UNIVERSITY OF CALIFORNIA
SANTA CRUZ

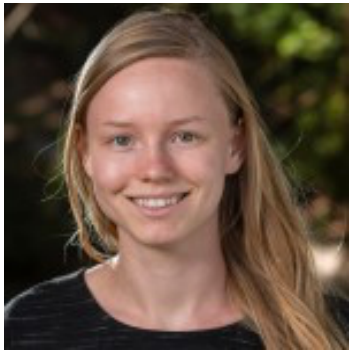
SCIPP
SANTA CRUZ INSTITUTE FOR PARTICLE PHYSICS

Multiwavelength Dark Matter Searches

Tesla Jeltema

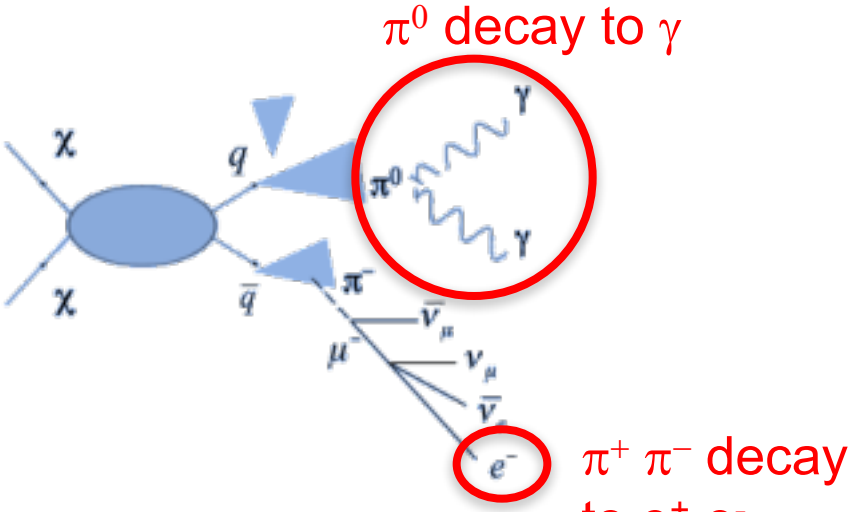
Santa Cruz Institute for Particle Physics
University of California, Santa Cruz

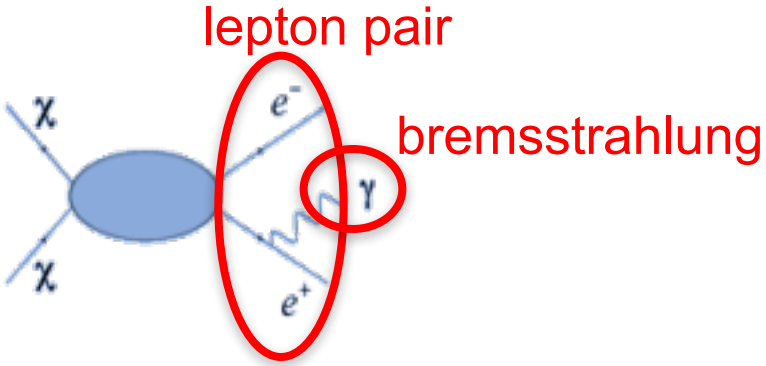
Alex McDaniel



Emma Storm

Dark Matter Annihilation Products





DM annihilation/decay products:

- Photons
- Electrons/positrons
- Neutrinos

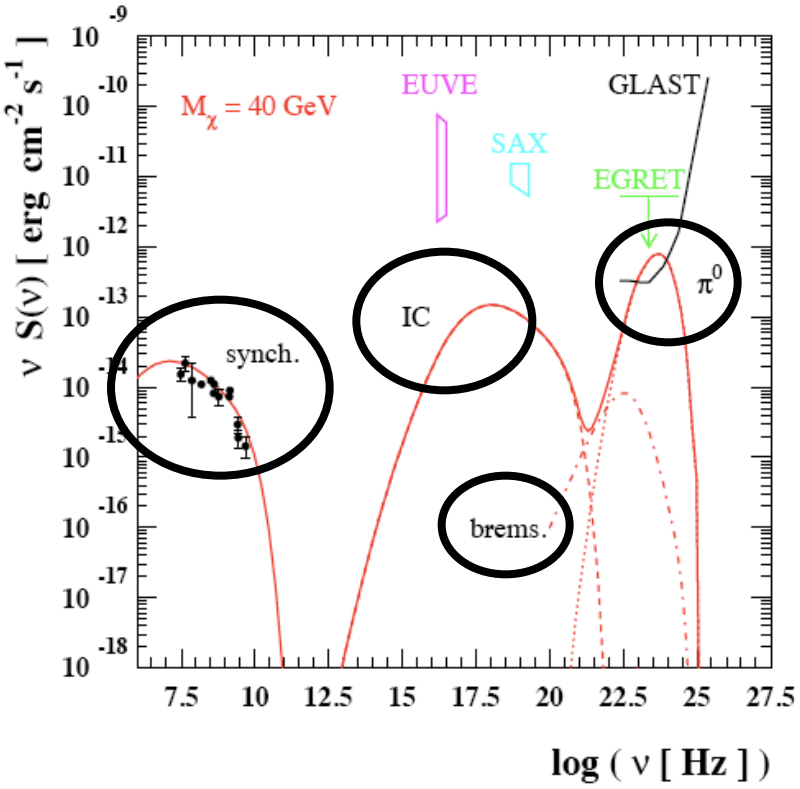
Multiwavelength Spectrum

- Dark matter annihilation/decay can lead to a broad spectrum of emission.

Gamma-ray: π^0 decay, direct production

X-ray: IC scattering of CMB by energetic e^+e^- produced

Radio: synchrotron emission in a magnetic field

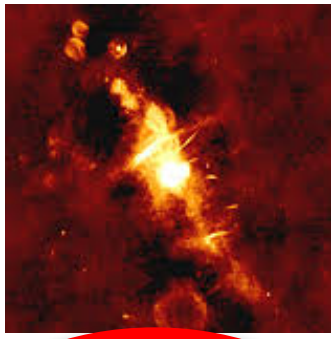


Example spectrum of DM annihilation in the Coma cluster (Colafrancesco et al. 2006)

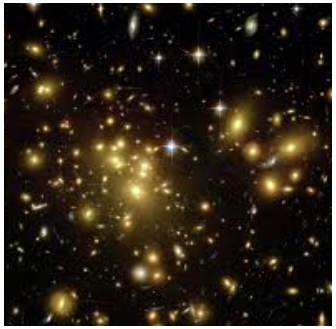
Targets for Dark Matter Searches

Dwarfs,
External Galaxies

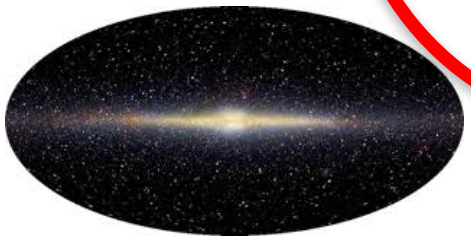
Galactic Center



Clusters of Galaxies



Diffuse: MW halo
Extragalactic



Considerations:

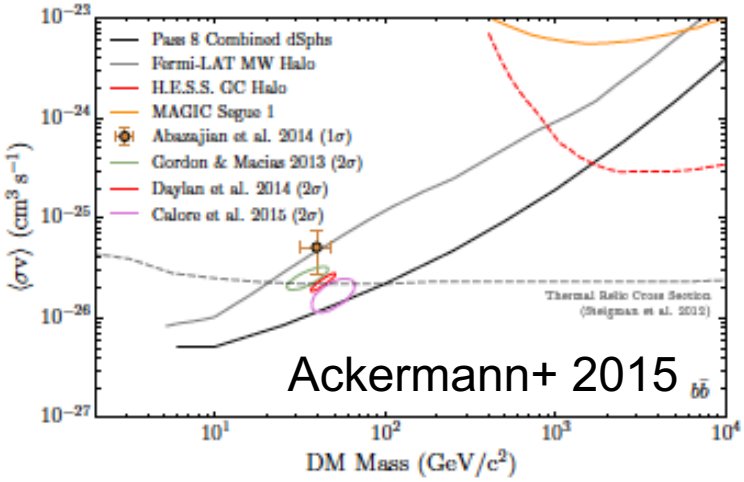
- "J-factor" (uncertainties in DM density, substructure, FOV)
- Astrophysical backgrounds (uncertainty in origin and modeling)

Secondary emission (IC, synchrotron):

- Particle diffusion
- Magnetic field

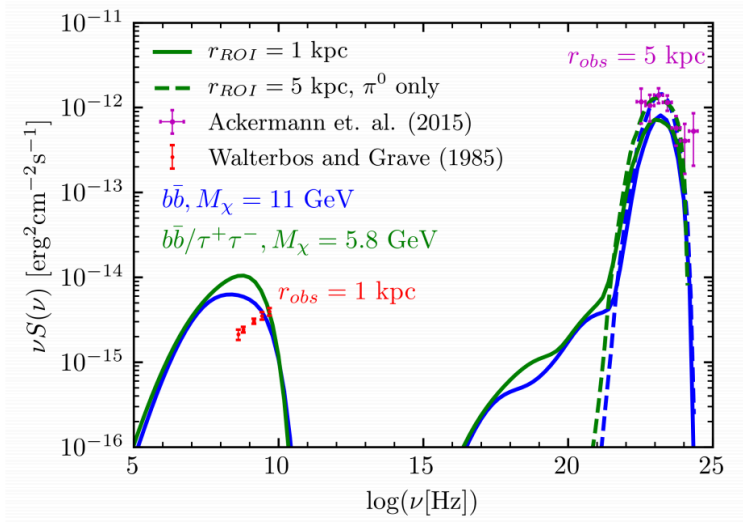
Targets for Dark Matter Searches

- Different targets have roughly similar predicted emission



Ackermann+ 2015

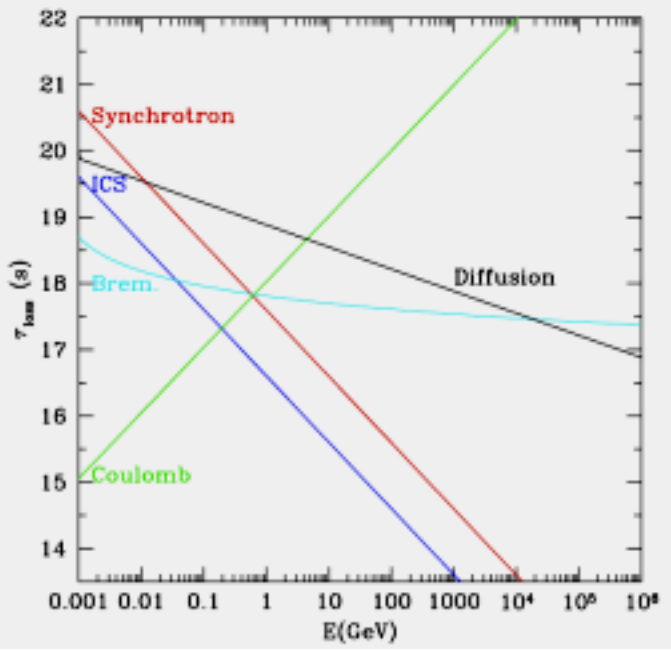
- A signal at one frequency often implies a corresponding signal at other frequencies



McDaniel+ 2018

Clusters for Dark Matter Searches

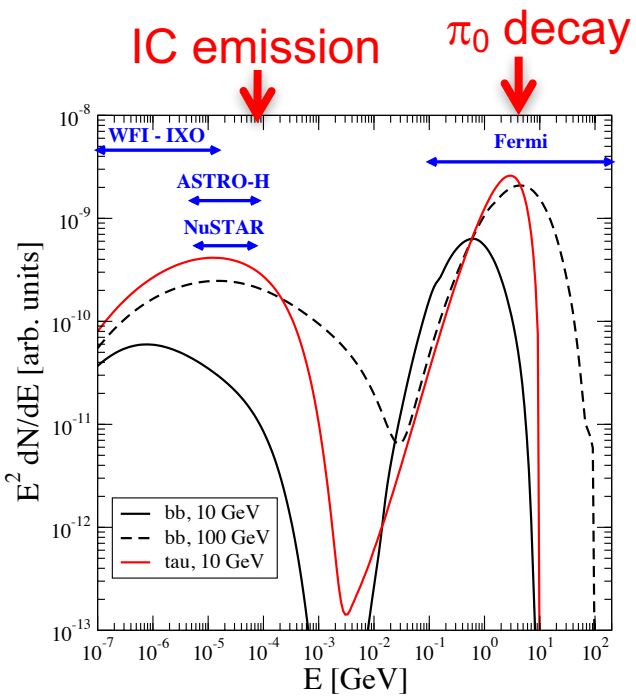
- Excellent for searches for secondary radiation:
  1. The energy loss timescale is much shorter than the diffusion time
  2. They have large-scale magnetic fields



Colafrancesco et al. 2006

X-ray Emission from Dark Matter

- IC emission from the scattering of the CMB or starlight by DM produced e^+ e^-.
- Current instruments are not competitive, but future instruments could be.



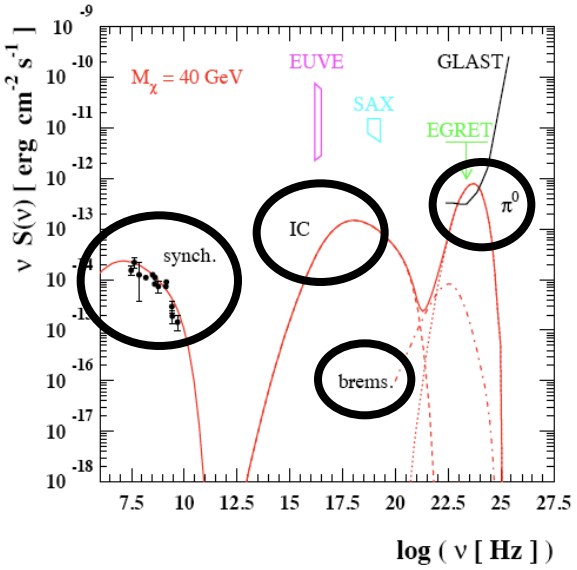
Jeltema & Profumo 2012

** X-rays of obvious interest for other DM candidates like the sterile neutrino

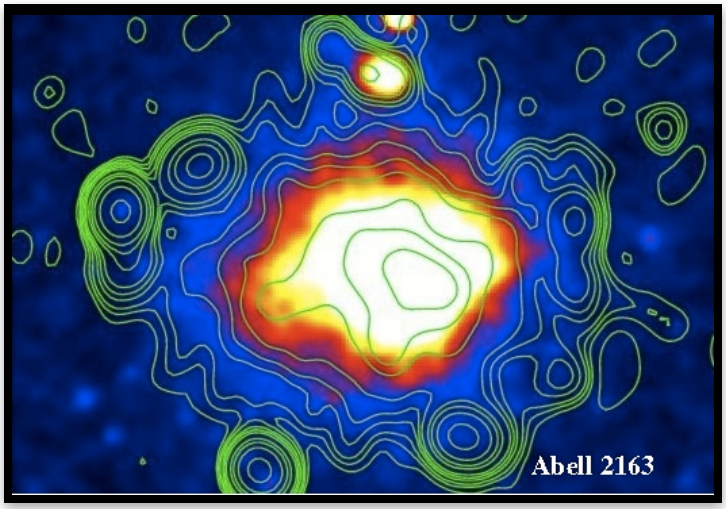
Radio Emission from Dark Matter

- Synchrotron emission from e^+ e^- produced in DM annihilation/decay in cluster B-fields.

- Some clusters have detected diffuse radio emission, but many do not or only host weak emission

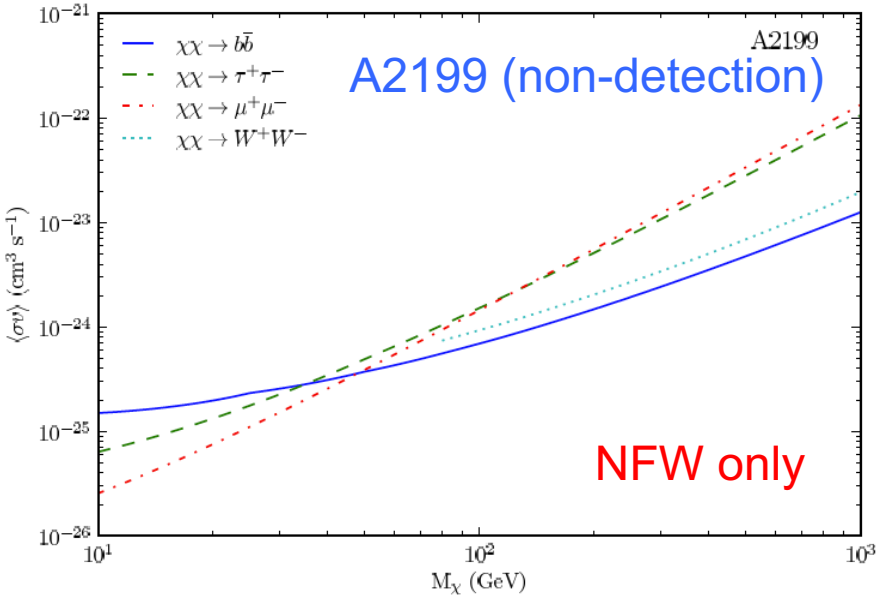


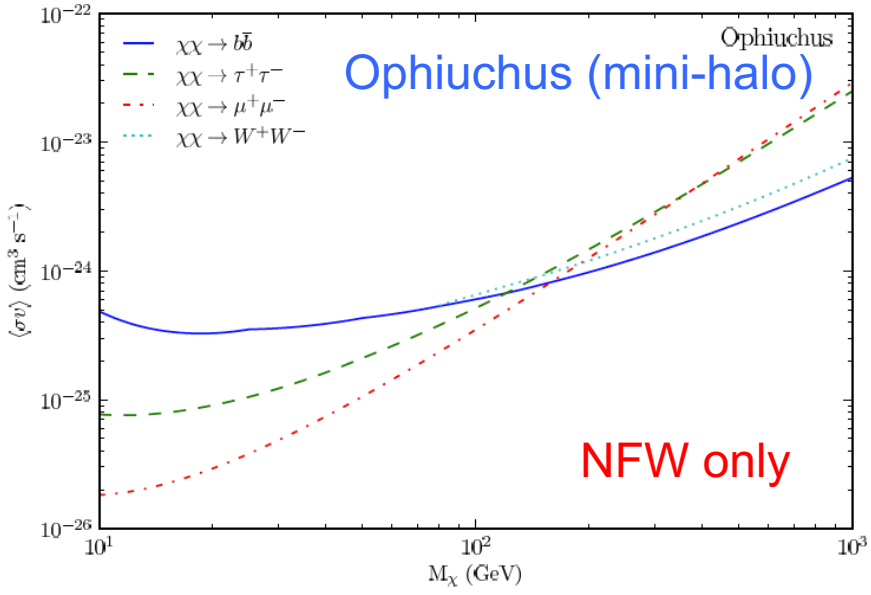
Colafrancesco et al. 2006



Radio Observations of Clusters

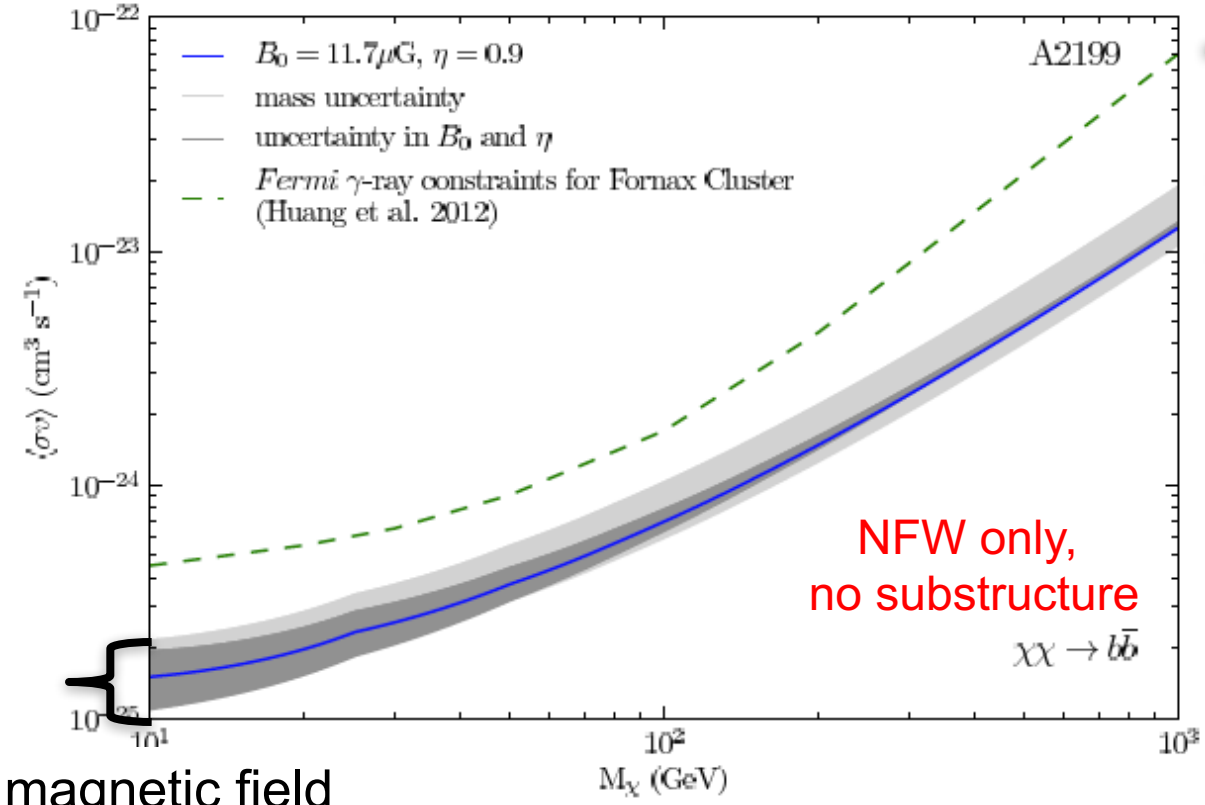
- The limits on DM annihilation in nearby clusters from radio emission
- Limits approach thermal cross-section at low mass even for a conservative density profile





Storm, Jeltema, Profumo, & Rudnick 2013

Dark Matter Annihilation Limits



Best individual Fermi cluster limits

cluster mass uncertainty

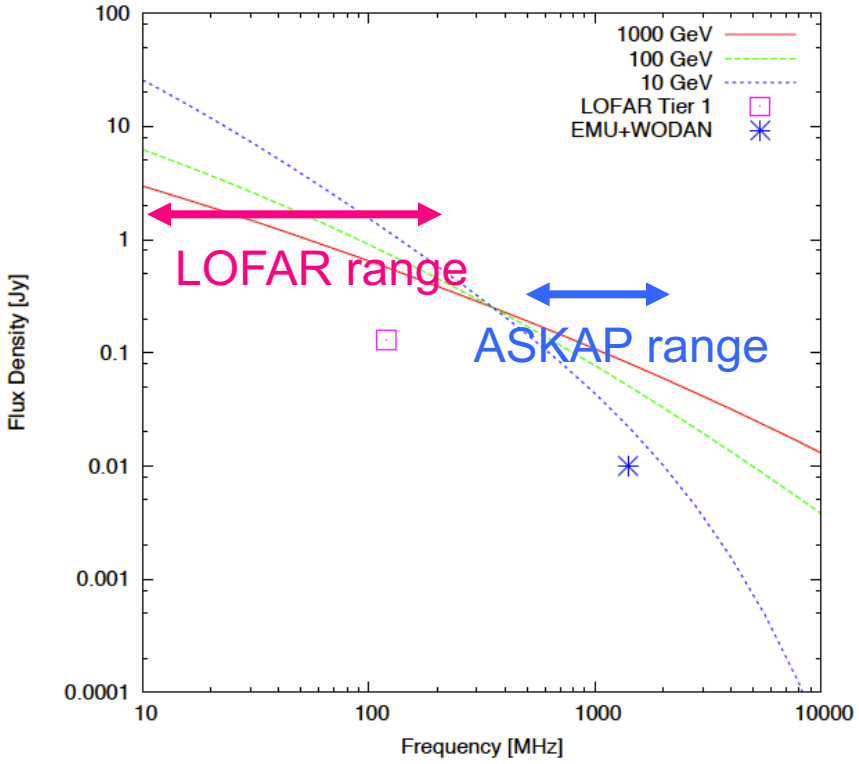
magnetic field uncertainty

Storm, Jeltema, Profumo, & Rudnick 2013

Future Radio Observations

Large near term gains from:

- New low frequency capabilities (LOFAR, LWA)
- Increased sensitivity at GHz frequencies (ASKAP, APERTIF, MeerKAT)

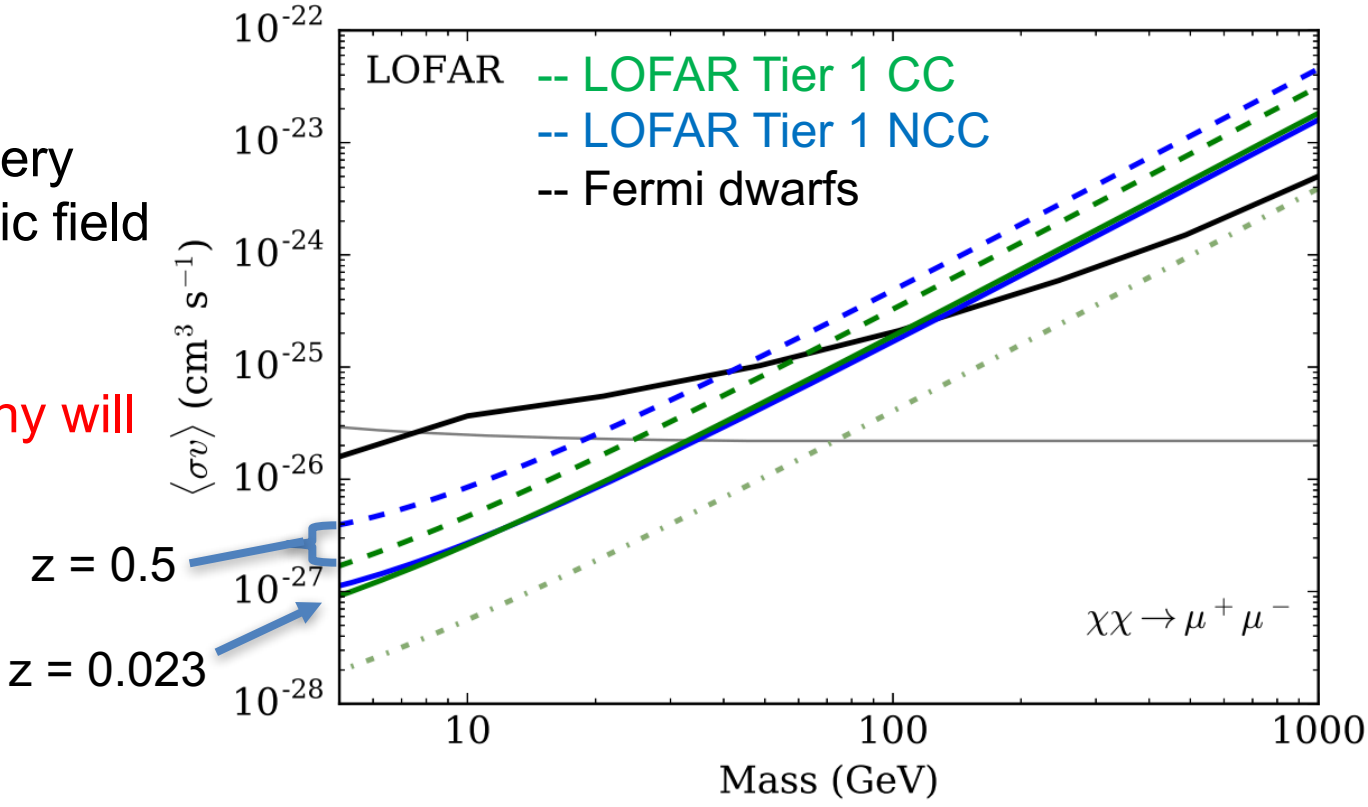


Predictions for LOFAR

- Predicted constraint for non-detection of Coma mass cluster in LOFAR Tier 1 survey (shallow, full northern sky)

The signal is not very redshift or magnetic field dependent.

If they light up many will light up!

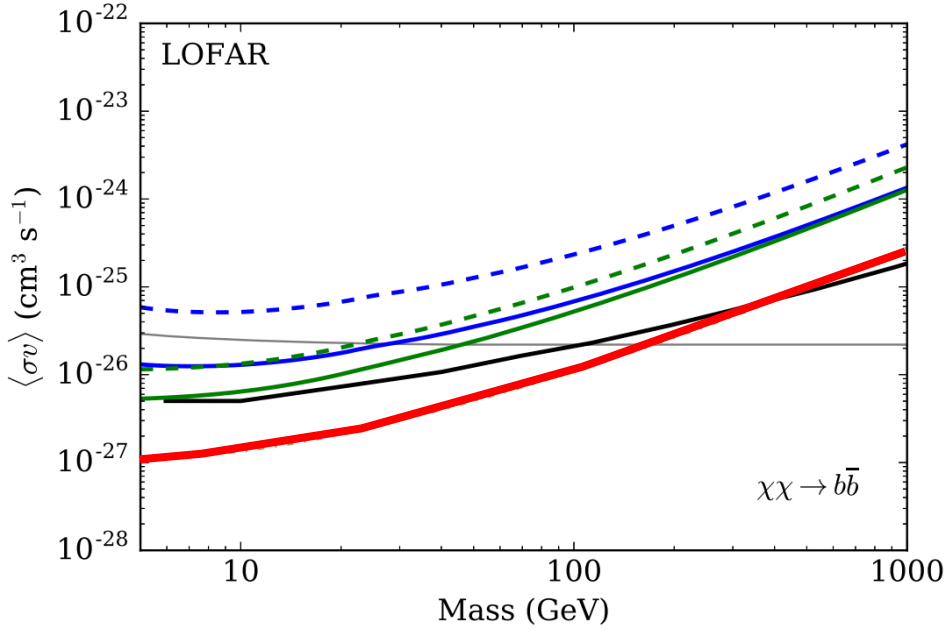


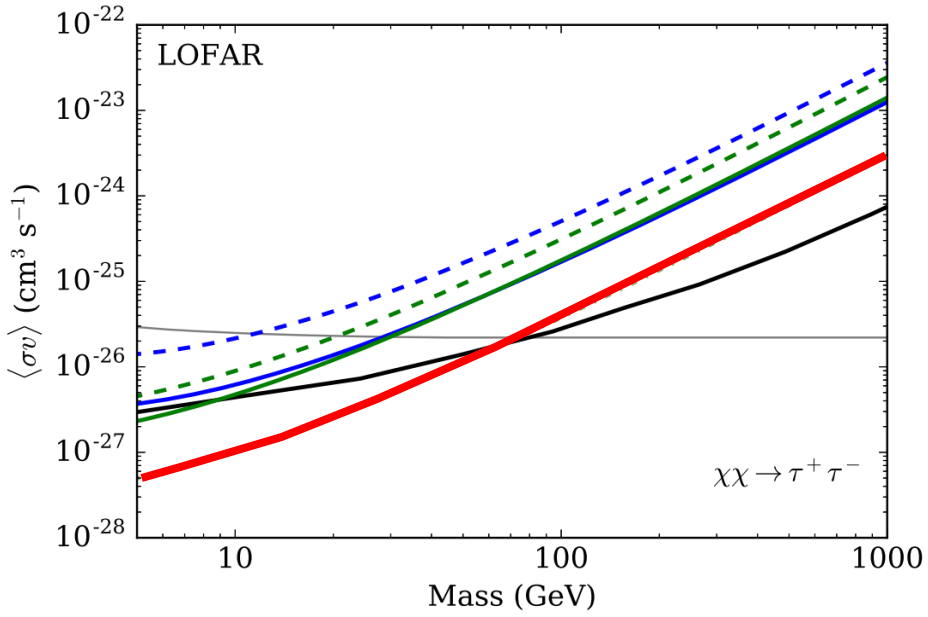
Storm et al. 2017

Future Radio Observations

Have the potential to be more constraining than all current indirect DM searches

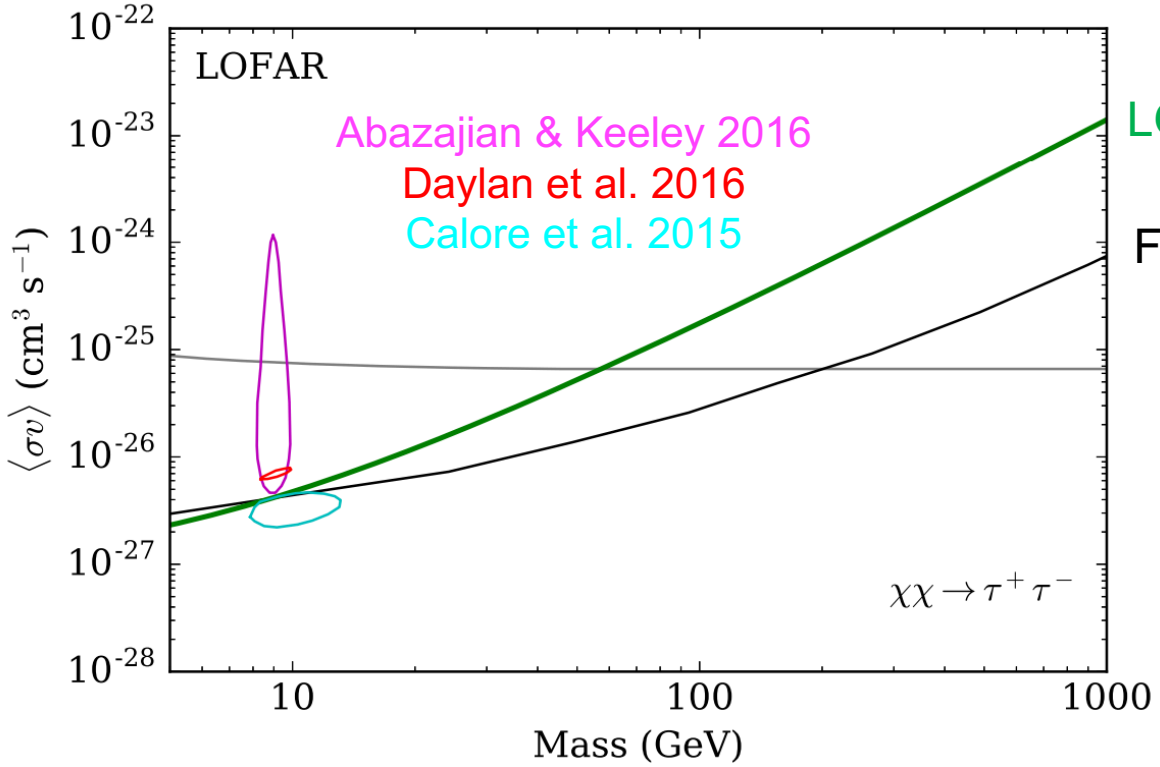
-- LOFAR Tier 2
-- LOFAR Tier 1 CC
-- LOFAR Tier 1 NCC
-- Fermi dwarfs





Storm et al. 2017

Future Radio Observations



LOFAR Tier 1, low-z

Fermi dwarfs

Independent check of signals at other frequencies

Storm et al. 2017

RX-DMFIT

Public tool to model multiwavelength emission from dark matter

https://github.com/alex-mcdaniel/RX-DMFIT

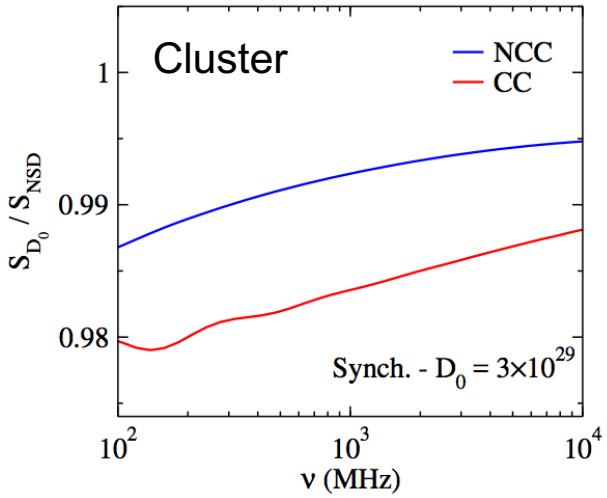
Customizable astrophysical and particle parameters including:

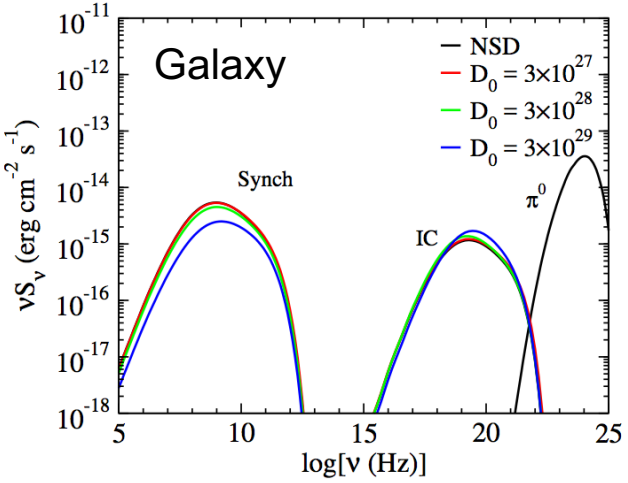
- Diffusion of charged particles
- All relevant radiative energy losses
- Magnetic field modelling

~15 physical parameters for size, magnetic field strength and profile, dark matter density profile, diffusion, thermal electron density, starlight, etc. can be chosen

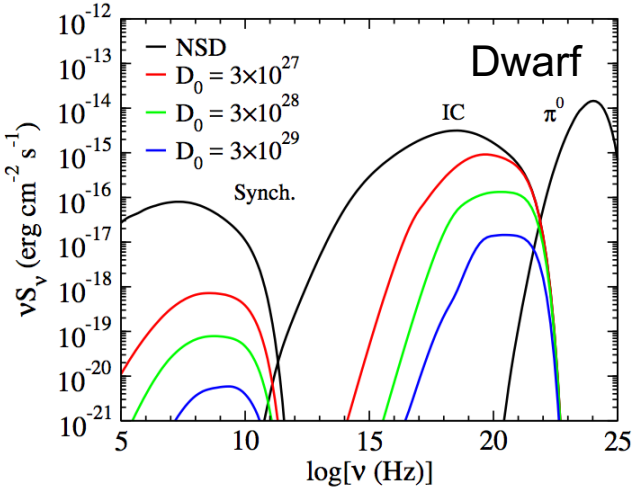
McDaniel et al. 2017

RX-DMFIT - Diffusion





- Can specify diffusion coefficient and energy scaling (multiple parametrizations)

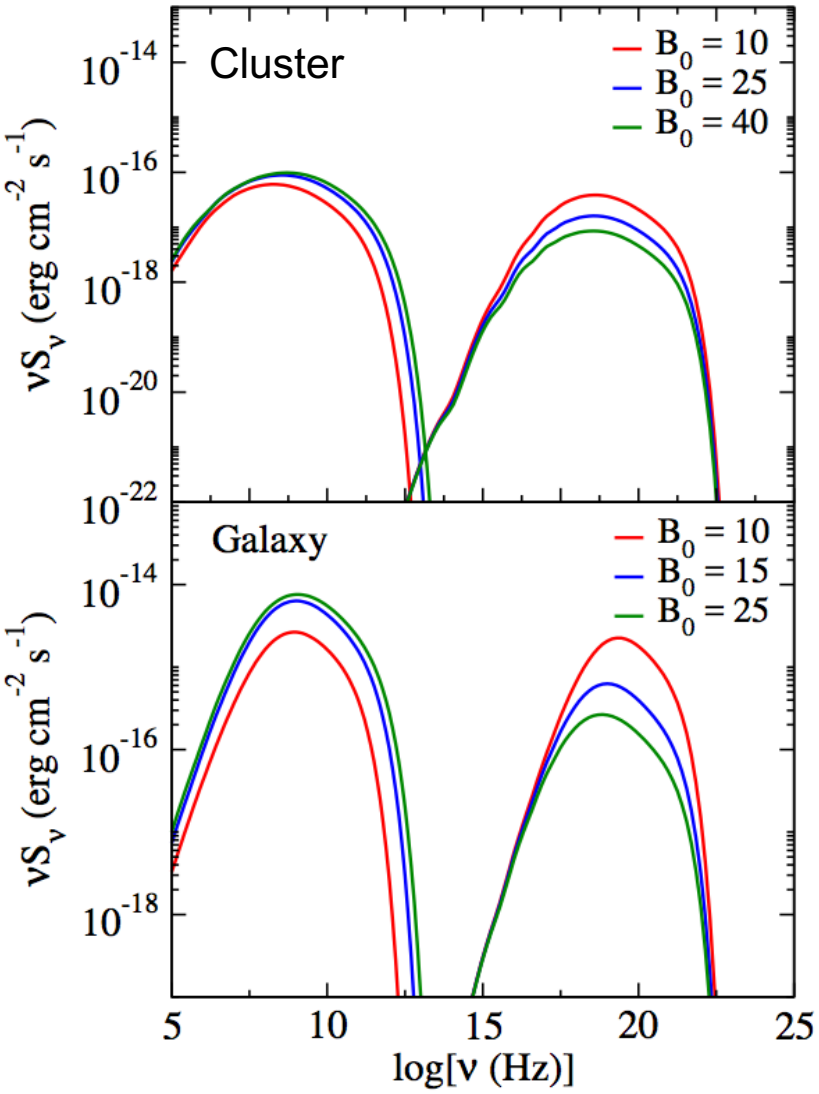


McDaniel et al. 2017

RX-DMFIT – Magnetic Field

RDMFIT

- Can specify central field strength and radial scaling (multiple parametrizations)

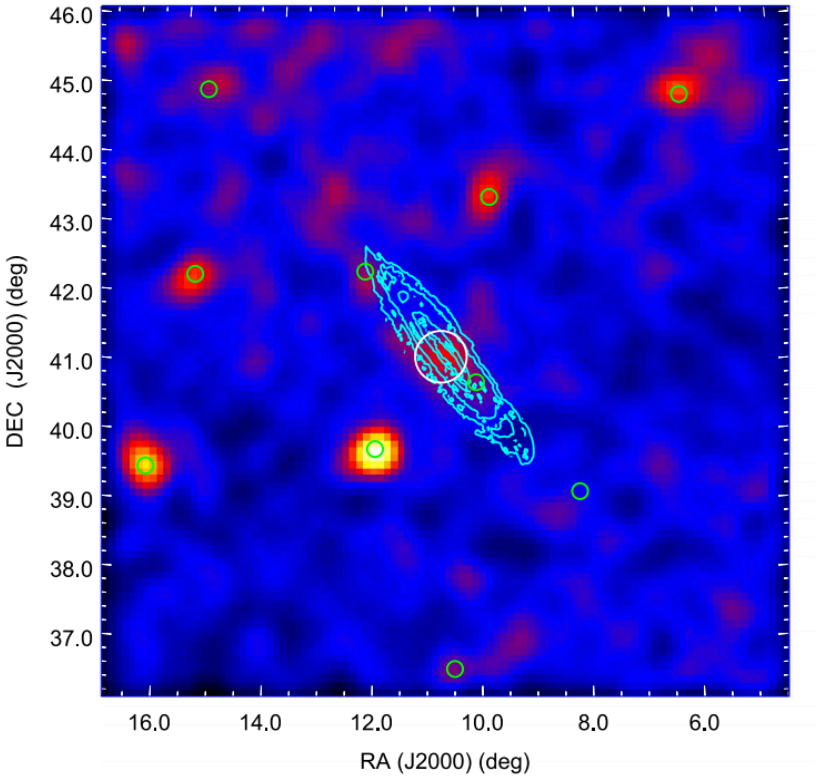


McDaniel et al. 2017

Application to Andromeda

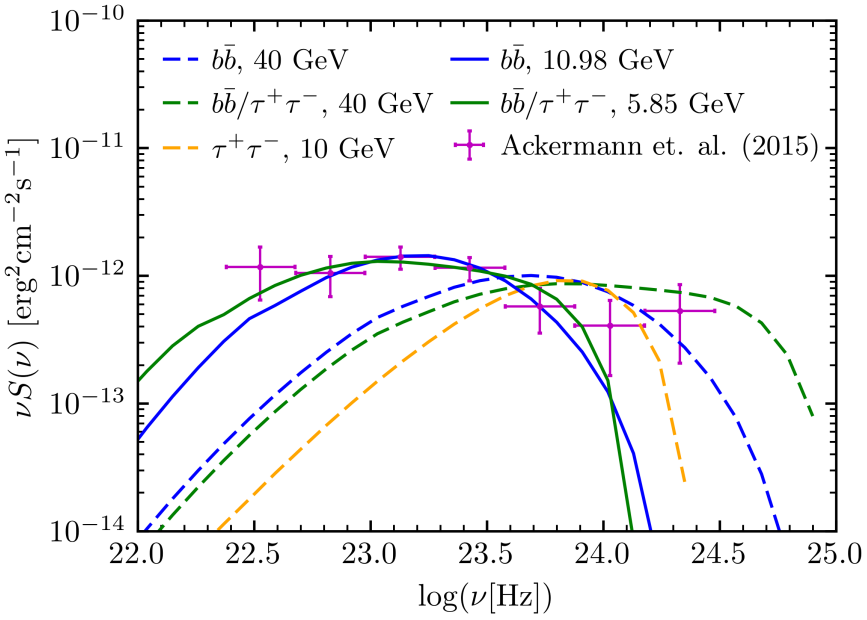
Observations of M31 and M33 with the *Fermi* Large Area Telescope: A Galactic Center Excess in Andromeda?

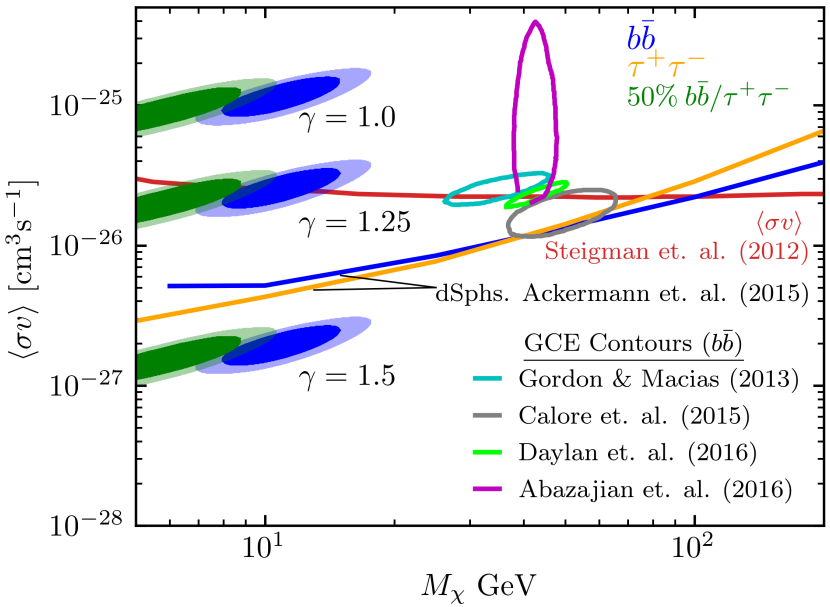
Ackermann et al. 2017



- Fermi-LAT detects extended gamma-ray emission from M31
- Emission does not appear to trace gas or star formation

M31 – Gamma-Ray Emission



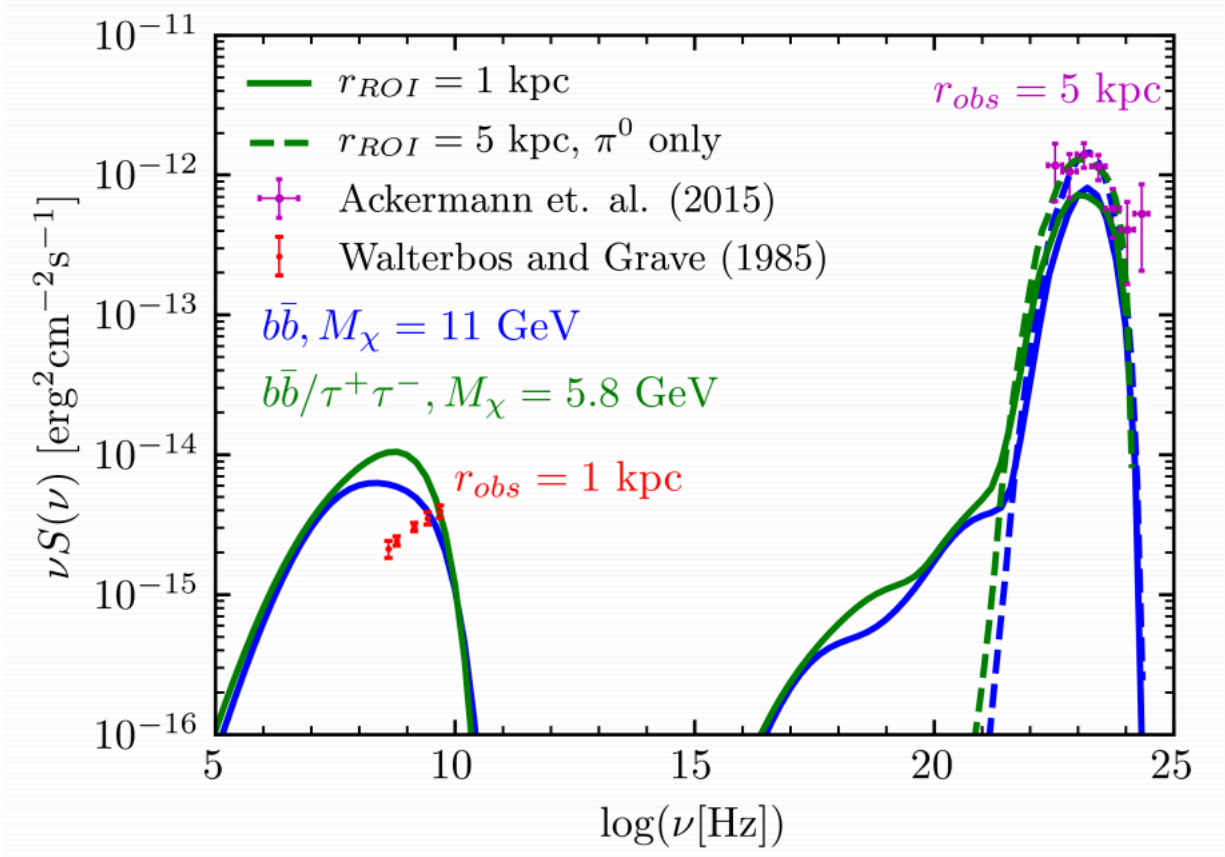


- DM spectra fitting the GC excess do not fit well M31, which prefers lighter mass
- Consistency with dwarf limits requires a relatively steep slope of DM density profile

McDaniel, Jeltema, Profumo 2018

M31 – Radio Comparison

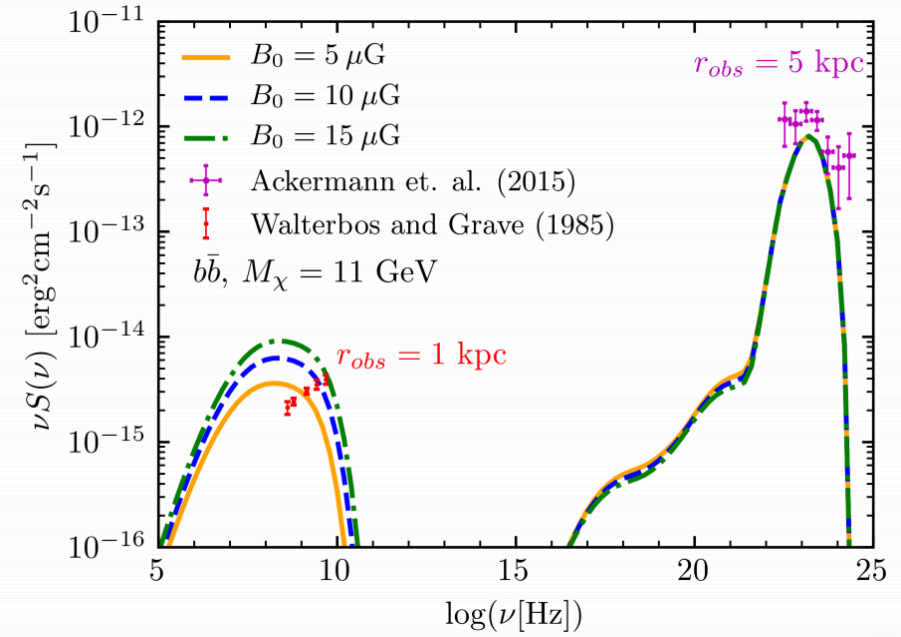
- Dark matter models which fit the gamma-ray emission tend to over predict the observed radio emission



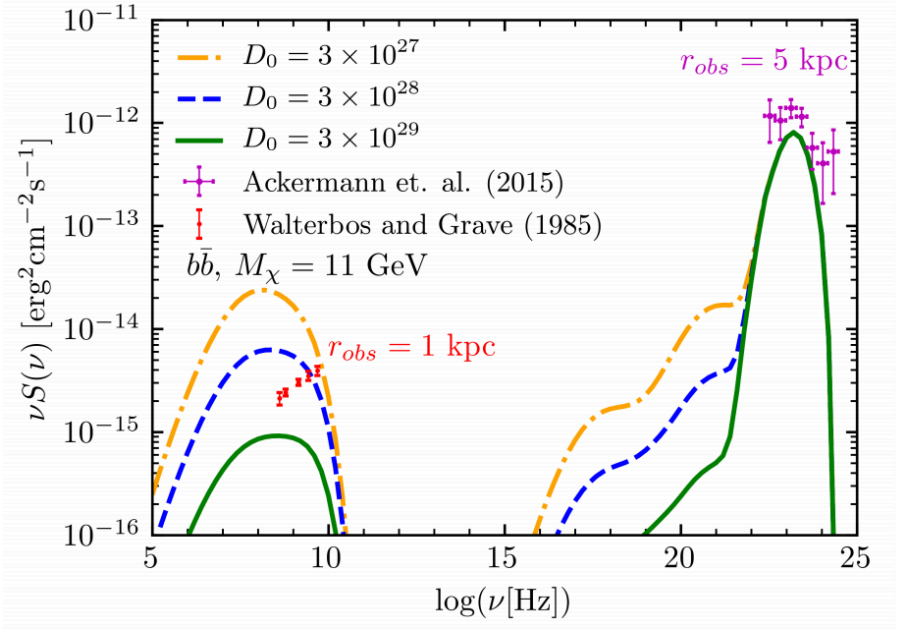
McDaniel, Jeltema, Profumo 2018

M31 – Radio Comparison

Varying magnetic field



Varying diffusion



- Varying the magnetic field does not relieve the tension. High enough diffusion can.

McDaniel, Jeltema, Profumo 2018

Conclusions

The use of multiple probes/wavelengths will be critical to identifying and understanding a dark matter signal.

(Radio rules!)

- Radio observations with upcoming instruments/surveys can be particularly constraining
- Secondary signals require understanding systematics associated to astrophysical conditions – RX-DMFIT

Thank you!