# Hunting dark matter with a MeerKAT

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DARK MATTER

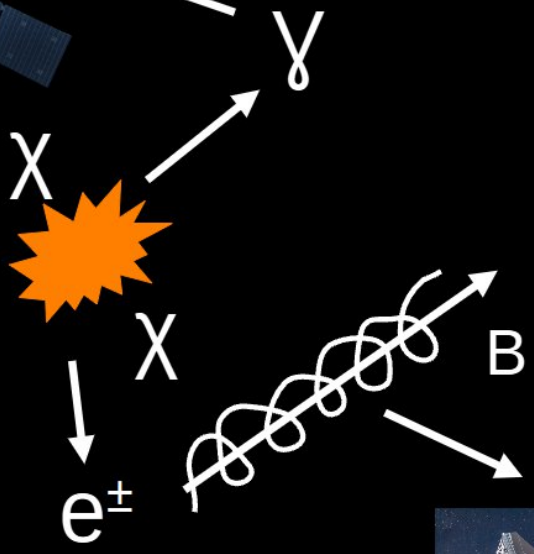
UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

# Talk outline

- Indirect detection in radio
- Previous searches with radio telescopes
- MeerKAT and the MGCLS
- Simulating MeerKAT and dSphs
- MeerKAT and Axions
- Conclusion


So how do we search for it?

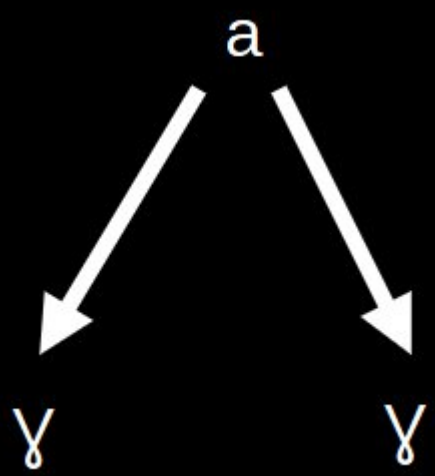
# Indirect detection: WIMPs


For large DM masses
(> 5 GeV)

# Indirect detection: Axions

Plain old decay (very slow)




Photons at frequencies given by energy of axion

- Narrow emission line
- Frequency at half axion mass
- For $m < 10^{-4}$ eV this is radio
- Stimulated decay
- Need large photon background at same frequency

# Why MeerKAT?

- High angular resolution (resolve small sources)
  Need to subtract point sources to see diffuse
- High sensitivity (faint DM emissions)
- Wide frequency bands
- Many frequency channels (line searches)

# WIMPs

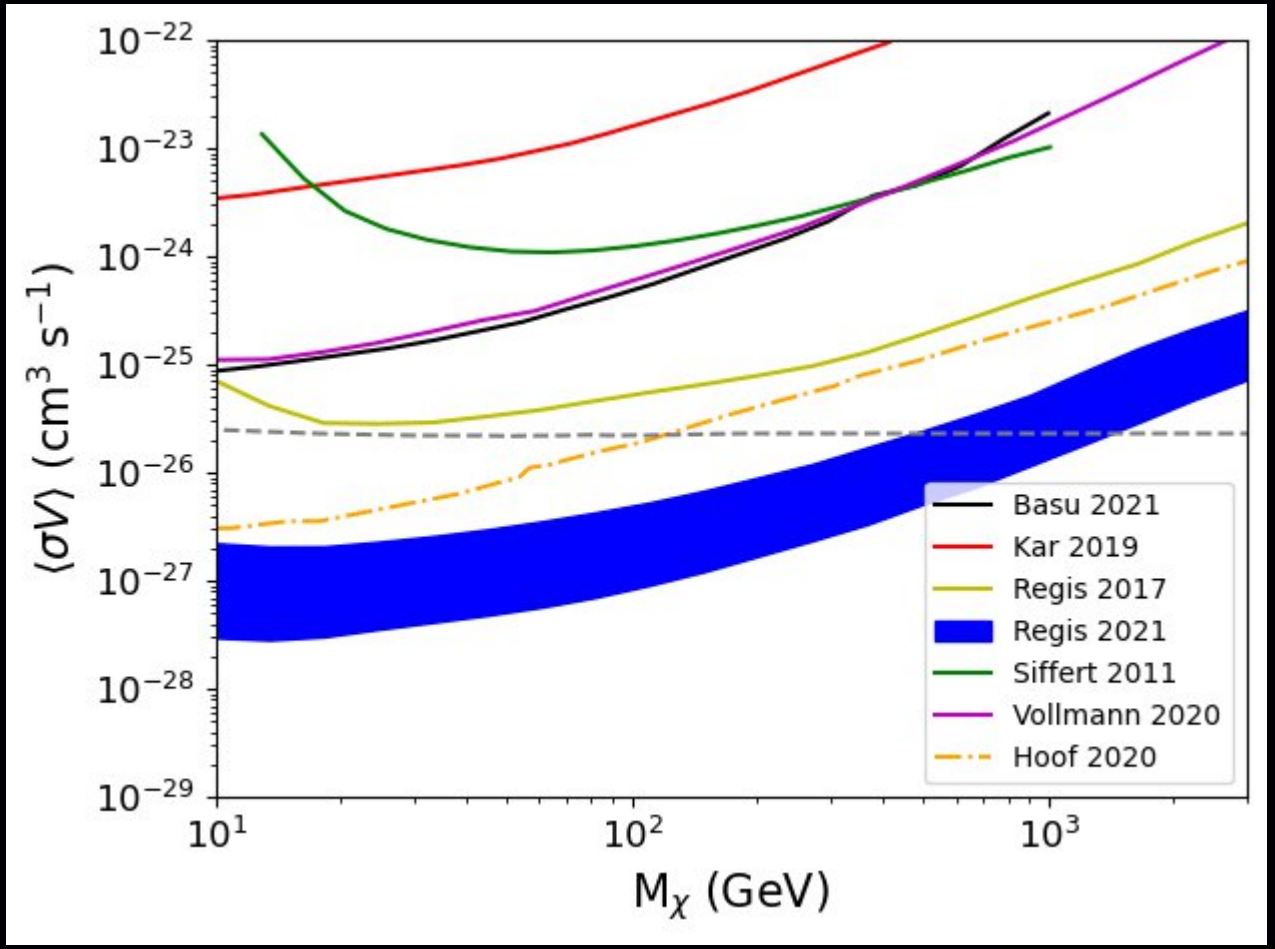
# Solving diffusion equations

$$\frac{d\,\psi}{d\,t} = \nabla(\mathrm{D(E,r)}\nabla\psi) + \frac{d}{dE}(\mathrm{b(E,r)}\psi) \; + \; \mathrm{Q(E,r)}$$

- Our own code: DarkMatters (will be public soon)
- Crank-Nicolson discretisation
- Accelerated ADI solver like Galprop
- Matrix equations solved with sparse solver
- Fast and accurate

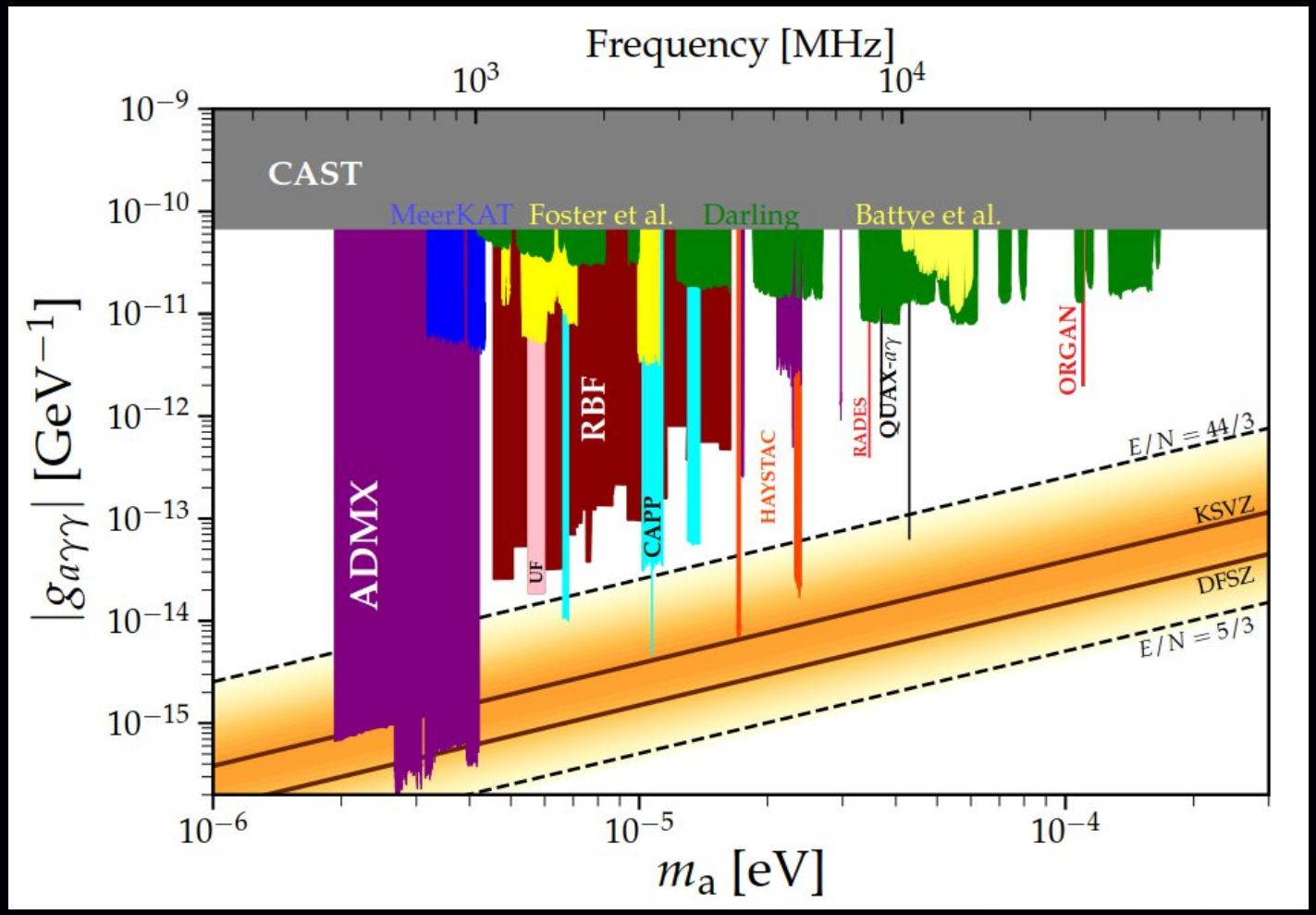
# Searches for WIMPs

- Haven't found DM
- Placed limits on annihilation rate



# Searches for Axions

- Haven't found DM
- See MeerKAT in blue (Zhou et al 2022)



# The MGCLS

MeerKAT Galaxy Cluster Legacy Survey, arXiv: 2111.05673

- 115 Galaxy clusters at L-band (900 - 1670 MHz)
- 6-10 hrs observation on each cluster
- 8 arcsecond resolution
- 3-5 μJy/beam sensitivity

- 62 with diffuse emission (56 of which are new)
- We want those without diffuse and at low z
- We need to pick those with halo information though!

**The MeerKAT Galaxy Cluster Legacy Survey**

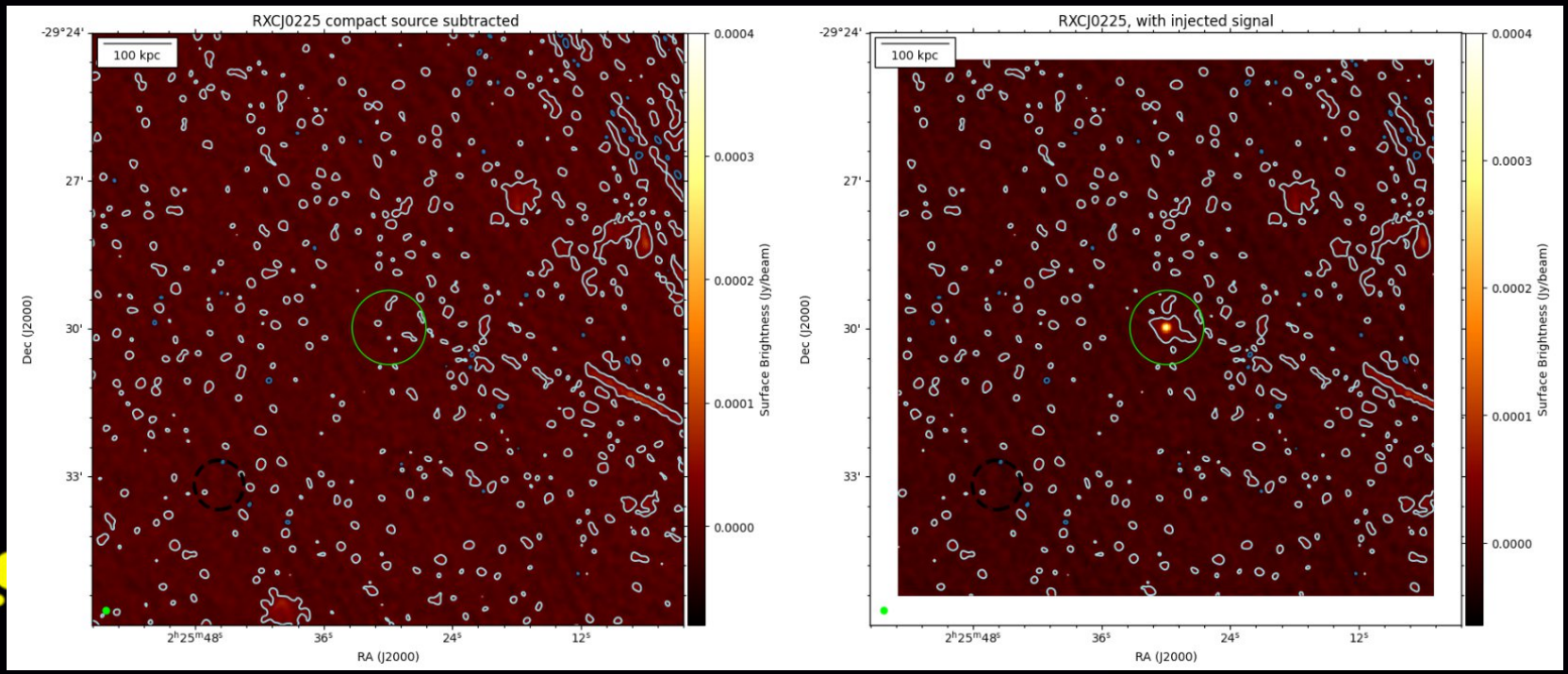
**I. Survey Overview and Highlights**

K. Knowles[1,2,3,⋆], W. D. Cotton[4,3], L. Rudnick[5], F. Camilo[3], S. Goedhart[3], R. Deane[6,7], M. Ramatsoku[2,8], M. F. Bietenholz[9,10], M. Brüggen[11], C. Button[7], H. Chen[12], J. O. Chibueze[13,14], T. E. Clarke[15], F. de Gasperin[11,16], R. Ianjamasimanana[2,3], G. I. G. Józsa[3,2,17], M. Hilton[1,18],

# The MGCLS: our method

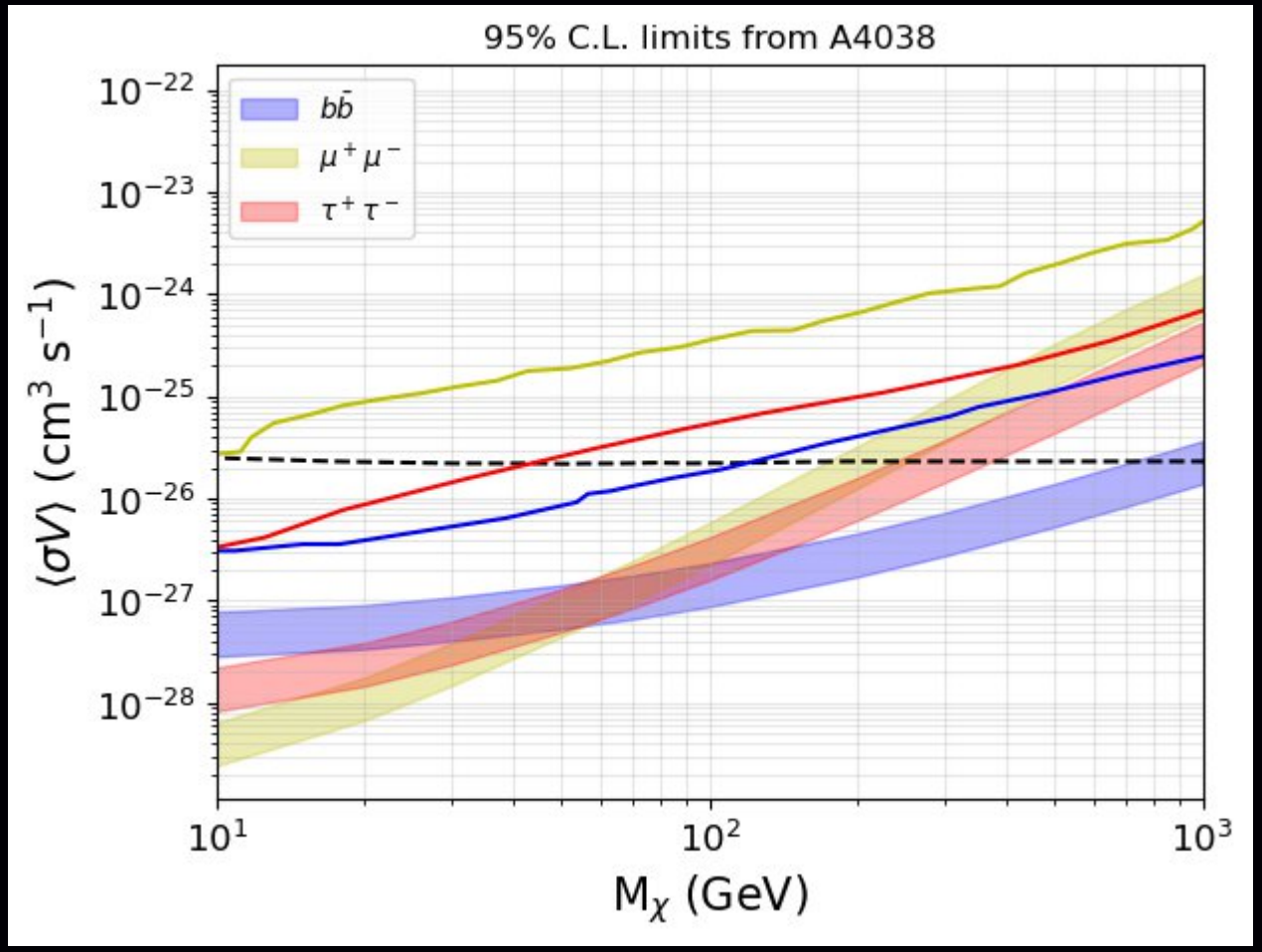
For each target we do the following:

- Subtract point sources (image plane only - PYBDSF)
- Compare residual map and DarkMatters map
- Perform $\chi^2$ test to find 95% confidence exclusion
- Consider both NFW and shallow cusp halos



# Results: A4038

Lavis, Sarkis, & Beck in prep




Way better than Fermi! Competes with Regis 2021

# MeerKAT simulations

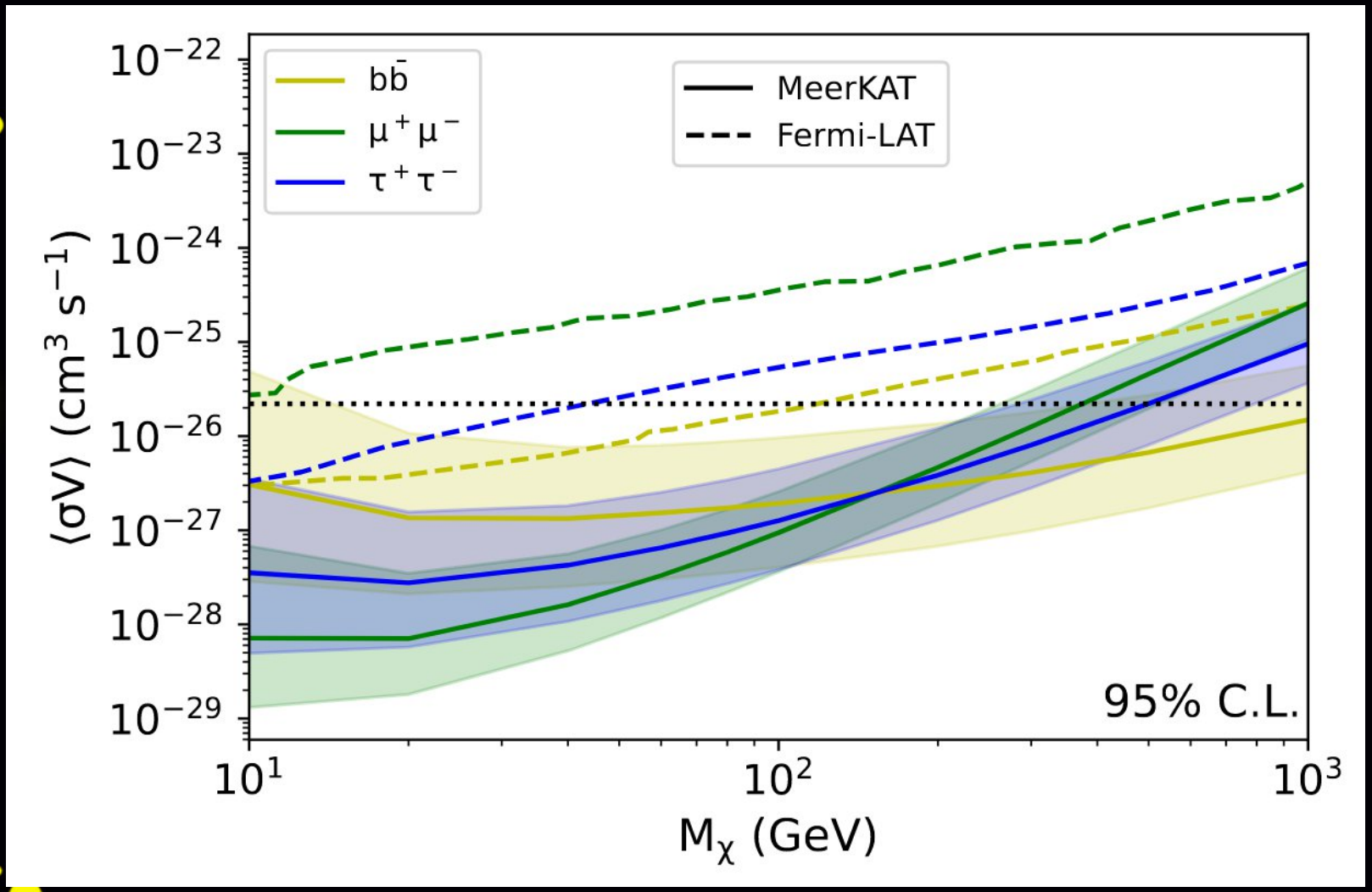
# Simulating MeerKAT

Stimela Package (https://github.com/ratt-ru/Stimela)
Written By Spheshile Makhathini (and others)

- Target Reticulum II
- Source model from Regis 2017
- CASA to simulate observations
- RFI Masking included
- MEQTrees to calibrate
- WSCLEAN
- RMS from residual = noise
- Compare to DM predictions

Beck & Makhathini 2022

# Reticulum II

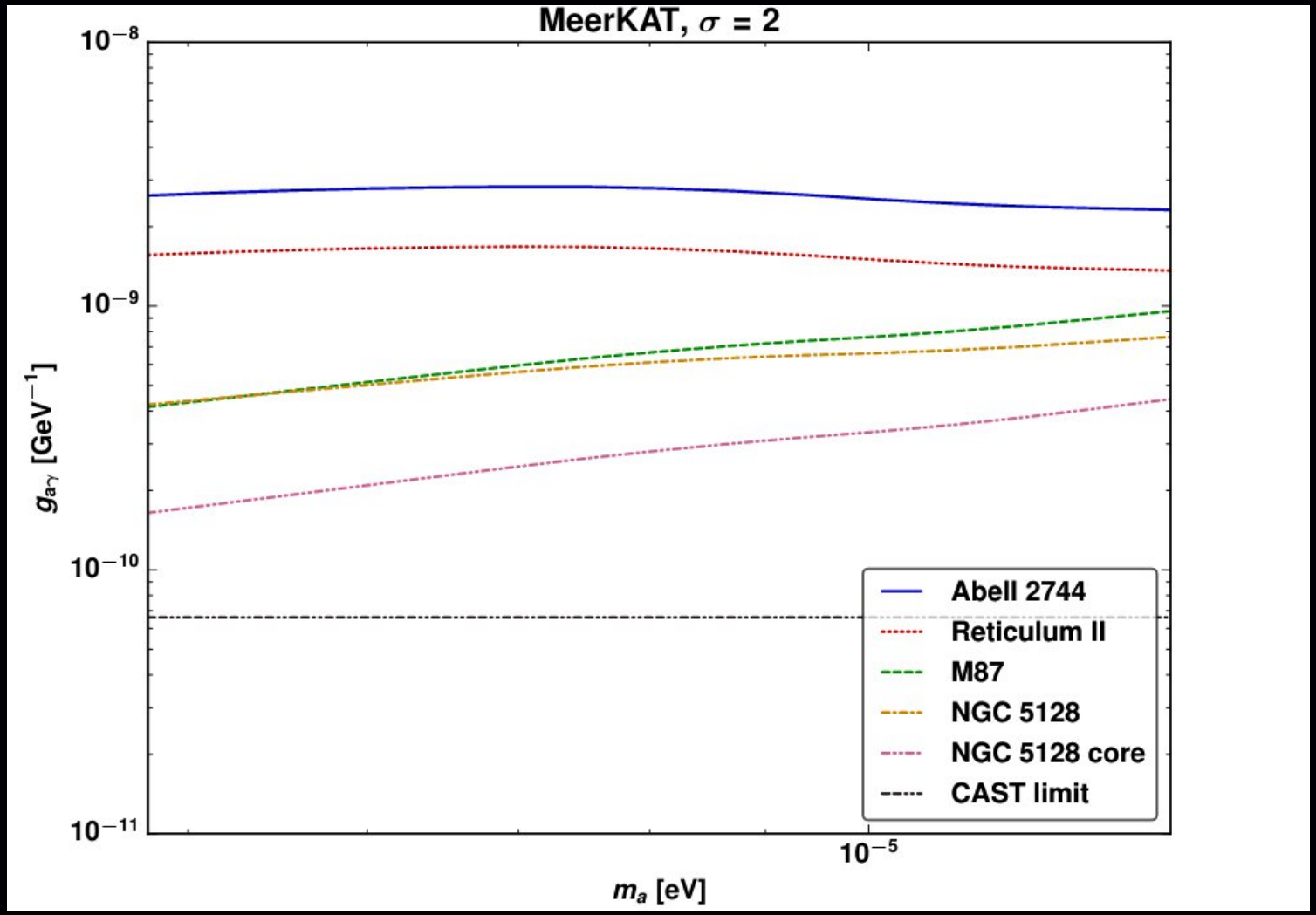



Way better than Fermi! Competes with Regis 2021

# Axions

Ayad and Beck 2022

# Results: Axions




Not very competitive, but uses very simple sensitivity estimates!

# Conclusions and the future

- Powerful limits from MGCLS, competitive with best in literature
- Dwarf galaxy analysis currently underway
- Discovery potential (not just constraints)?
- Axion reduction on the same data?

**MeerKAT and South Africa are on the cutting edge of DM searches**