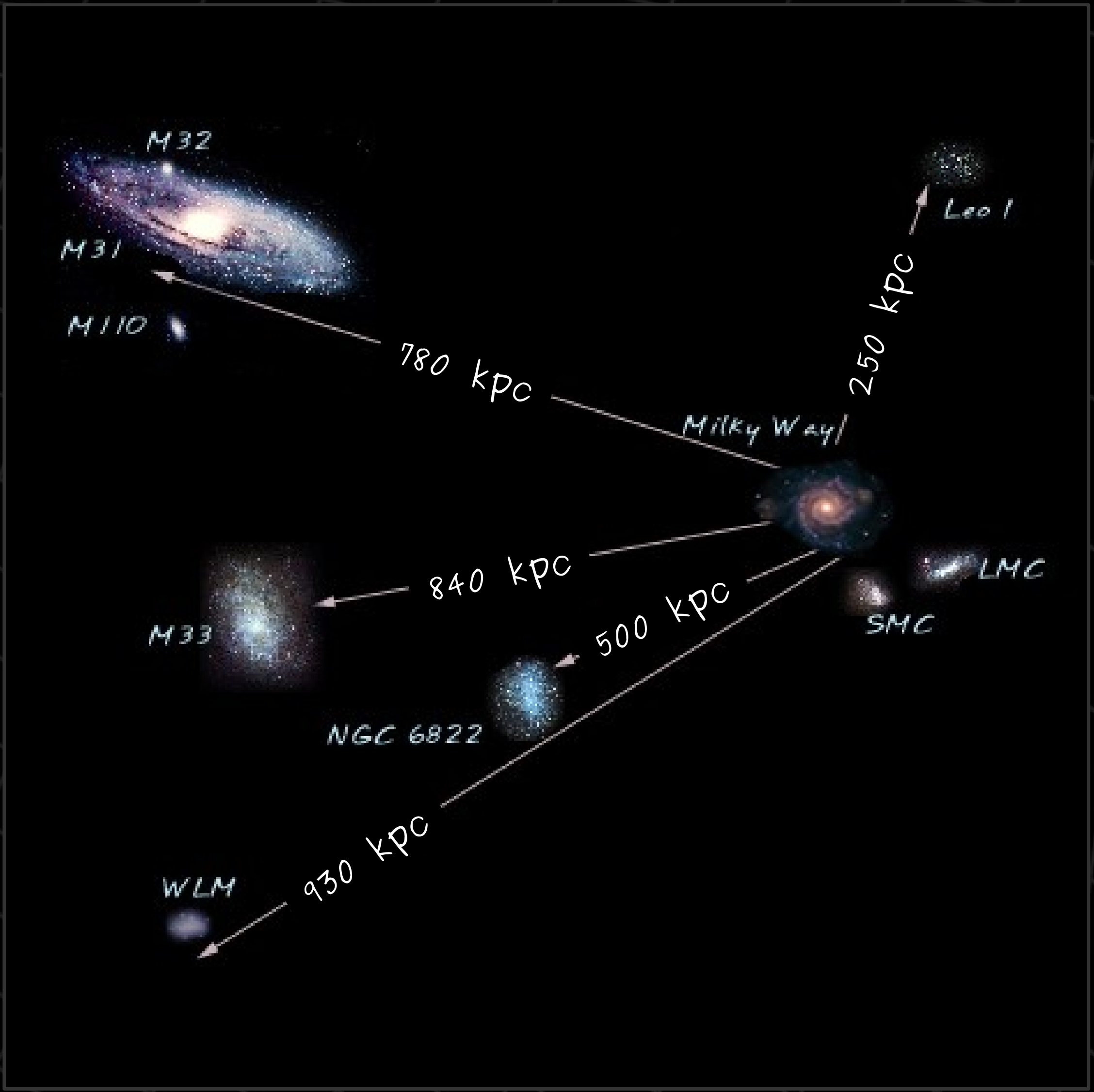
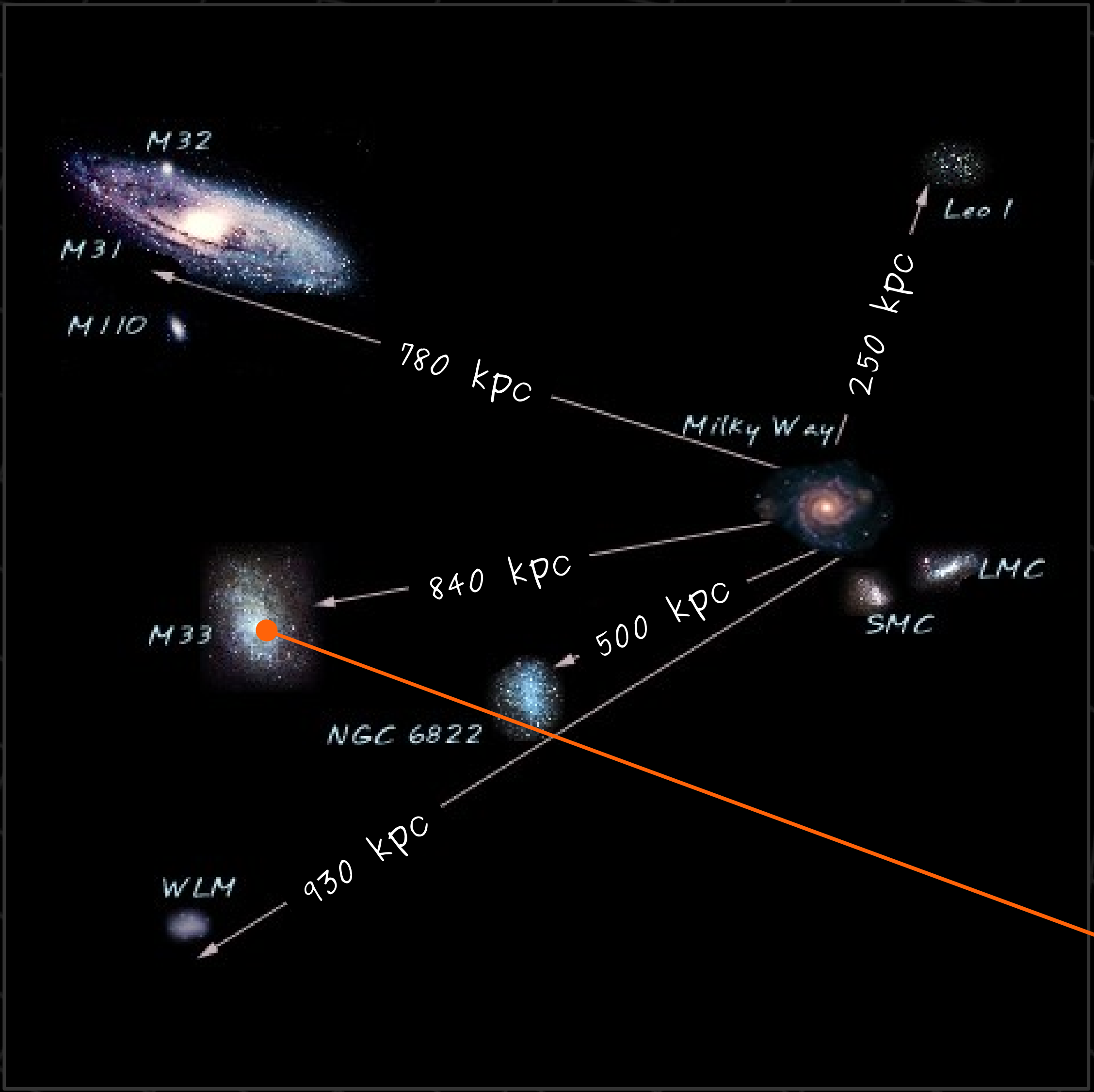
The Local Group



The Local Group

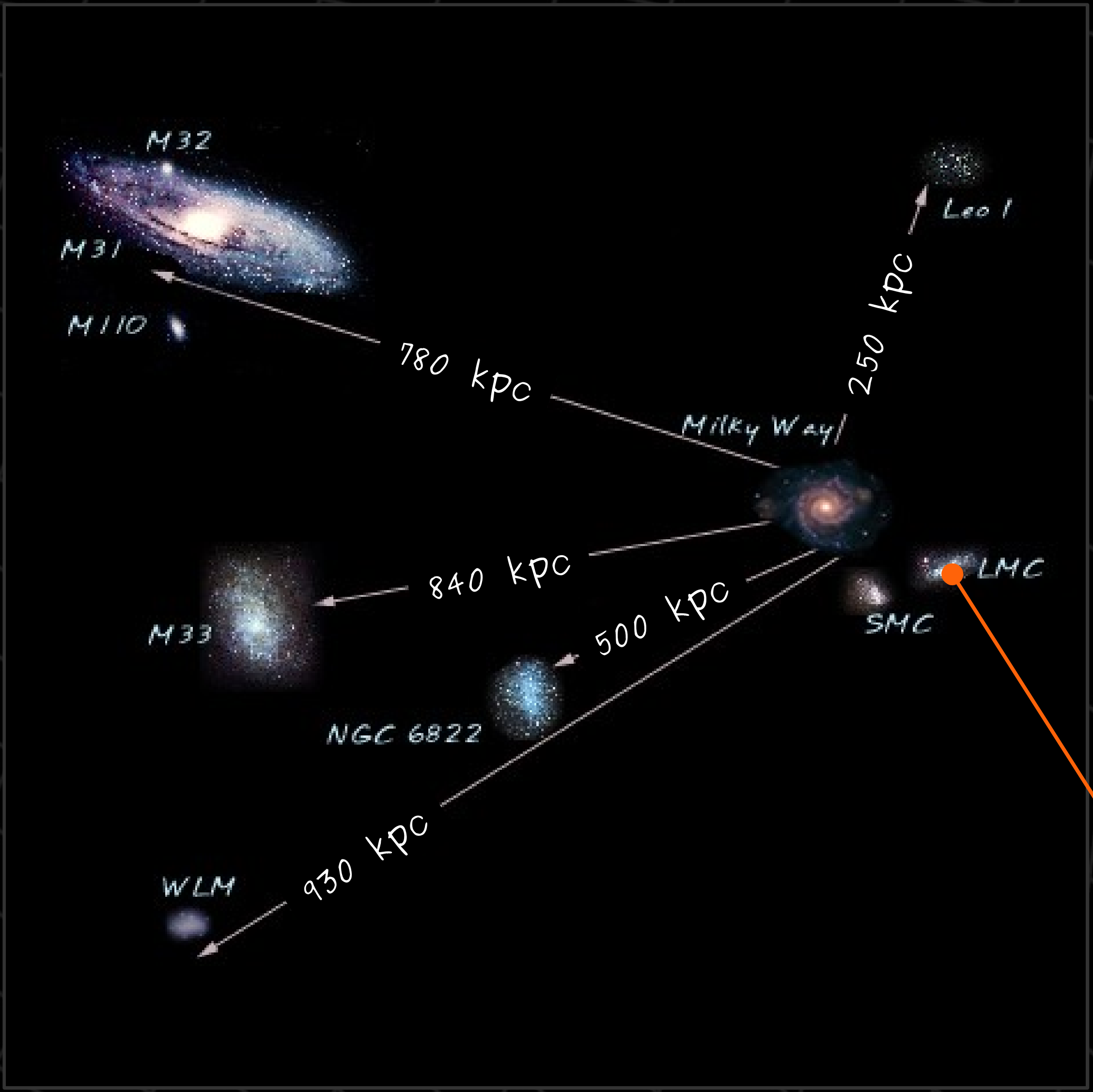


M33 is a **spiral galaxy** approximately 840 kpc away. It is the **third largest galaxy** in the Local Group, after the Andromeda Galaxy and the Milky Way.

It has an inclination of **56°**, therefore its spiral structure is clearly visible.

It has been extensively studied at all wavelengths, from radio to X-rays.

The Local Group

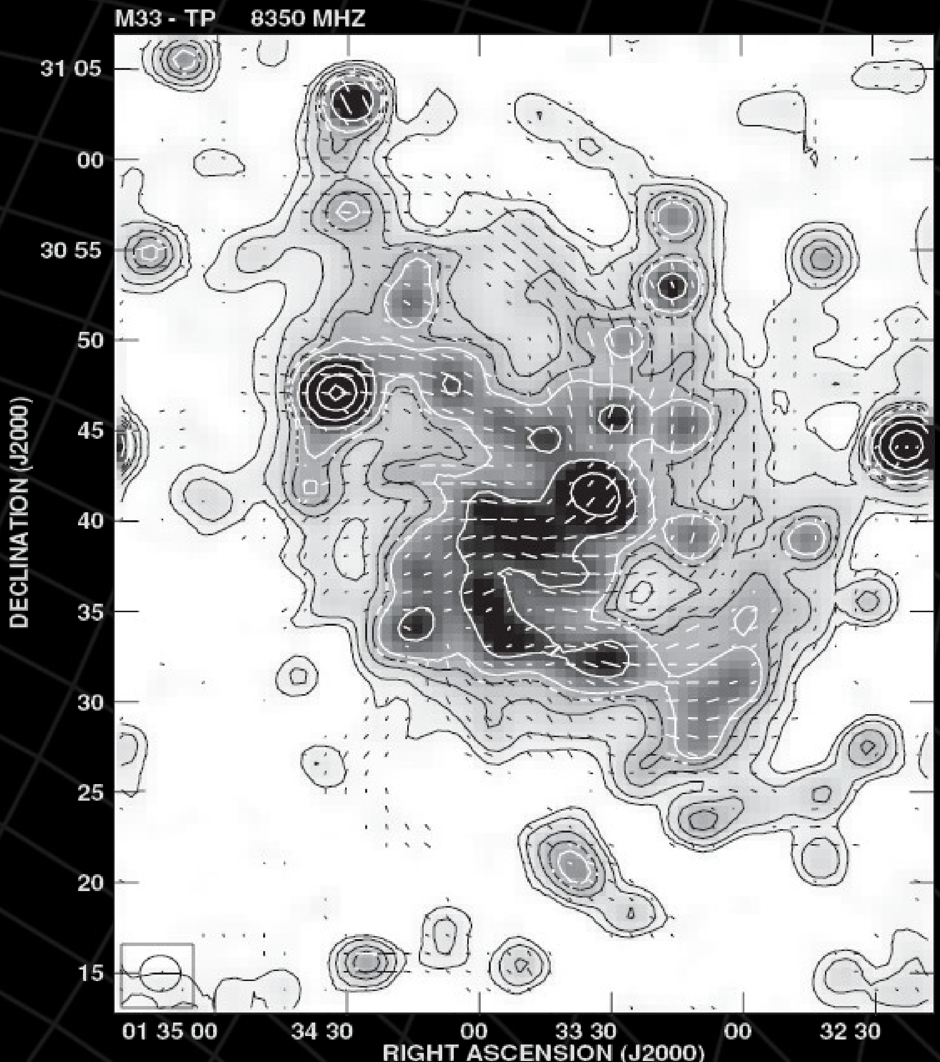


LMC, is a nearby **ir-regular galaxy**, located at a distance of only 50 kpc from us.

It is one of the best stu-died galaxies in almost all frequency bands.

It is nearly face-on (its disk forms an angle of **35°** with the plane of the sky),

The Radio Cavity of M33



Radio map of M33 at 3.6 cm (8.35 GHz)

M33 posses many regions characterized by a **low emissivity** at radio frequencies.

In particular there is a ***Radio Cavity*** located at only 2 kpc from the centre where the flux reaches its minimum.

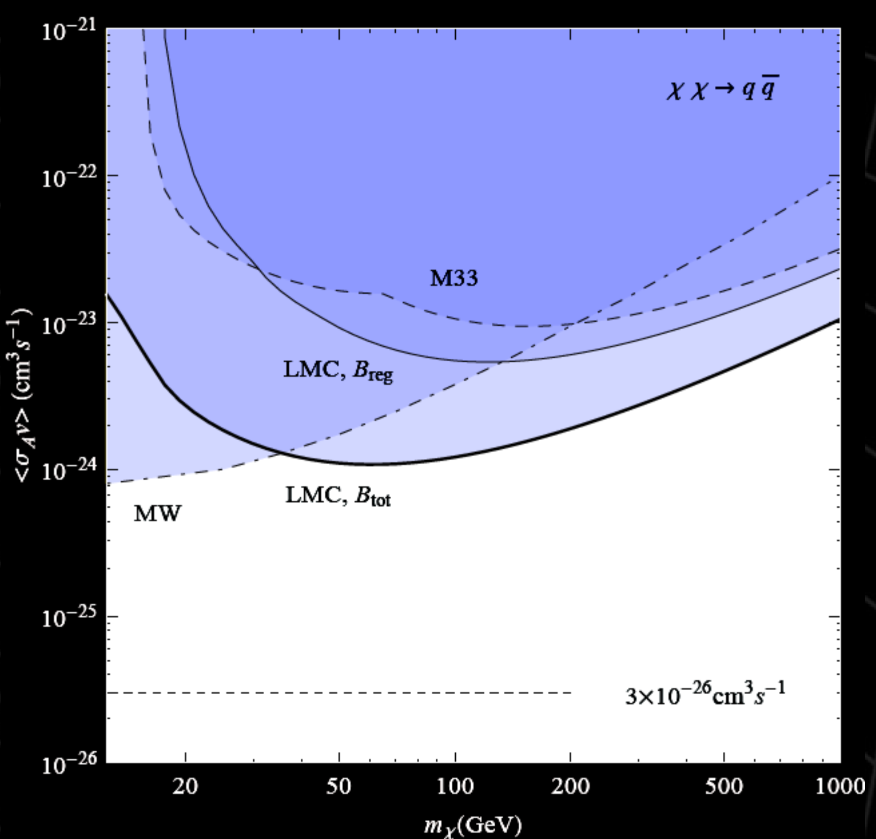
Mean magnetic field: 6.4 μG

Magnetic field in the cavity: **7.1 μG**

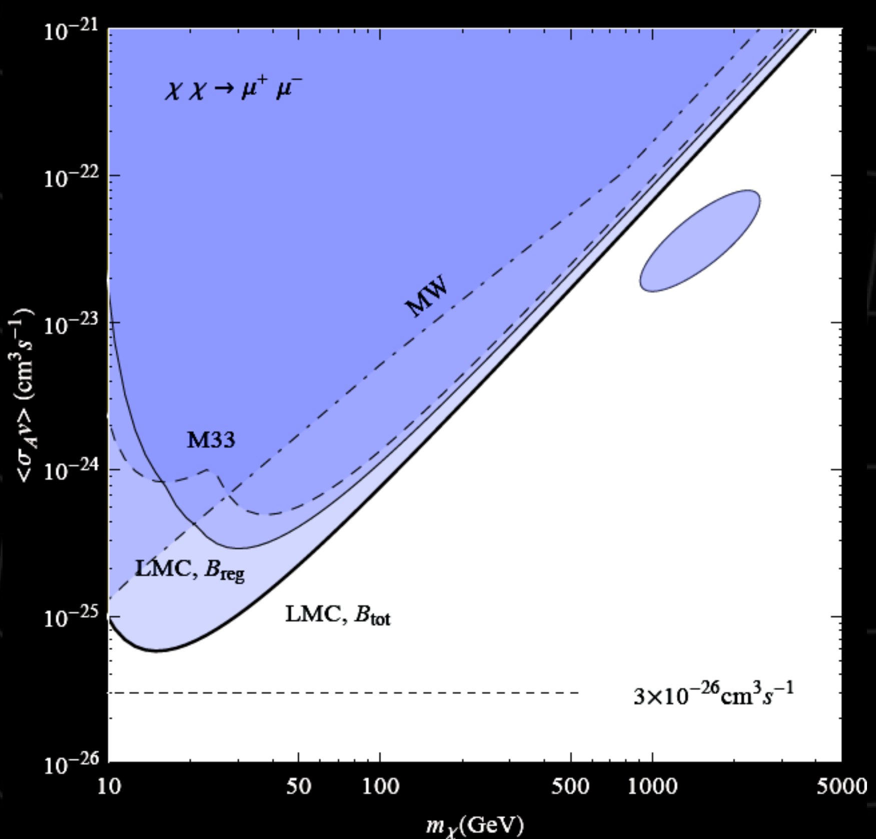
This Radio Cavity looks like the **ideal place** where to look for a DM signal.

F.S. Tabatabaei, M. Krause, R. Beck, Astron. Astrophys. **472** (2007) 785.

Radio constraints from M33 and LMC



$\chi\chi \to q\,\bar{q}$



$\chi\chi \to \mu^+\mu^-$

Forecasts for ALMA (140 GHz)

A better scan of the radio cavity could lead to two improvements:

ALMA Sensitivity Goals for the 12 m Array

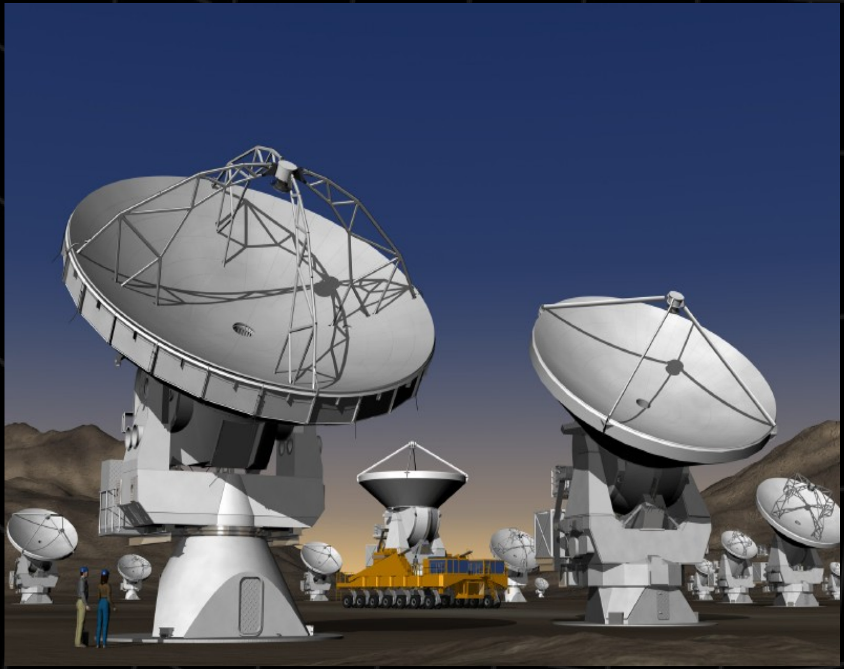
For an integration time of 60 seconds, a spectral resolution of 1 km s^{-1}, the RMS flux density, ΔS, and brightness temperature sensitivity, ΔT, with a 64 antenna array and maximum baseline, B_{max}, will be:

Frequency (GHz)	Continuum ΔS (mJy)	Spectral Line ΔS (mJy)	B_{max} = 0.2 km: Beam (arcsec)	B_{max} = 0.2 km: ΔT_{cont} (K)	B_{max} = 0.2 km: ΔT_{line} (K)	B_{max} = 14.7 km: Beam (arcsec)	B_{max} = 14.7 km: ΔT_{cont} (K)	B_{max} = 14.7 km: ΔT_{line} (K)
110	0.047	7.0	3.18	0.0005	0.070	0.038	3.3	482
140	0.055	7.1	2.50	0.0005	0.071	0.030	3.8	495
230	0.100	10.2	1.52	0.0010	0.104	0.018	6.9	709
345	0.195	16.3	1.01	0.0020	0.167	0.012	13.5	1128
409	0.296	22.6	0.86	0.0031	0.234	0.010	20.5	1569
675	1.042	62.1	0.52	0.0108	0.641	0.006	72.2	4305

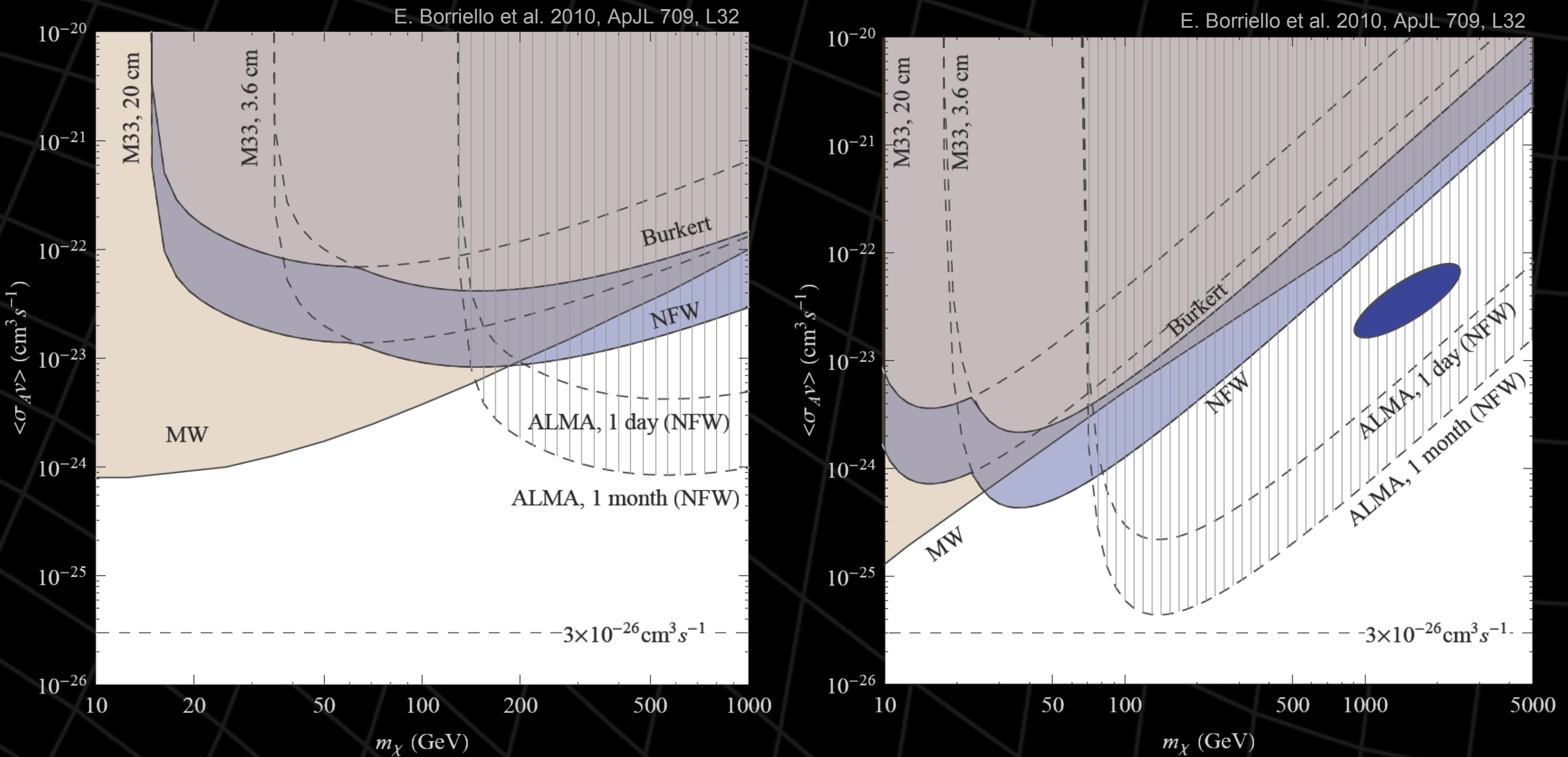
We could find a pixel from which we observe no flux (a flux comparable to the experimental sensitivity).

A spectral analysis of the different foreground contributions could lead to a foreground removal (at least around the least flux region).

Therefore, to test the potentiality of the method we deduce the bounds we would be able to put in the case of **"null detection"**.



Forecasts for ALMA (M33, 140 GHz)



$$\chi\,\chi \to q\,\bar{q}$$

$$\chi\,\chi \to \mu^+\mu^-$$

Conclusions

Key elements to obtain good constrains from astrophysical observations at radio frequencies:

■ Intense magnetic field:

High GMF → High DM radio flux, but High CR synchrotron flux, too.

■ Low foreground contaminations:

– Foreground removal:

- **LOFAR** is under construction.	10-250 MHz
- **SKA** is under design.	0.3-30 GHz
- **Planck** has started its second all sky survey.	30-900 GHz
- **ALMA** will start its full-scale operation in 2012.	31-950 GHz

– Spectral analysis +
High ang. resolution → Model independent foreground parametrization?

Thank you for your attention =)