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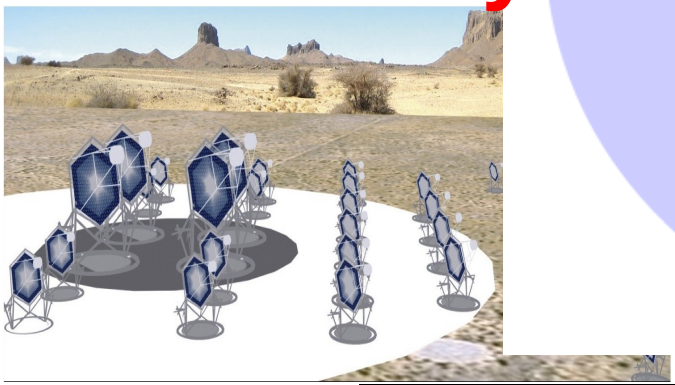
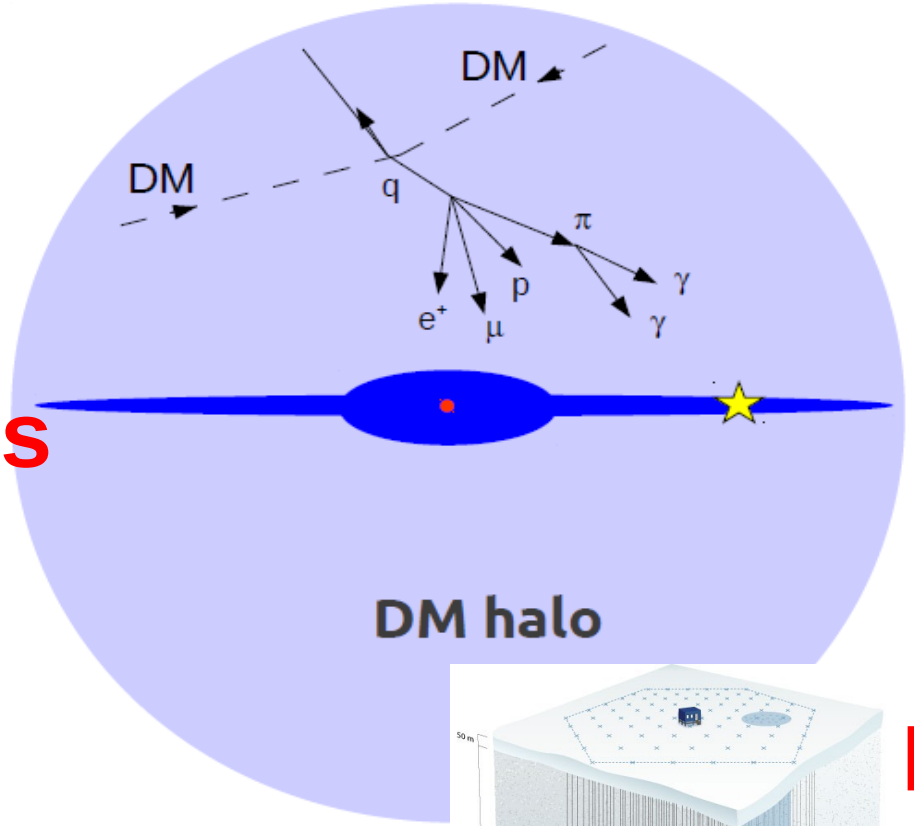
Dark Matter searches with radio observations

IDM 2012
Chicago, 23-27 July

Search for DM with astrophysical observations

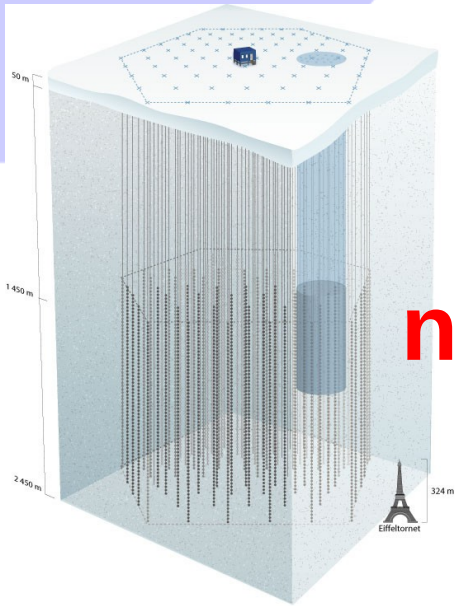
Gamma- rays





Microwave

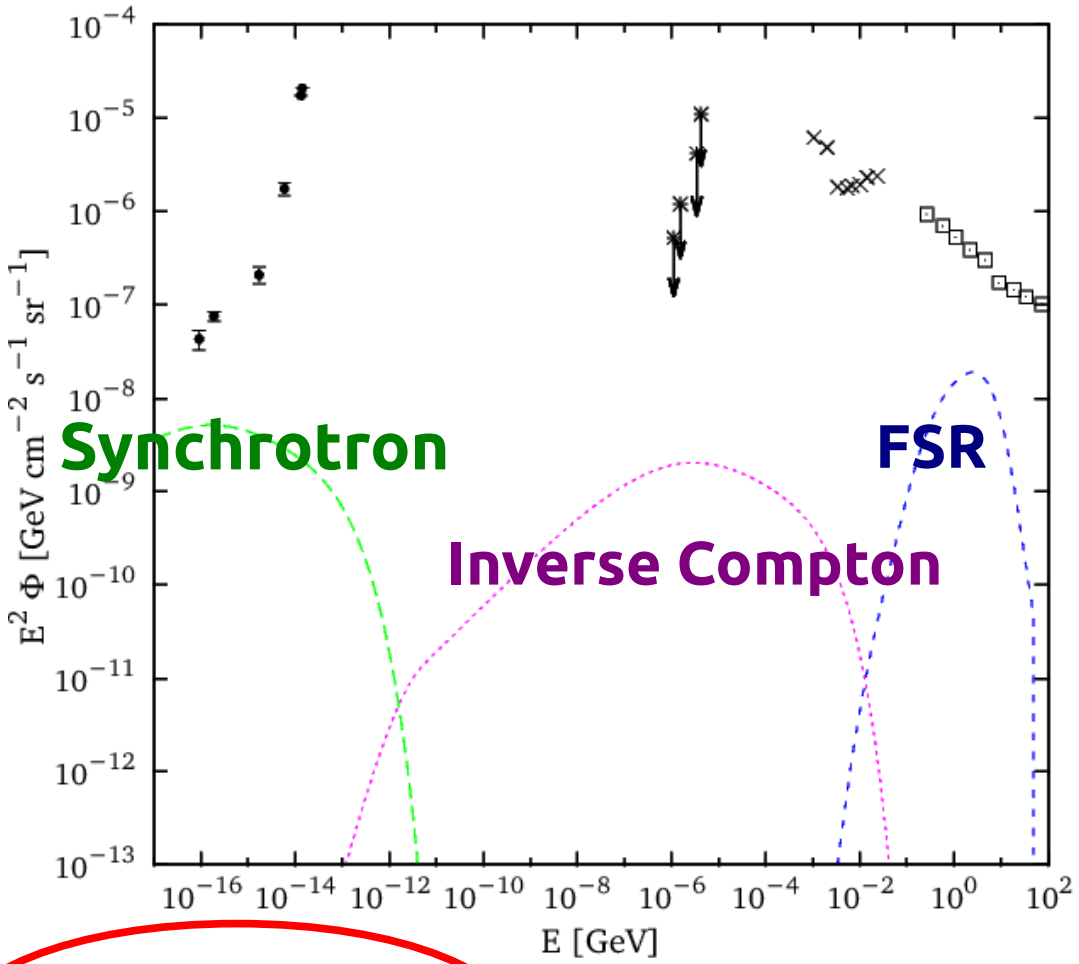
Radio



neutrinos

X- rays

Search for DM with astrophysical observations



Radio - Microwave

X-rays

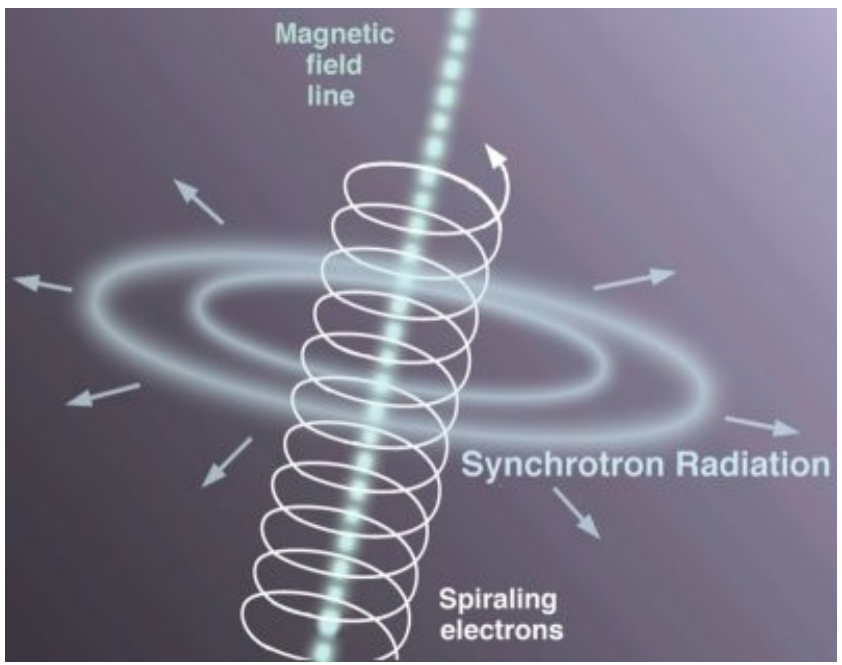
gamma-rays

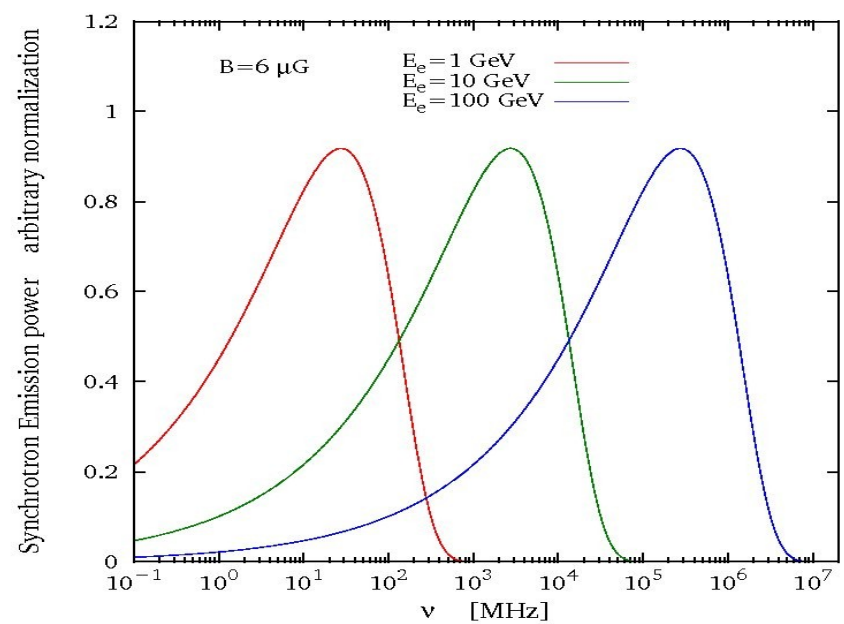
Search for DM with astrophysical radio observations

Annihilations or decays of DM produces $e^{\pm}$

$e^{\pm}$ spiraling in the magnetic field produce synchrotron radiation

$$\nu \sim 30 \text{ MHz} \frac{B}{6\ \mu\text{G}} \left(\frac{E_e}{1 \text{ GeV}}\right)^2$$



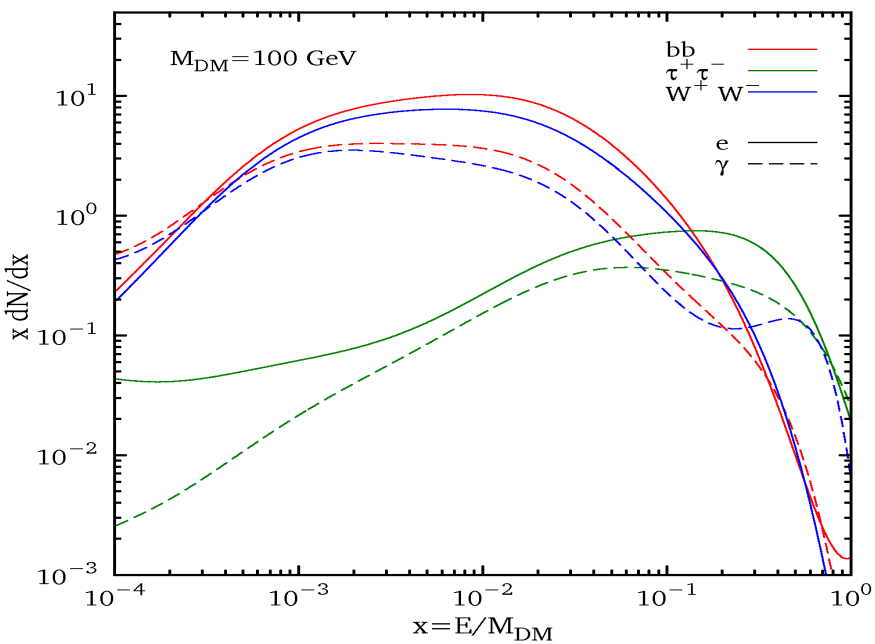


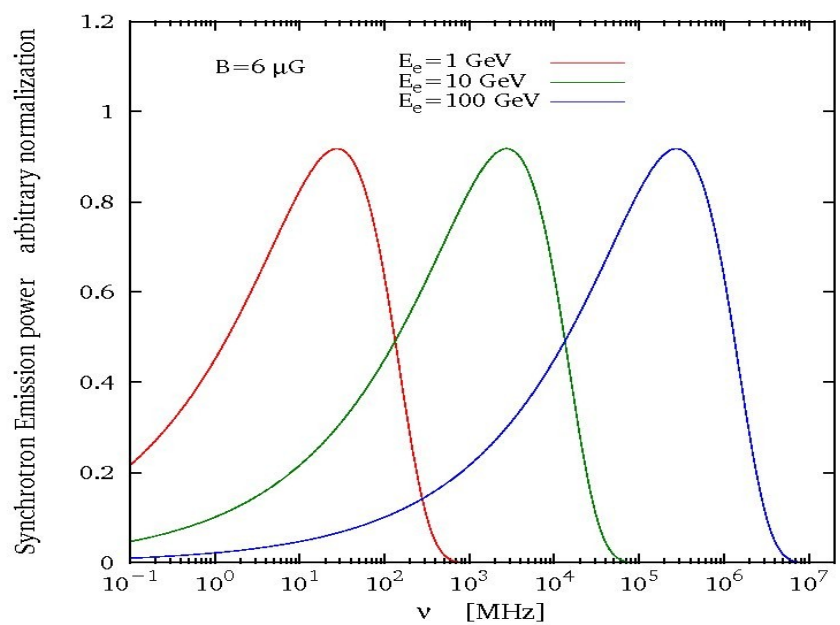
Search for DM with astrophysical radio observations

Different frequencies probe different regions of the electron spectrum.

Predictions affected by uncertainties on electrons propagation & Magnetic Fields

$$\nu \sim 30 \text{ MHz } \frac{B}{6\ \mu\text{G}} \left(\frac{E_e}{1 \text{ GeV}}\right)^2$$

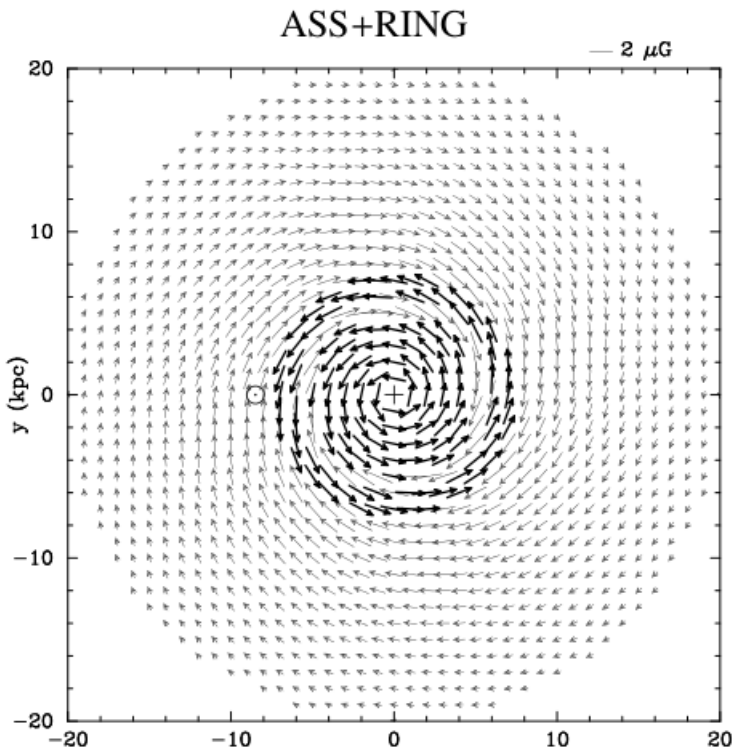




Probing Galactic Magnetic field & CR electron spectrum

Synchrotron probes both the interstellar CR electron density & Galactic magnetic field.

Use also Cosmic-Rays data and Faraday rotation measurements to break the degeneracy

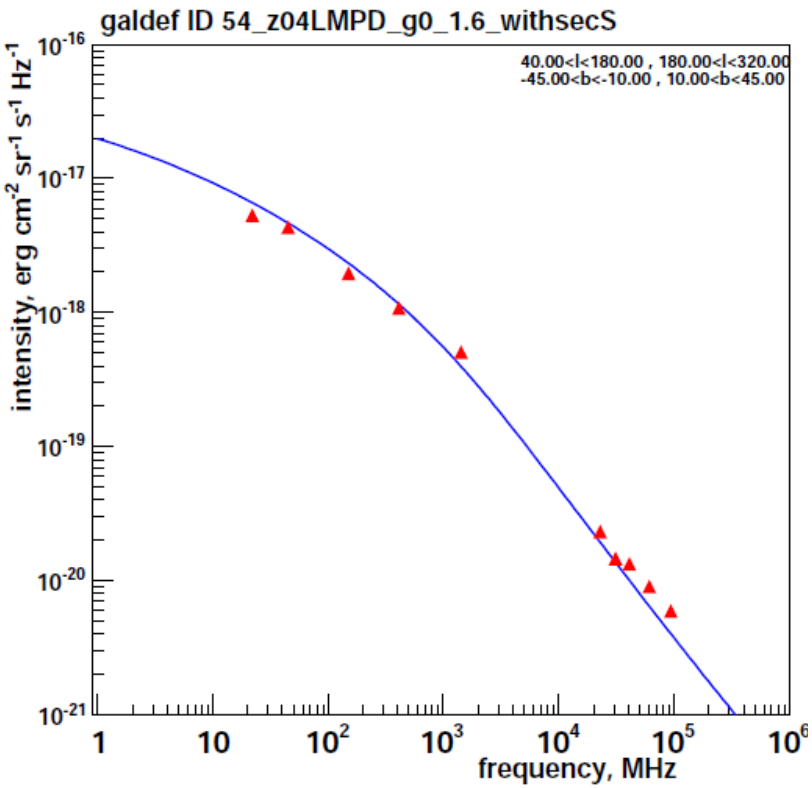


Sun et al. 2008

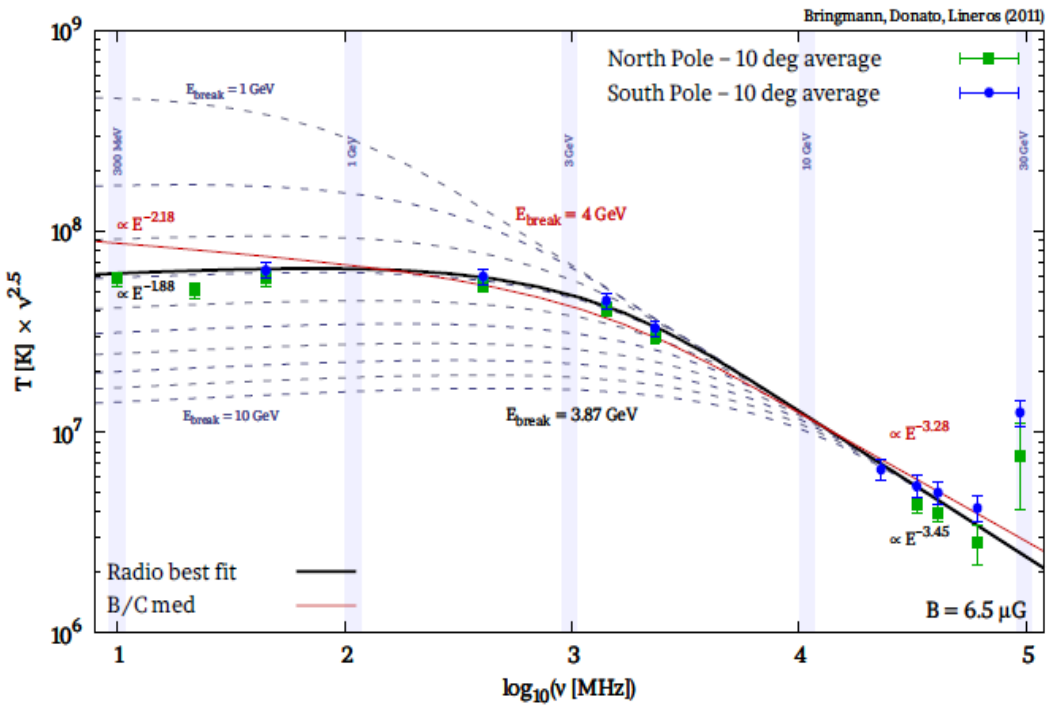
See also Strong et al. 2011, Jaffe et al. 2011

Radio maps: a tool to study CRs and magnetic fields

Consistent model of GMF and CRs propagation to tune against synchroton diffuse emission.



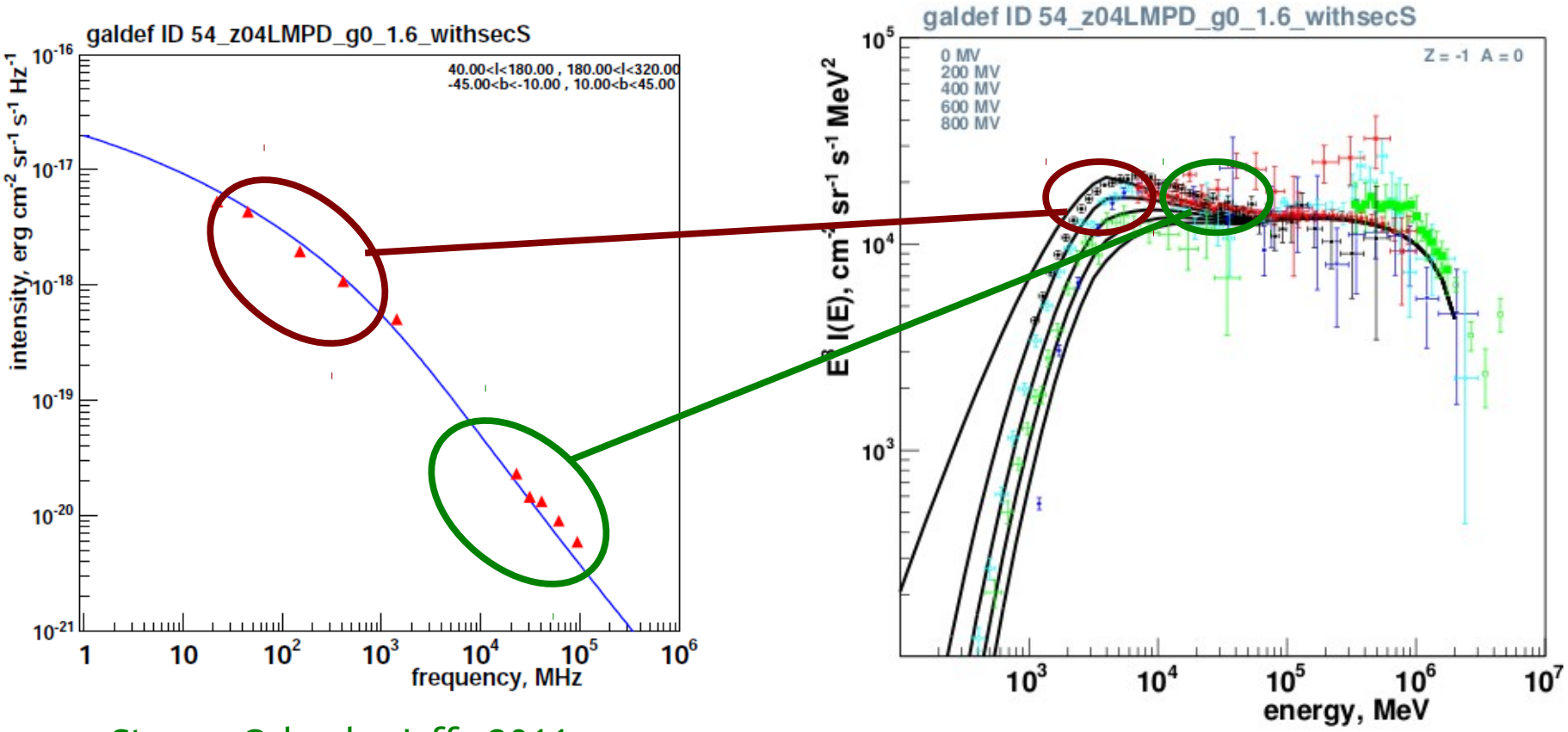
Strong, Orlando, Jaffe 2011



Bringmann, Donato, Lineros 2011

Radio maps: a tool to study CRs and magnetic fields

Low/high frequency surveys probe different parts of the interstellar electron spectrum

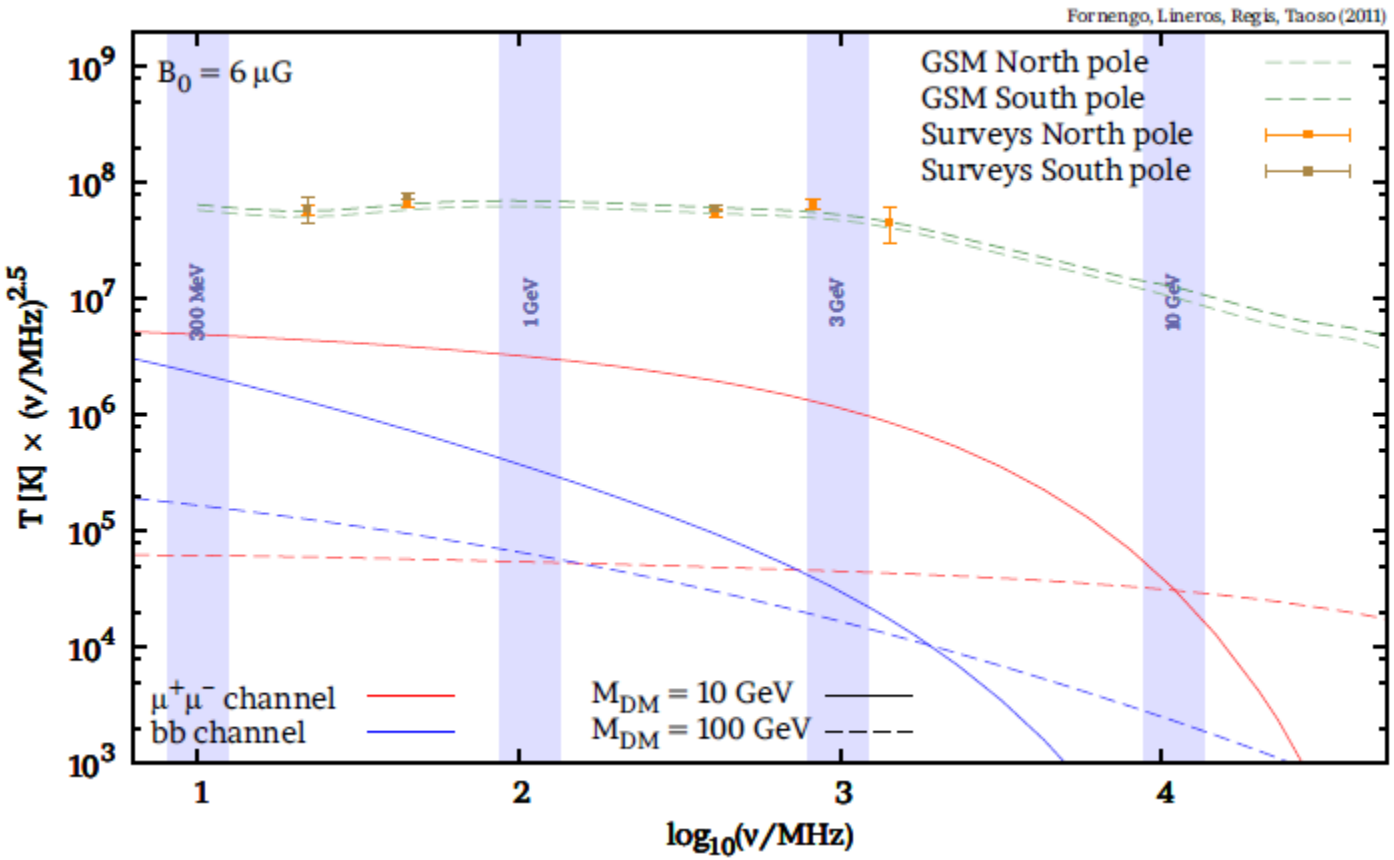


Strong, Orlando, Jaffe 2011

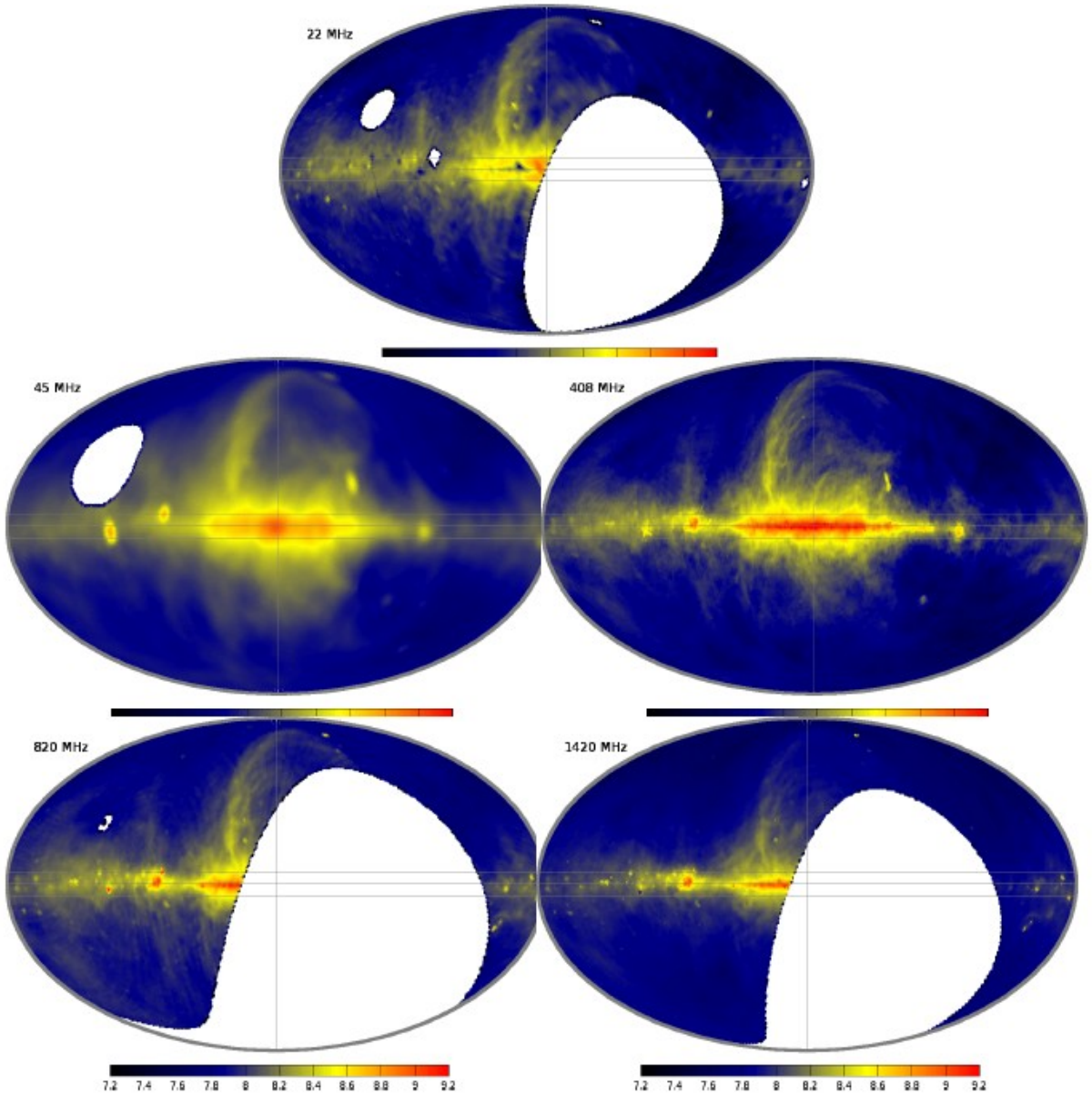
Galactic DM radio signal at different frequencies

Low frequencies particularly useful to test light DM :

electrons < few GeV give a synchrotron peak at 5-50 MHz (1-10 μB GMF)



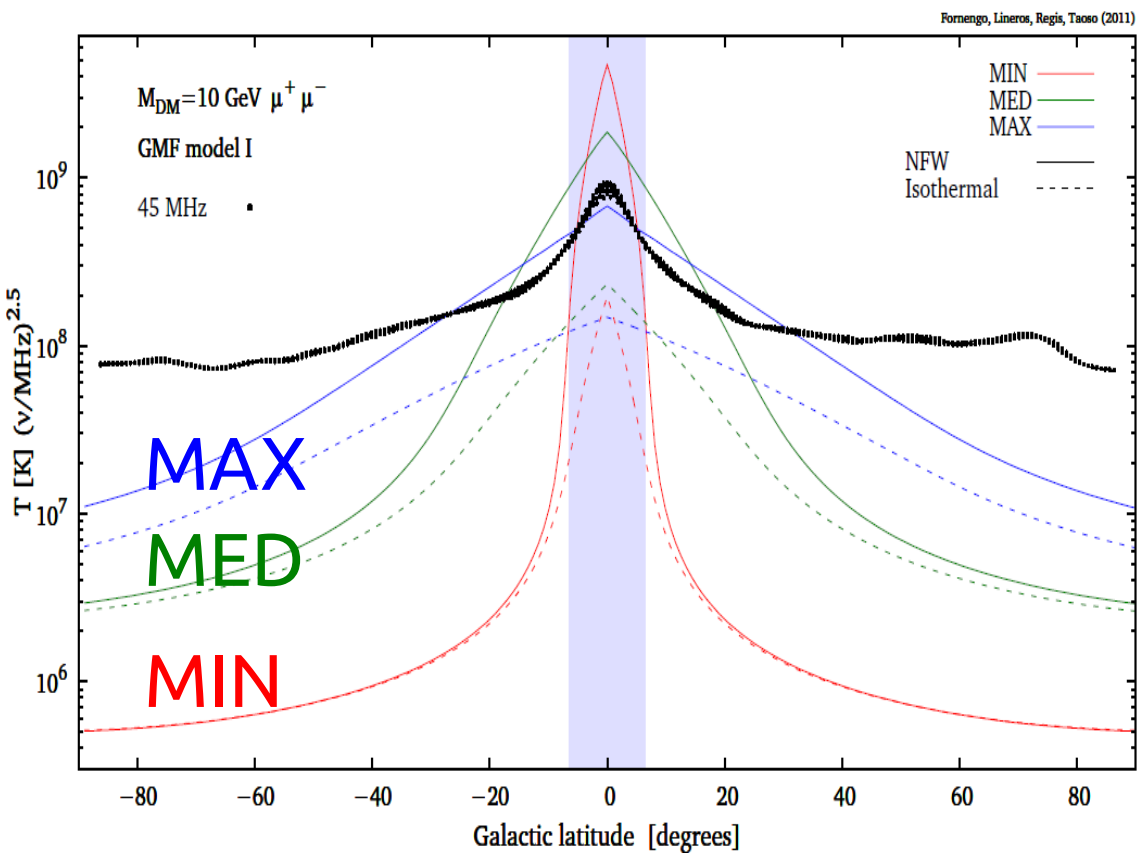
Radio surveys from 22MHz to 1420 MHz

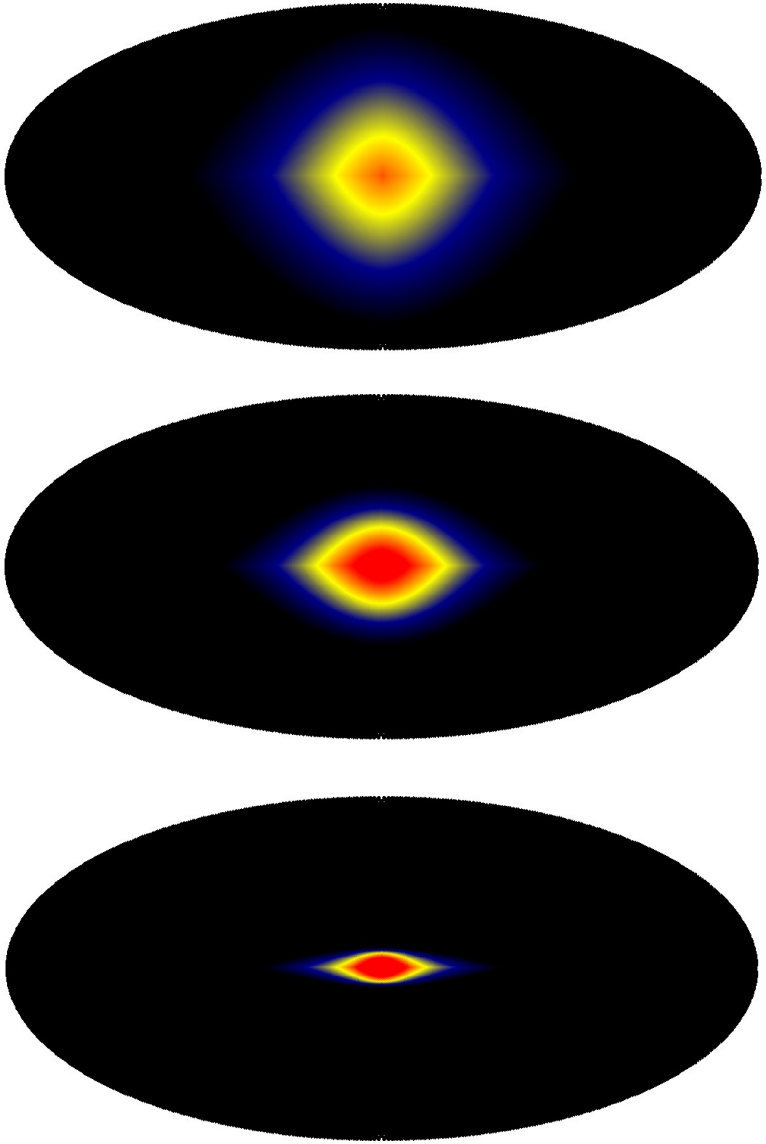


Galactic DM radio signal

The usual suspect: Galactic Center

Larger DM signal & astro uncertainties!

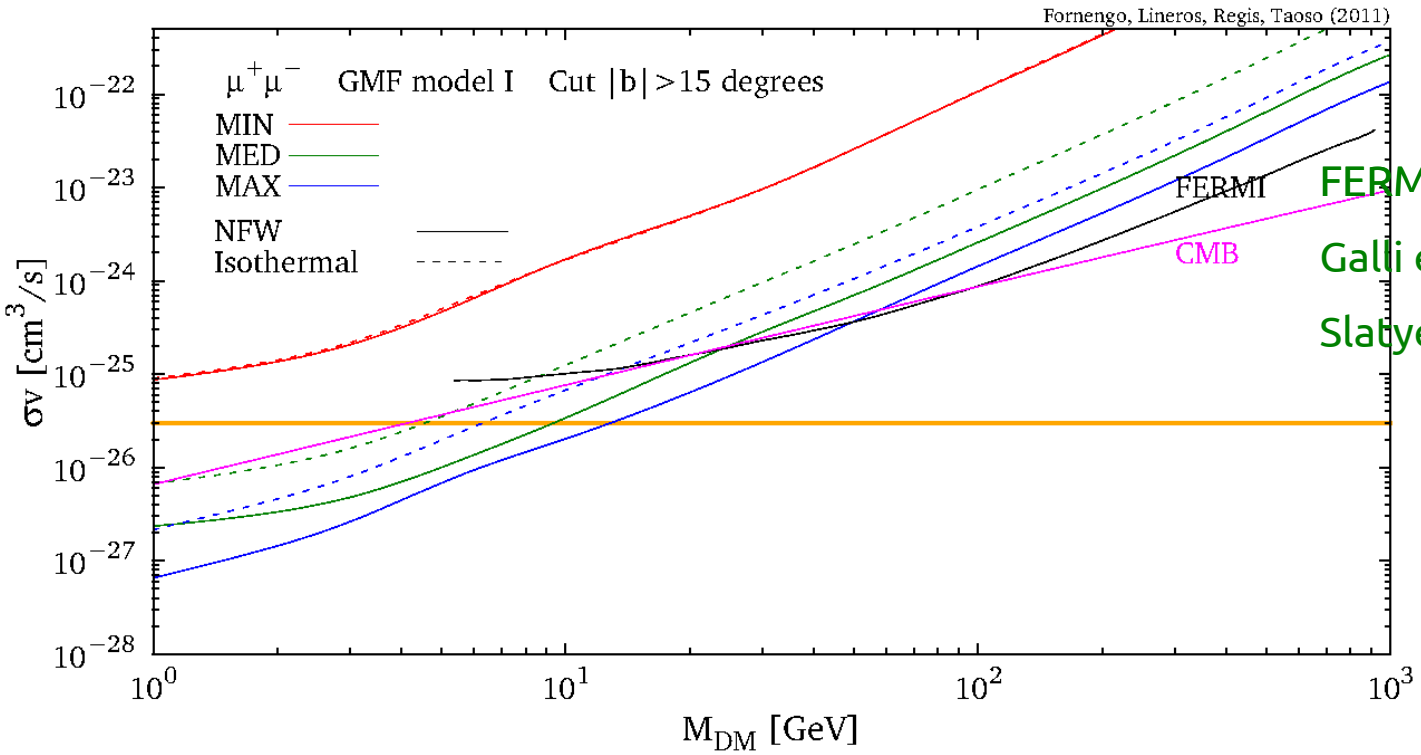




Constraints on DM

Radio constraints competitive with those from other searches

depending on the annihilation channel



FERMI-LAT 1108.3546

Galli et al. 2009

Slatyer et al. 2009

Fornengo,Lineros,Regis, MT 2011

Similar analysis in Mambrini+ 12

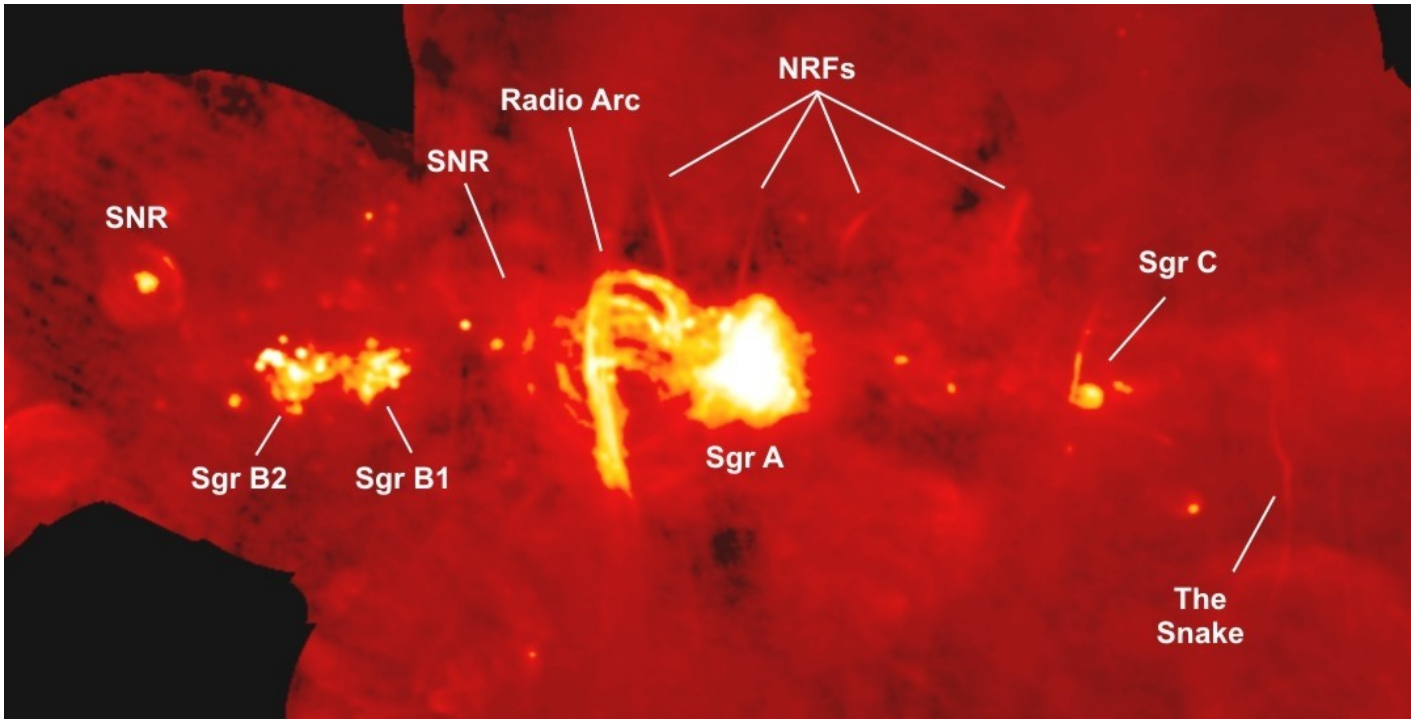
Many constraints from radio! e.g. Barger+ 09, Bertone+ 09, Bergstrom +09, Boehm+ 09, Borriello+ 09, Cholis+09, Cuoco 09, Caceres+ 08, Delahaye+ 10, Hooper 08, Ischiwata+ 09, Linden+ 10, Pato+ 10, Siffert 11, Zhang+ 09, …..

Galactic center

Radio image of the Galactic center from VLT and GBT

Advantage of radio: closer look thanks to the good angular resolution

DM signal may lie somewhere here



Credit: NRAO/AUI/NSF Yusef-Zadeh, et.al.

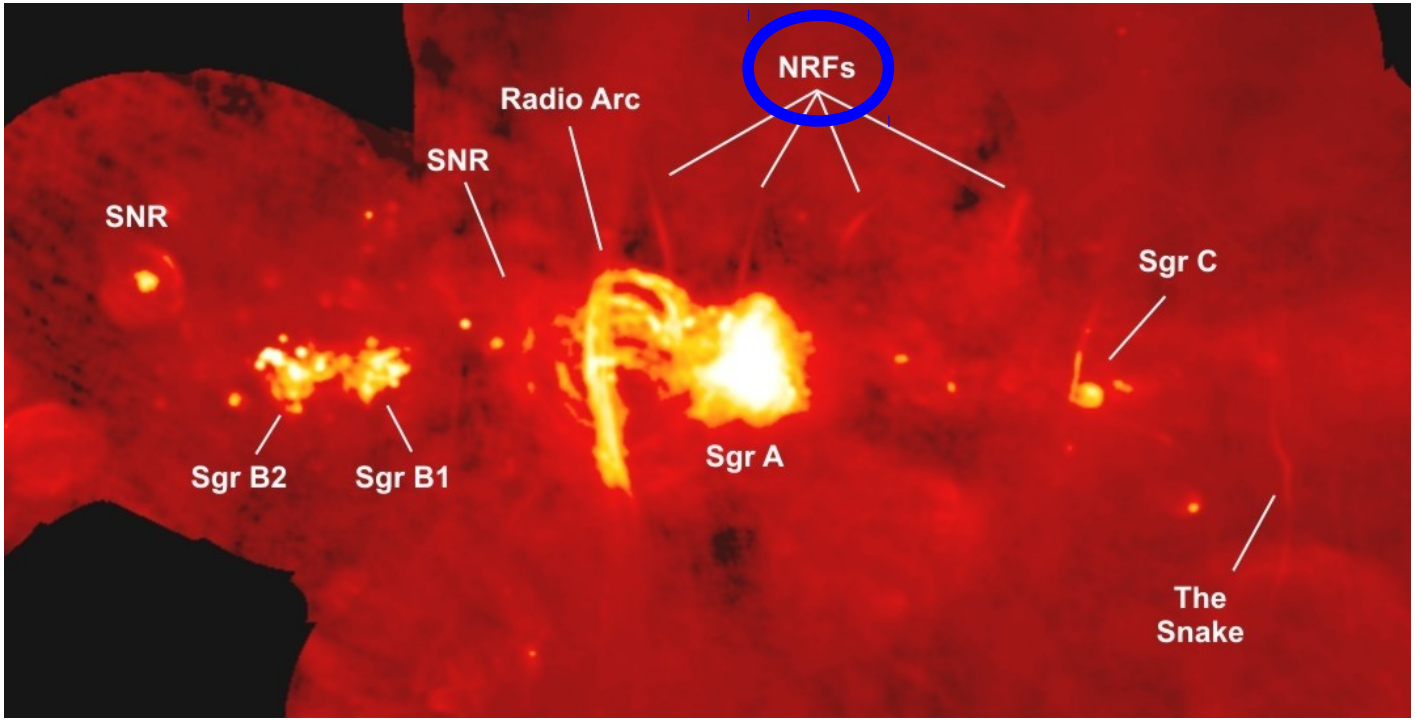
Galactic center

Non thermal radio-filaments. Highly polarized and hard radio emission.

Origin not yet understood.

DM is an option

Linden Hooper Yusef-Zadeh 2011



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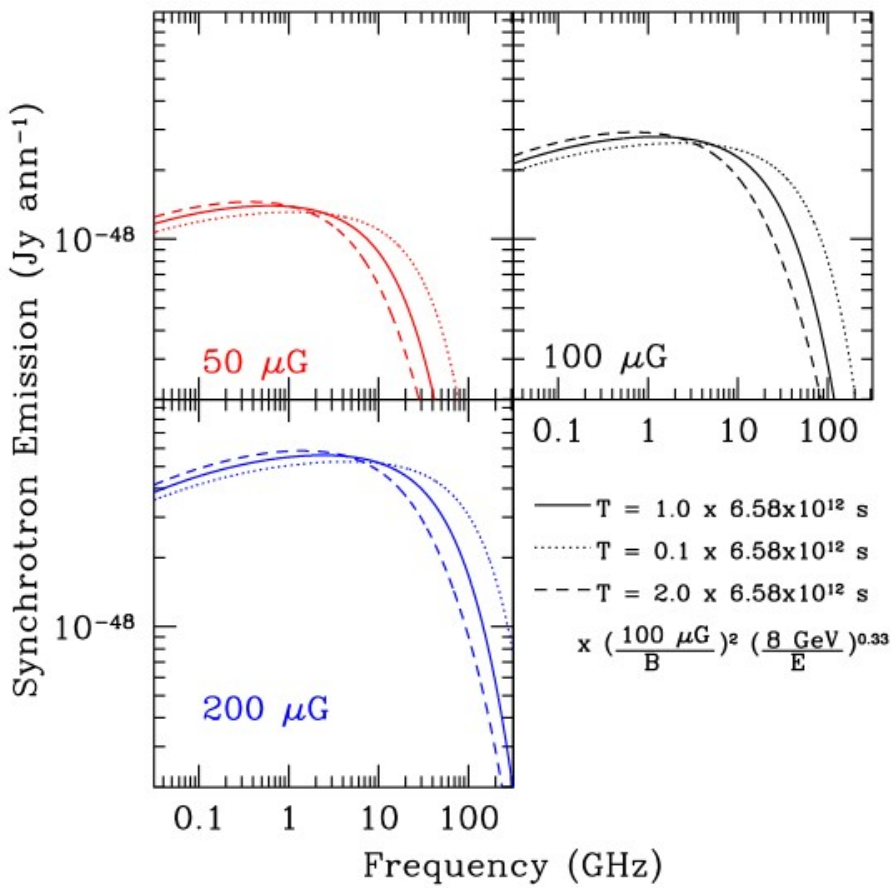


Galactic center

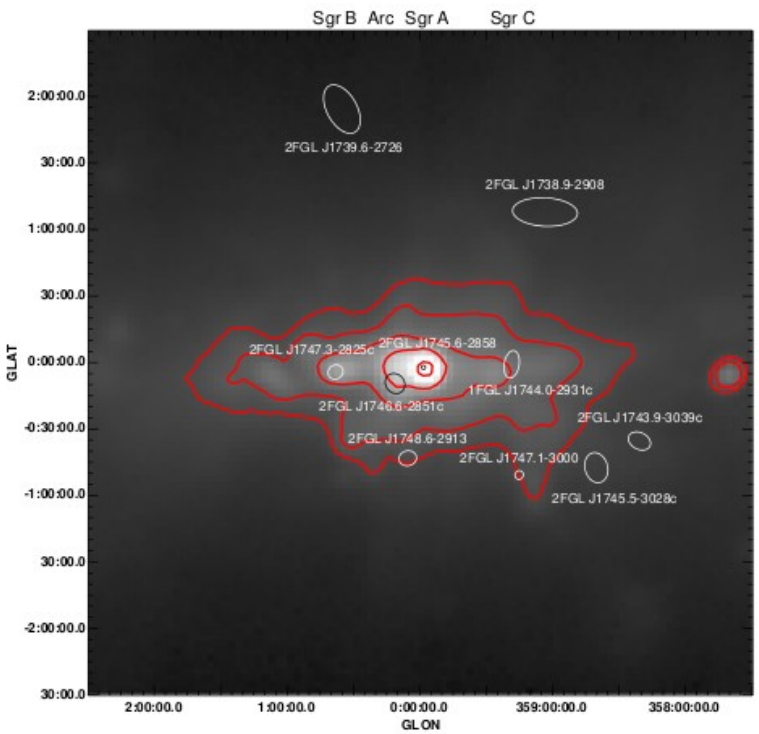
Combination of radio and gammas to test the origin of unknown emission

Claim that Fermi GeV emission correlates with 20cm radio emission

Suggested a common origin in terms of electrons emission:

synchrotron (radio) and bremsstrahlung (gamma)

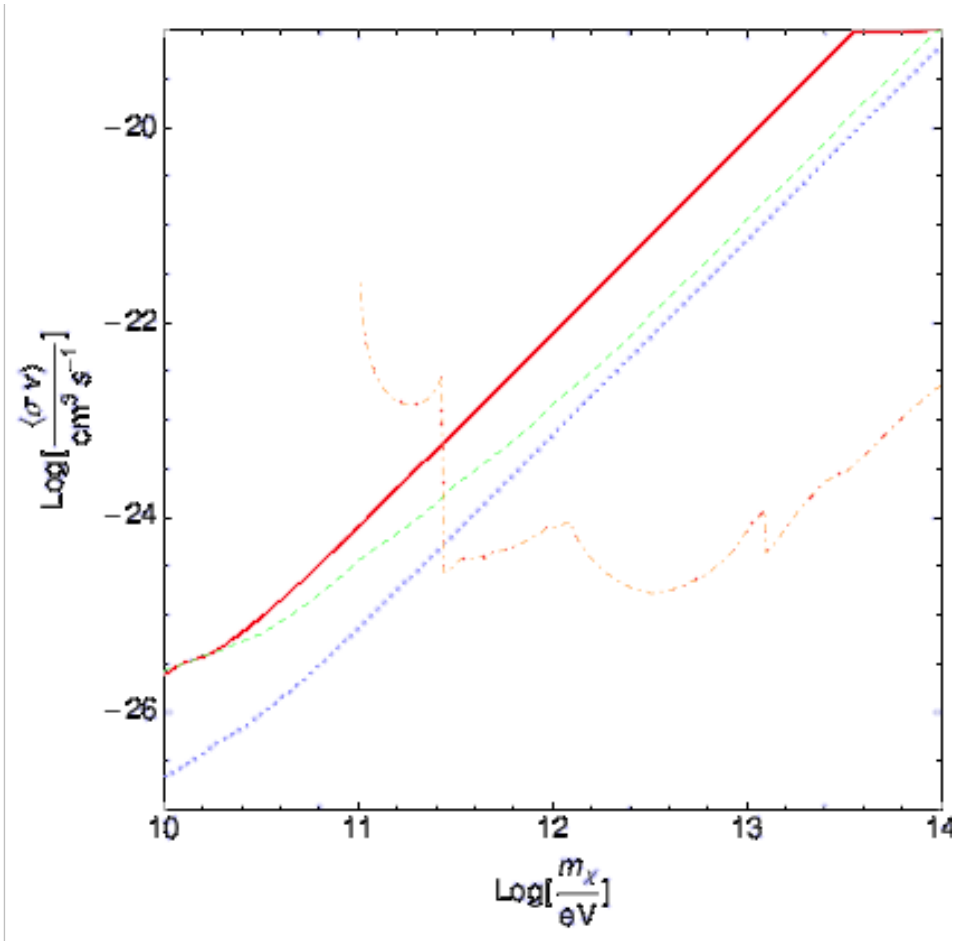
A multiwalenght perspective should be followed to look for DM signals



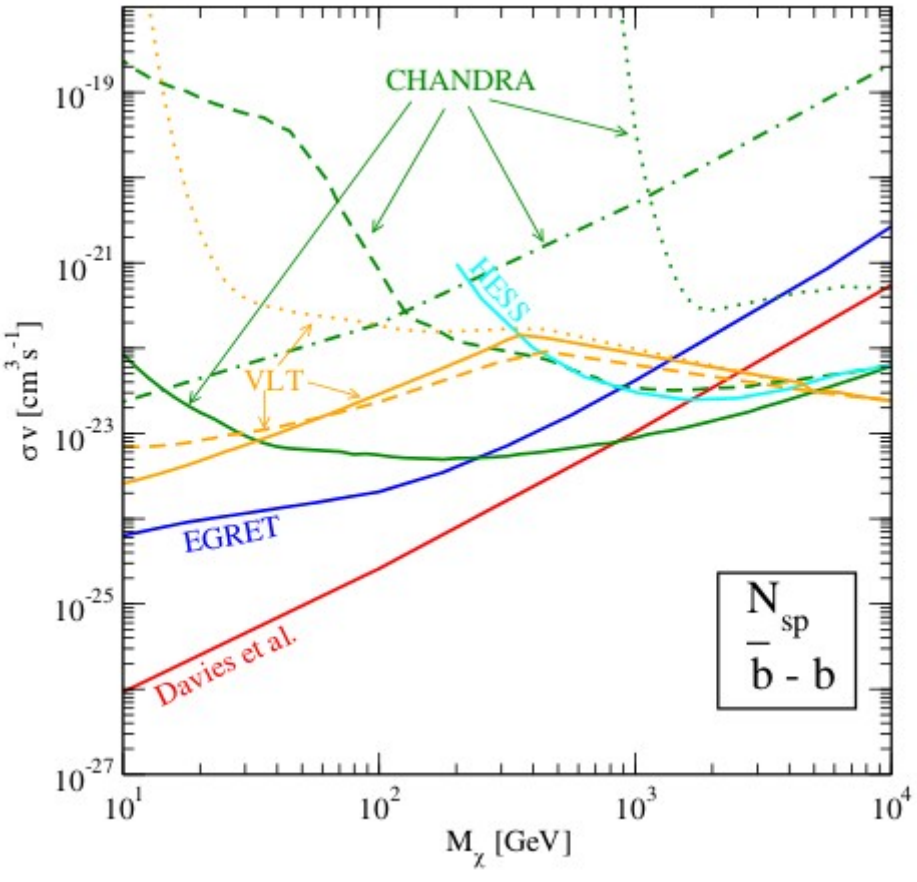
Zadeh et al. 2012

Constraints on DM

Multiwavelenght constraints from the GC region



Crocker et al 2010



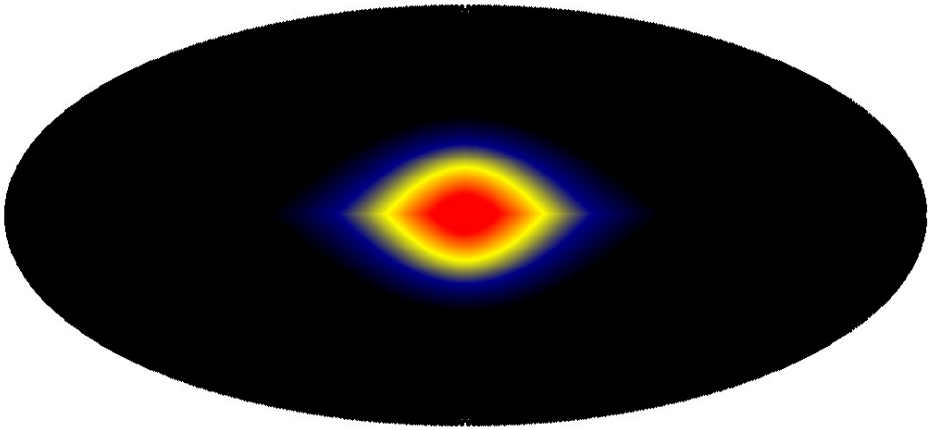
Ullio Regis 2008

What do we look for?

Bright emission around GC

Shape, normalization & spectra consistent with realistic assumption on DM

Need to remove the astro emission. Hard work!!!!



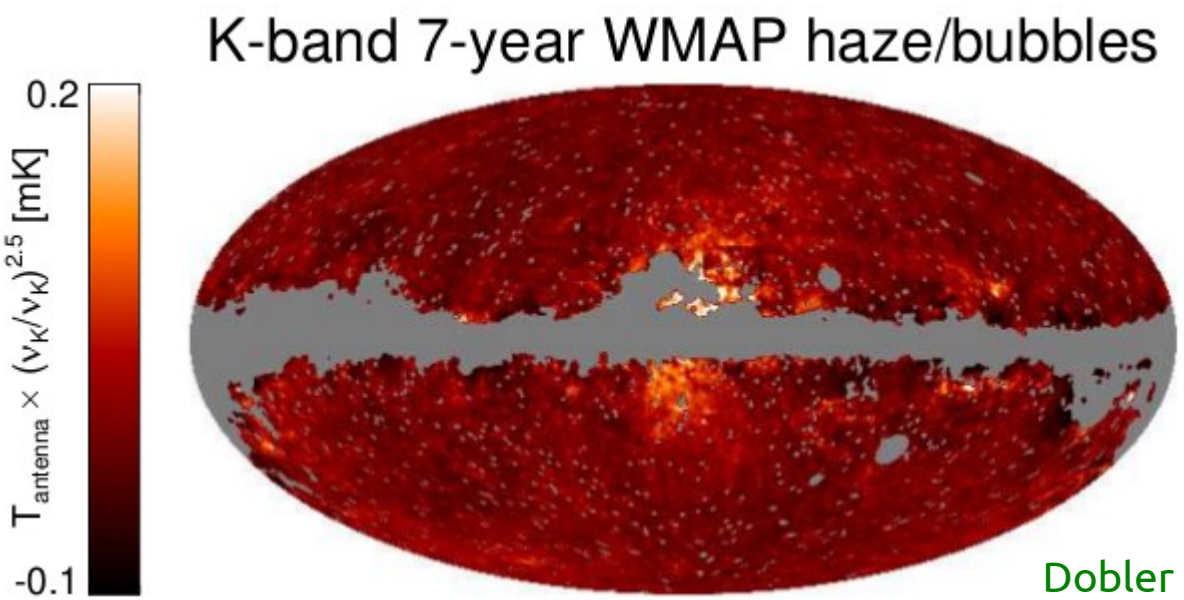
We have something similar! The microwave haze!

WMAP Haze

Discovered in WMAP data after subtraction of CMB and foregrounds

Roundish spot around GC. Finkbeiner 2004

Spectrum suggest synchrotron from hard population of electrons



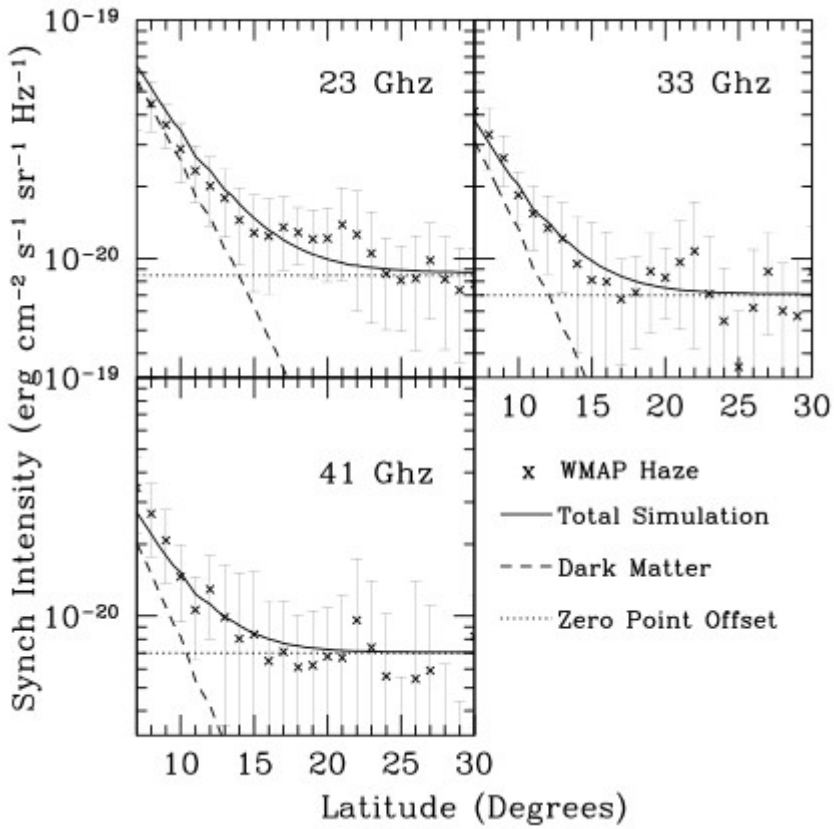
Dobler 2012

WMAP Haze & DM

DM works fine with reasonable assumptions on B field and propagation

No real preference for the DM mass: from GeV to TeV DM

Light WIMPs (around 10 GeV) need large magnetic fields close to the GC



Hooper, Linden 2011

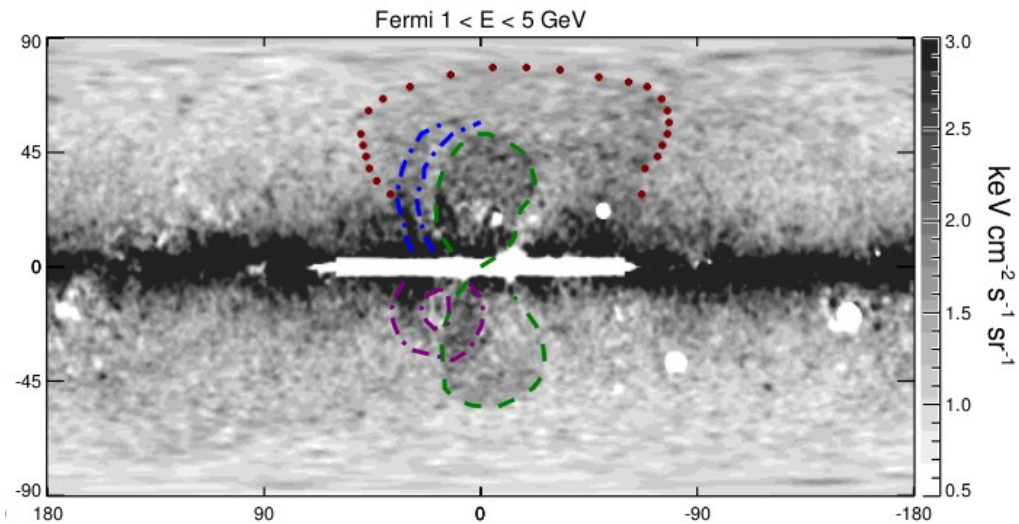
WMAP Haze & Fermi bubbles

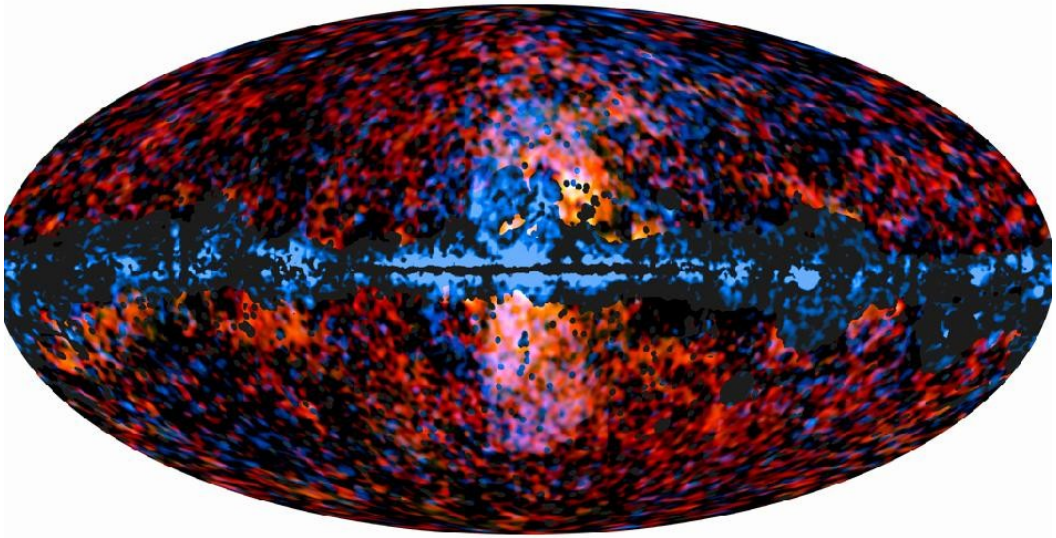
These 2 emissions seem to be correlated

WMAP Haze can be the synchrotron counterpart of IC Fermi bubbles

DM option for haze seems more involved

Maybe with prolate halos + anisotropic diffusion? Dobler et al. 2011





Su et al. 2010

http://www.nasa.gov/mission_pages/planck

Searches of DM signals

Microwave haze : DM is an option

WMAP haze and Fermi bubbles show that the GC region has complicated dynamics: a complication for DM searches and potential issue for the robustness of the constraints.

To search DM signals we need good templates to understand the bkg:

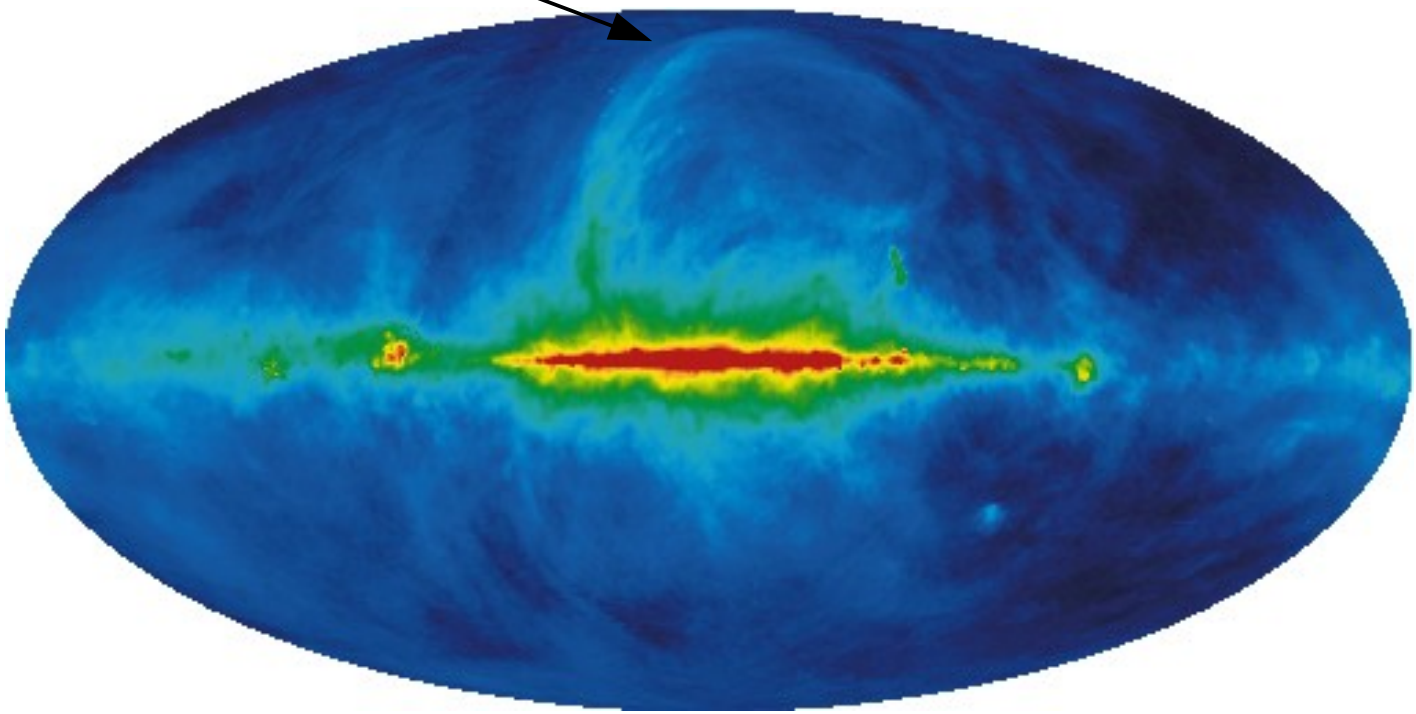
LOFAR (10-240 MHz)

PLANCK microwave

Multiwavelenght analysis to check the mechanism at work

Where to look for DM signals?

Diffuse extragalactic radio emission can be extracted from the maps looking at high latitudes



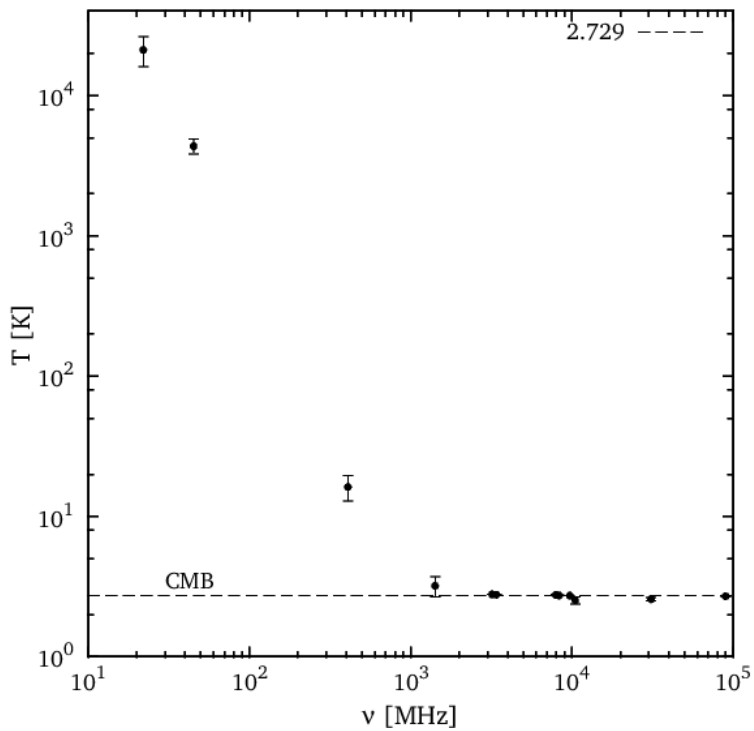
Extragalactic isotropic radio background

Data from low frequency surveys 22 MHz 45 MHz 408 MHz 1420 MHz +

ARCADE-2 3.2 GHz – 90 GHz

Galactic emission estimated with 2 methods:

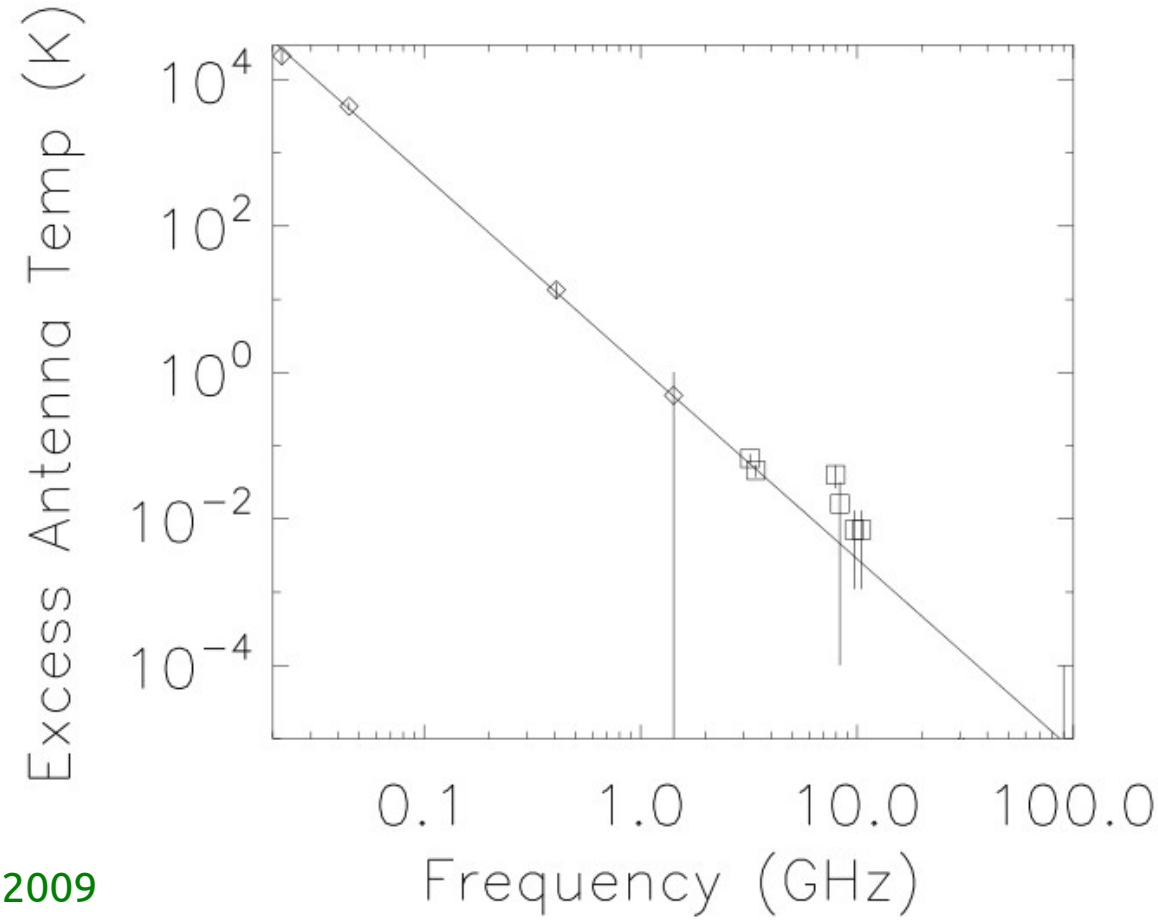
plane parallel model & correlation with CII map Fixsen et al. 2009, Kogut et al. 2009



Extragalactic isotropic radio background

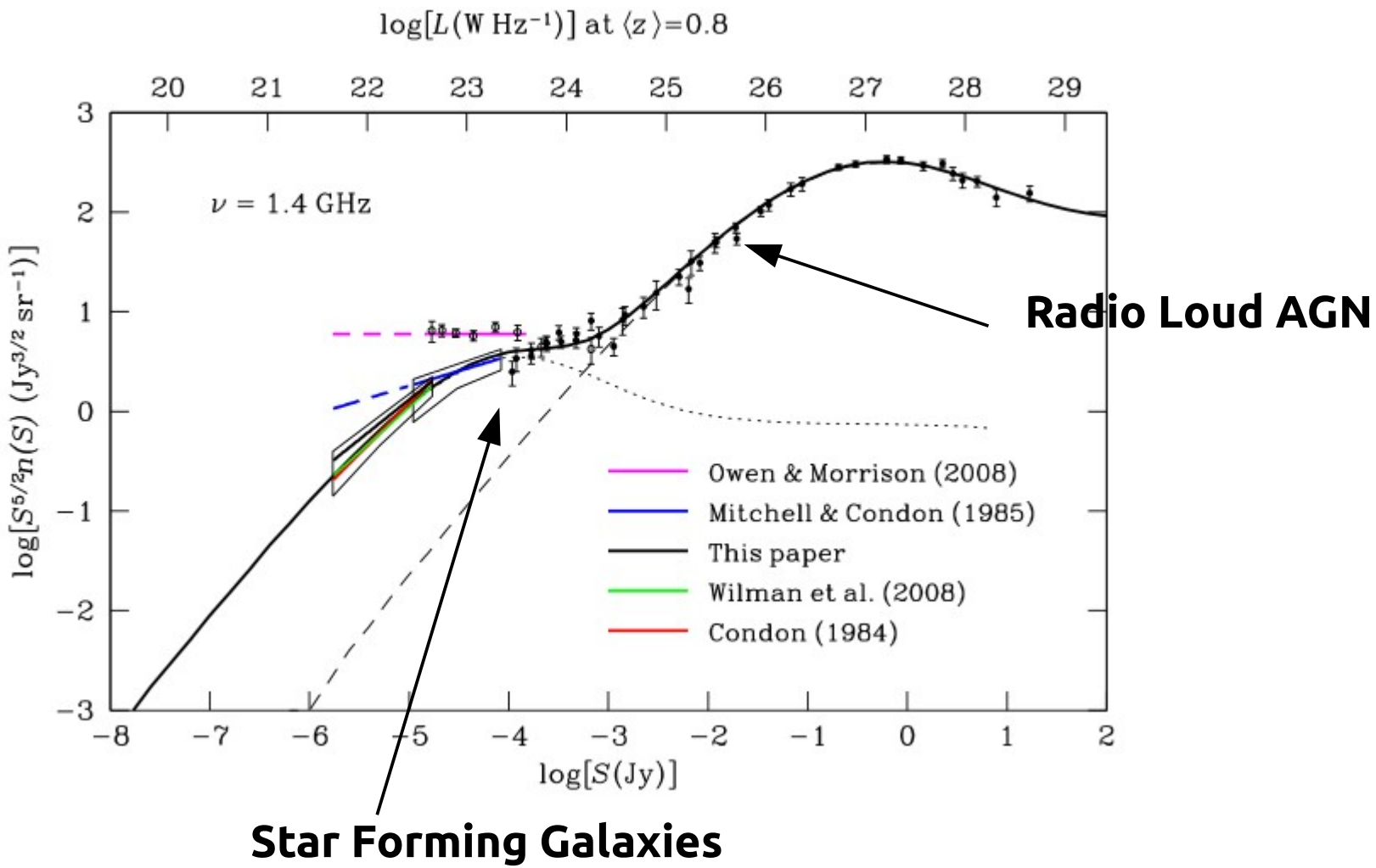
Removing the CMB monopole the extragalactic bkg is detected < 10 GHz

Consistent with a power law with index -2.62



Fixsen et al. 2009

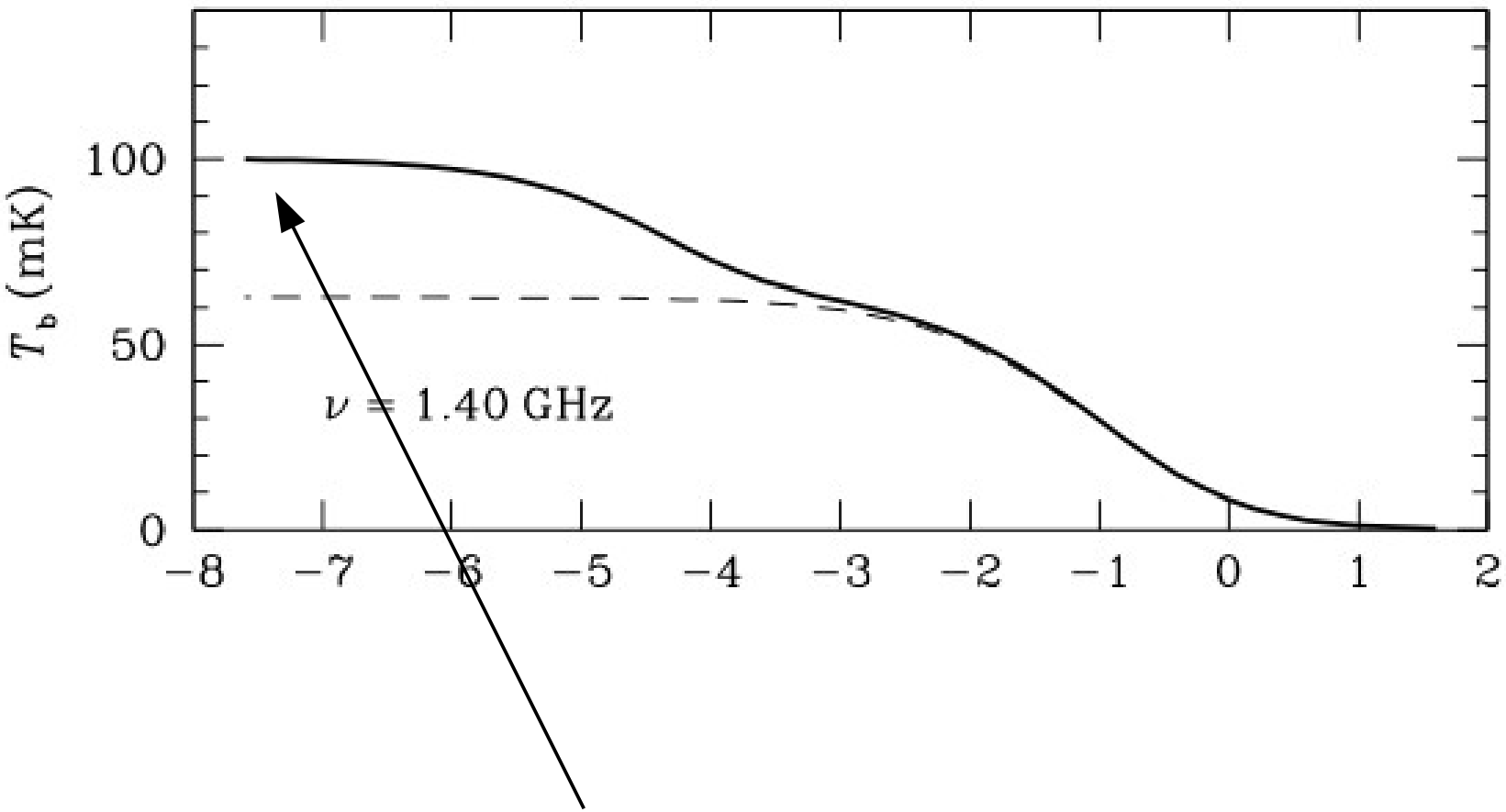
Source number counts



Vernstrom, Scott, Wall 2012

Source number counts

CRB inferred by ARCADE-2 is 480 mK !



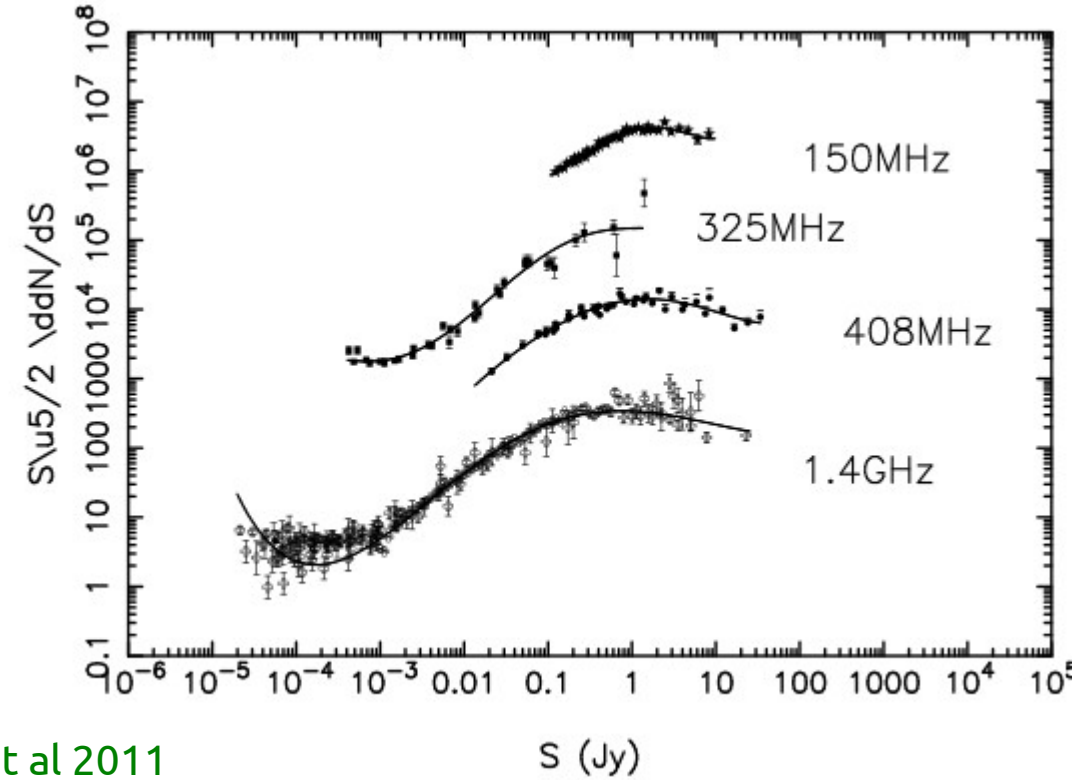
Expected contribution of radio sources to CRB

Vernstrom, Scott, Wall 2012

ARCADE excess

Also counts at other frequencies give the same result:

the extragalactic radio bkg is a factor 5 higher than expected

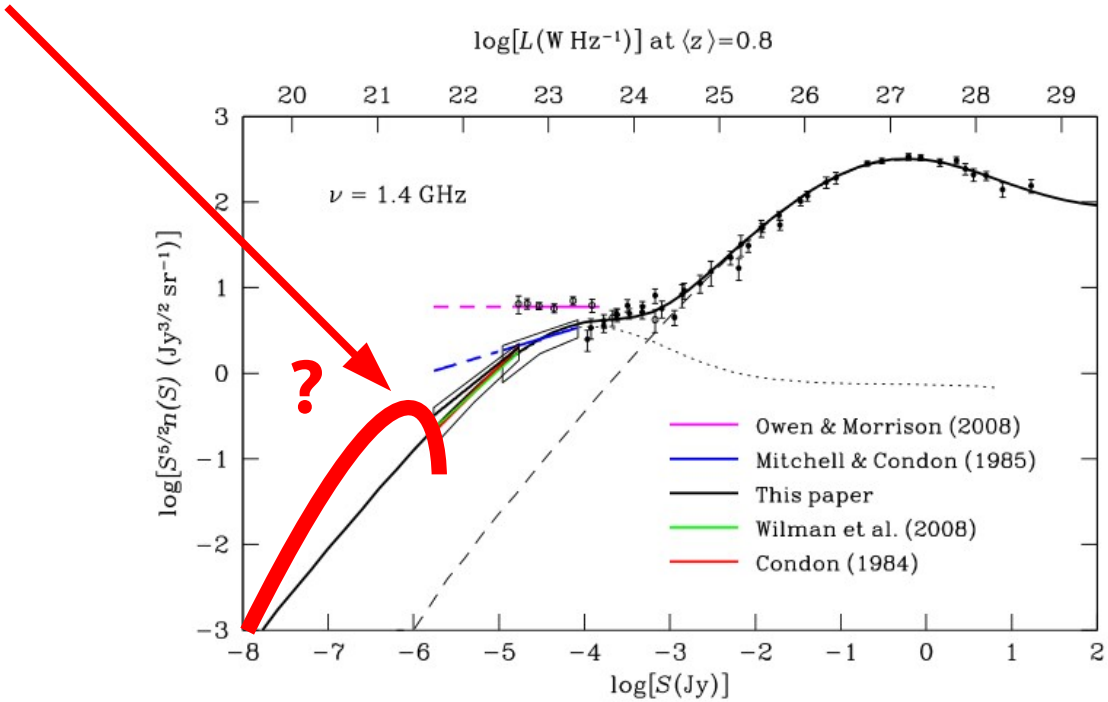


Vernstrom et al 2011

See also Singal et al. 2010, Ponente et al. 2011, Gervasi et al. 2008

Possible explanation of the ARCADE excess

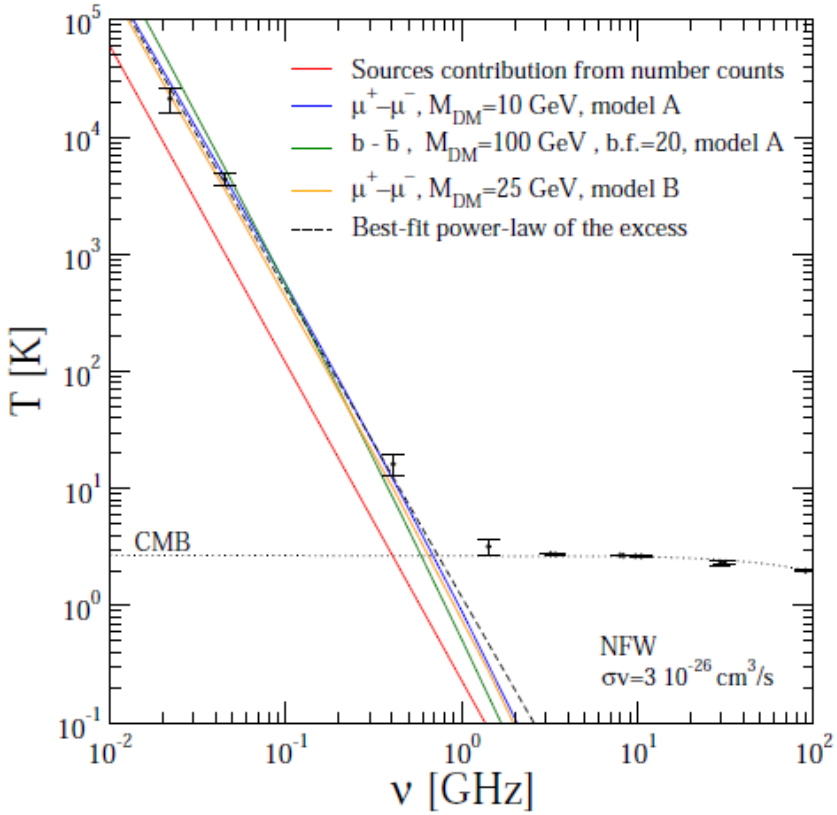
Undetected population of radio sources with < μJy fluxes



Potential problems with standard astro-sources, e.g. constraints from gamma and X-rays (diffuse emission intragalactic) or Infrared (for Star Forming galaxies)

Singal et al 2010, Lacki 2010, Ponente et al. 2010

DM interpretation of the ARCADE excess

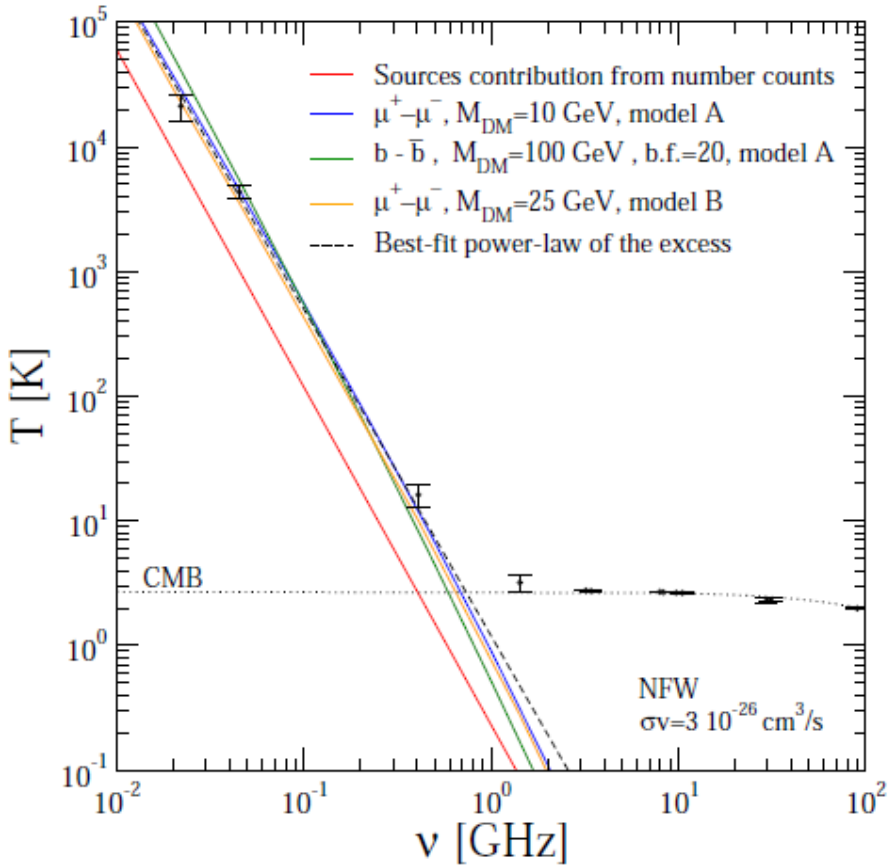


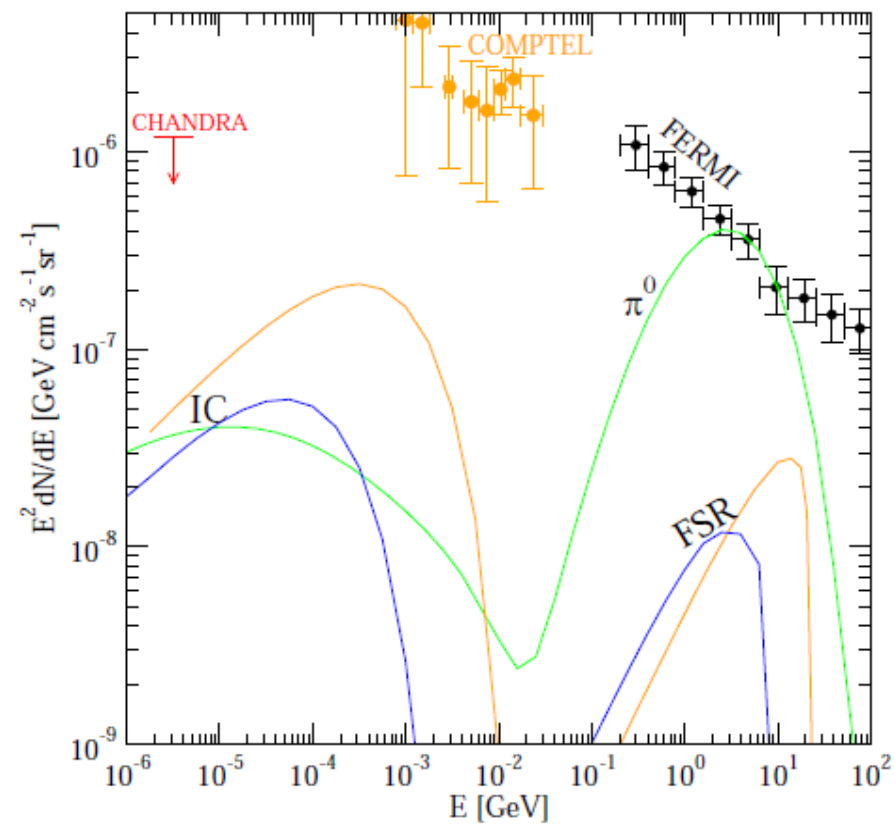
Fornengo, Lineros, Regis, M.T. 2011

Faint and numerous extragalactic DM halos can explain the excess.

Good fit only with leptonic channels.

DM interpretation of the ARCADE excess



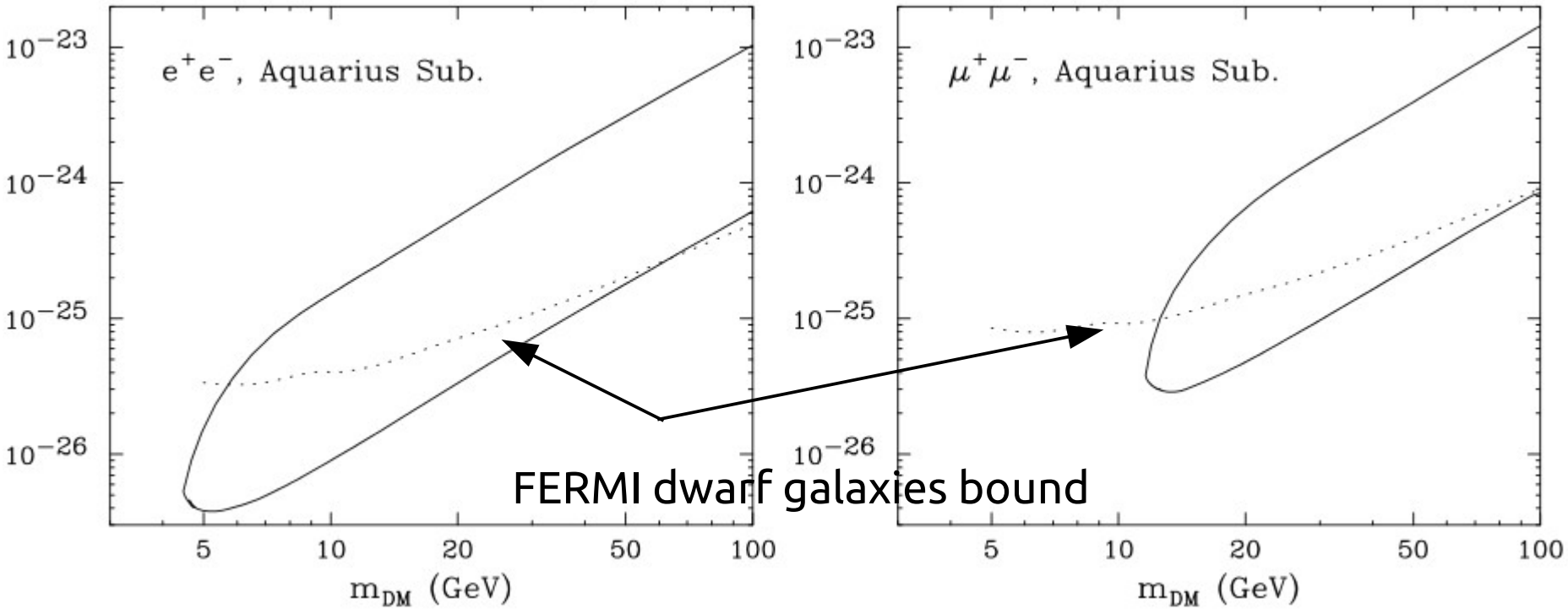


Extragalactic DM signal can explain the excess.

Ok with bounds from extragalactic gamma-ray background

DM interpretation of the ARCADE excess

Hooper, Belikov, Jeltema,Linde,Profumo,Slatyer 2012



DM interpretation can work for reasonable assumption of clustering and Bfields

Ok with gamma-ray constraints.

ARCADE-2 mistery, possible options:

1) The radio background estimated by ARCADE-2 collaboration is off, for instance because is contaminated by galactic foreground

2) There is an undetected population of faint and numerous radio sources with small enough emission at other wavelenghts

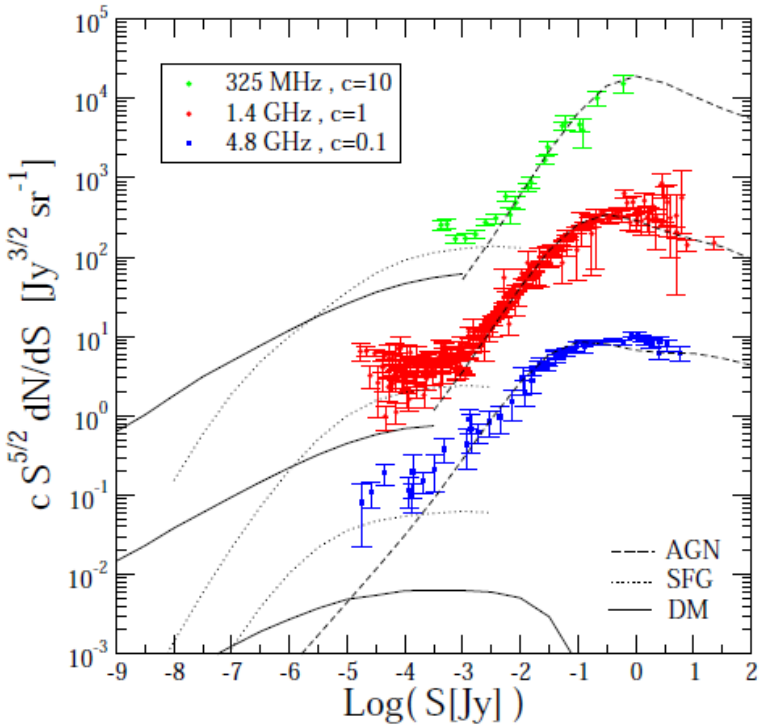
DM is an option. Difficult to test it since the the signal is featureless

Milder assumption:

DM contribution to the ERB intensity comparable to astro contribution

DM can dominate number counts at sub μJy fluxes

Future telescopes: EVLA and ASKAP soon, SKA (long term project)



Fornengo, Lineros, Regis, MT 2012

Conclusions

Radio observations set interesting constraints on the DM parameters

DM possible option for some puzzling observation

Potentially interesting prospects for extra-galactic DM searches with future surveys.

However many uncertainties both in the modeling of DM signal and astro-background

Need data from Planck, LOFAR, EVLA, ASKAP, SKA + other wavelengths

THANKS