Dark matter searches with MeerKAT

Geoff Beck, University of the Witwatersrand

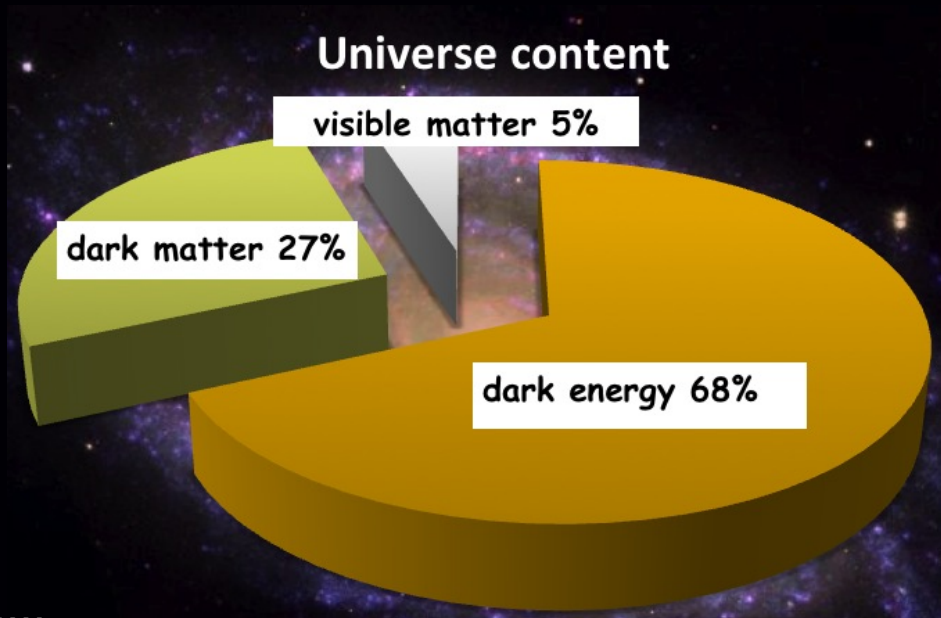
9 July 2026, SAIP Annual Conference

DARK MATTER

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

What do we know about dark matter?

- It’s important
- It’s massive
- It’s probably a particle
- Electrically neutral

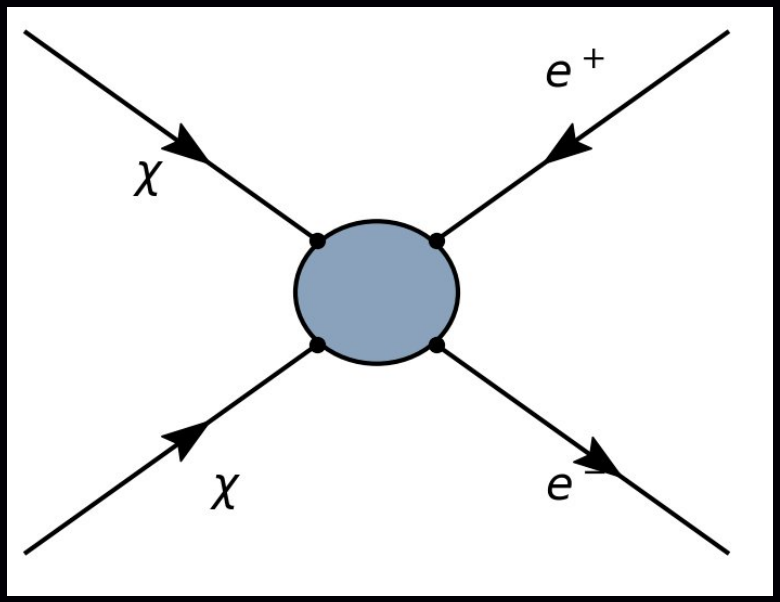


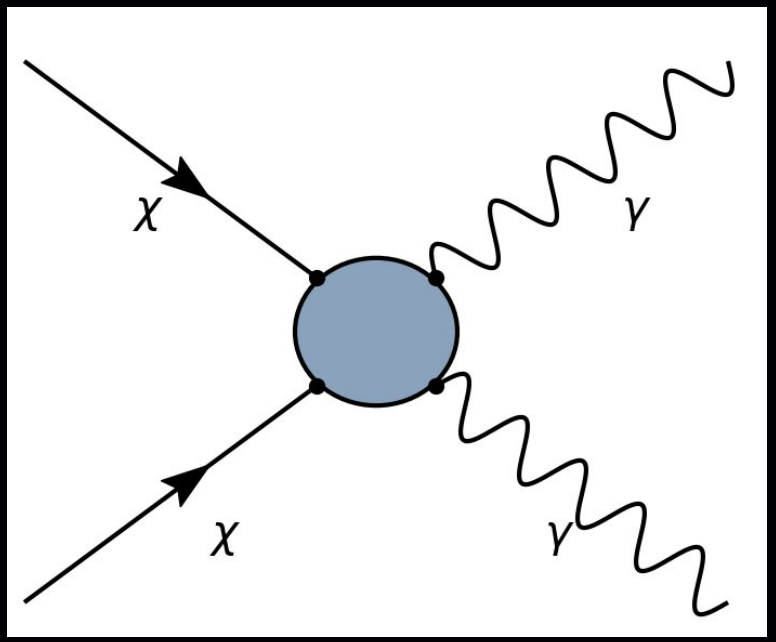
That’s not much to go on....

So how do we search for it?

WIMPs (Weakly Interacting Massive Particles)

- Very “generic” type of dark matter (lots of possible models!)
- Massive, neutral particle with weak interactions
- Could decay or self-annihilate

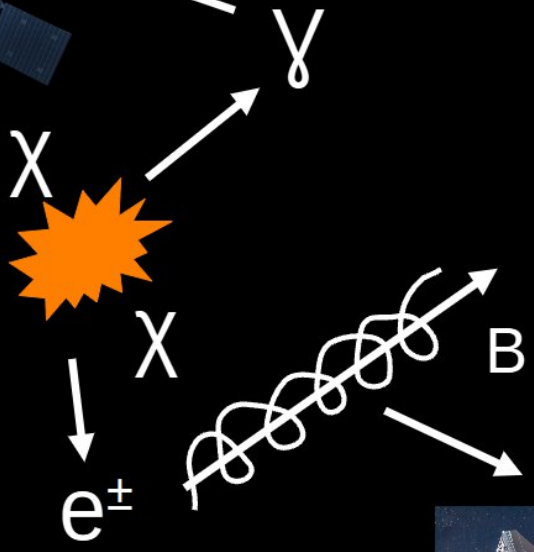




The standard model products are visible!

What to look for?

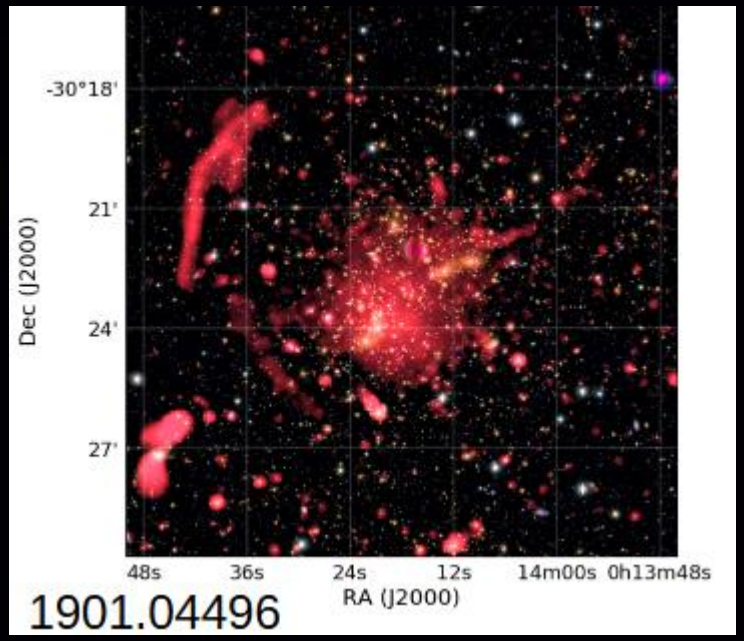
Gamma-rays (Fermi-LAT)



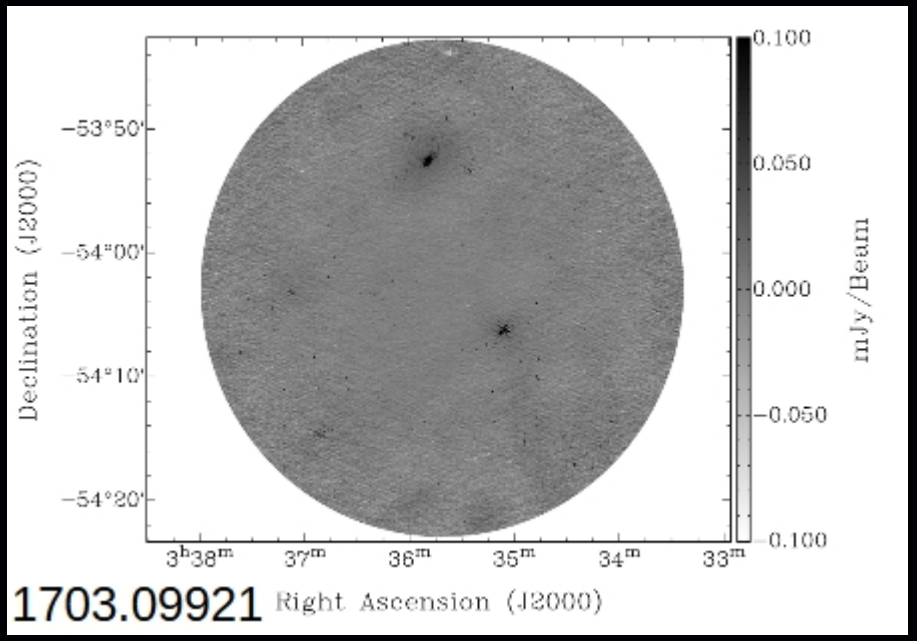
For large DM masses
(> 5 GeV)

Signatures in radio

- Diffuse emission: no clear point source
- Dark matter exists in a halo
- Strong central emission from high density



Diffuse



Point sources

Solving diffusion equations

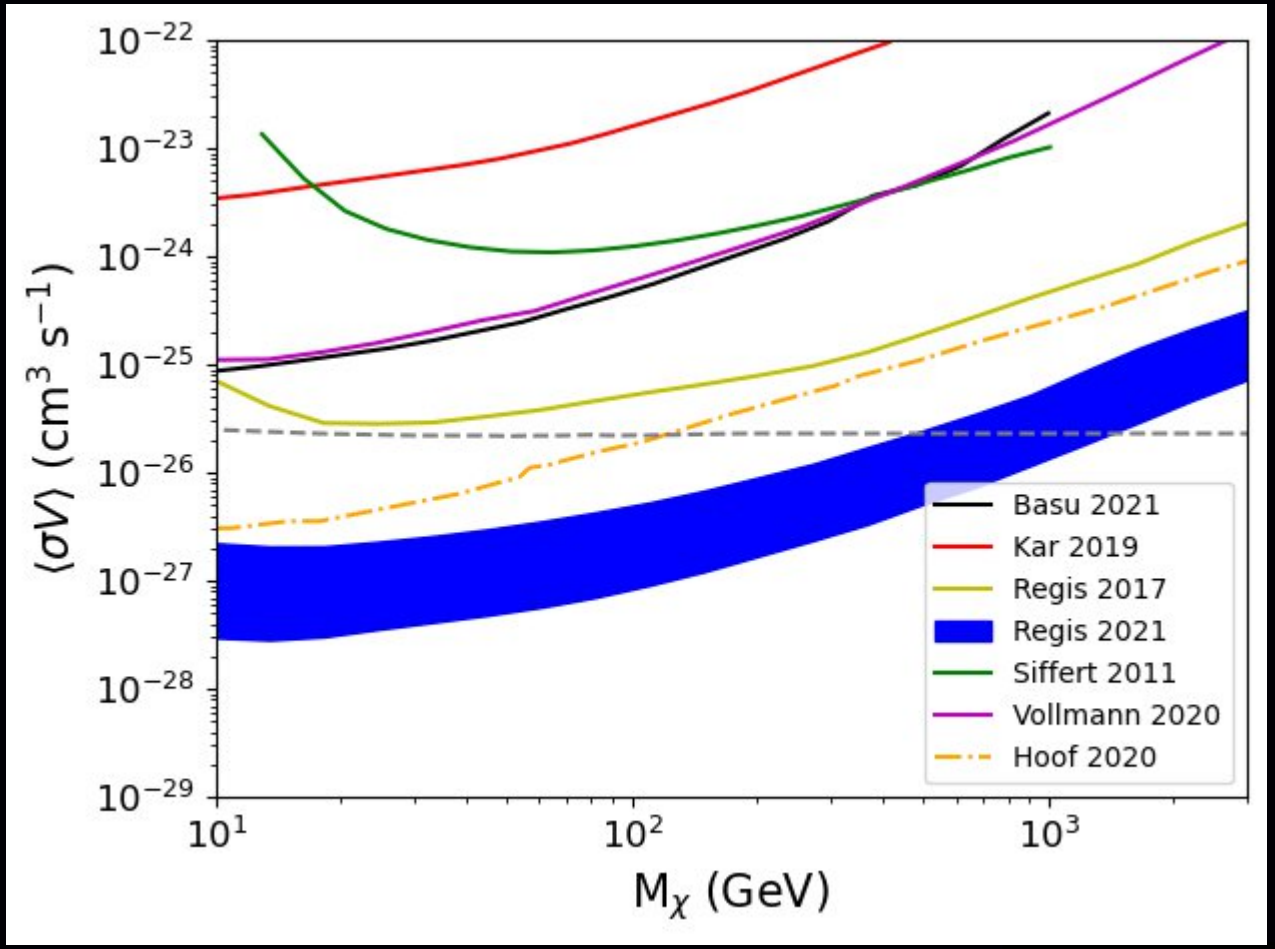
$$\frac{d\,\psi}{d\,t} = \nabla(\mathrm{D(E,r)}\nabla\psi) + \frac{d}{dE}(\mathrm{b(E,r)}\psi) \; + \; \mathrm{Q(E,r)}$$

- 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

Particle physics
+
Dark matter halo
+
Magnetic field
+
Diffusion environment

Searches for WIMPs

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



Galaxy clusters vs dwarfs

Galaxy clusters:

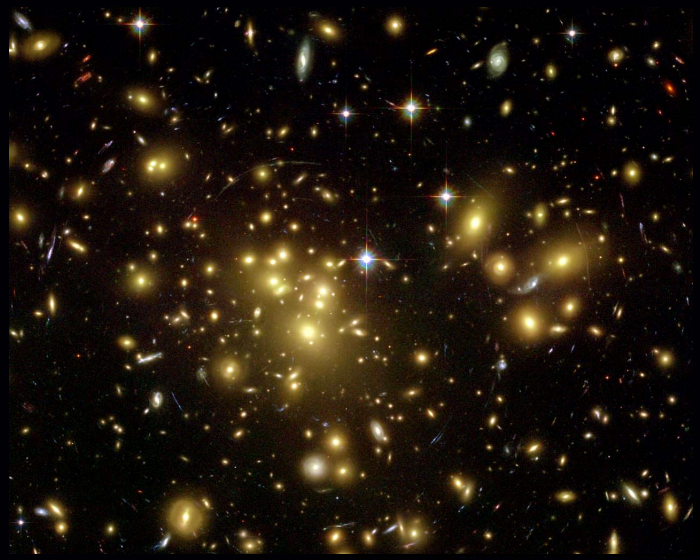
Pros:
Highly DM dominated
Magnetic field information
Diffusion information
Halo information

Cons:
Baryonic backgrounds

Dwarf galaxies:

Pros:
Highly DM dominated
Low baryonic backgrounds

Cons:
Magnetic field unknown
Diffusion environment unknown
Halo uncertainties



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)

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],

Our method

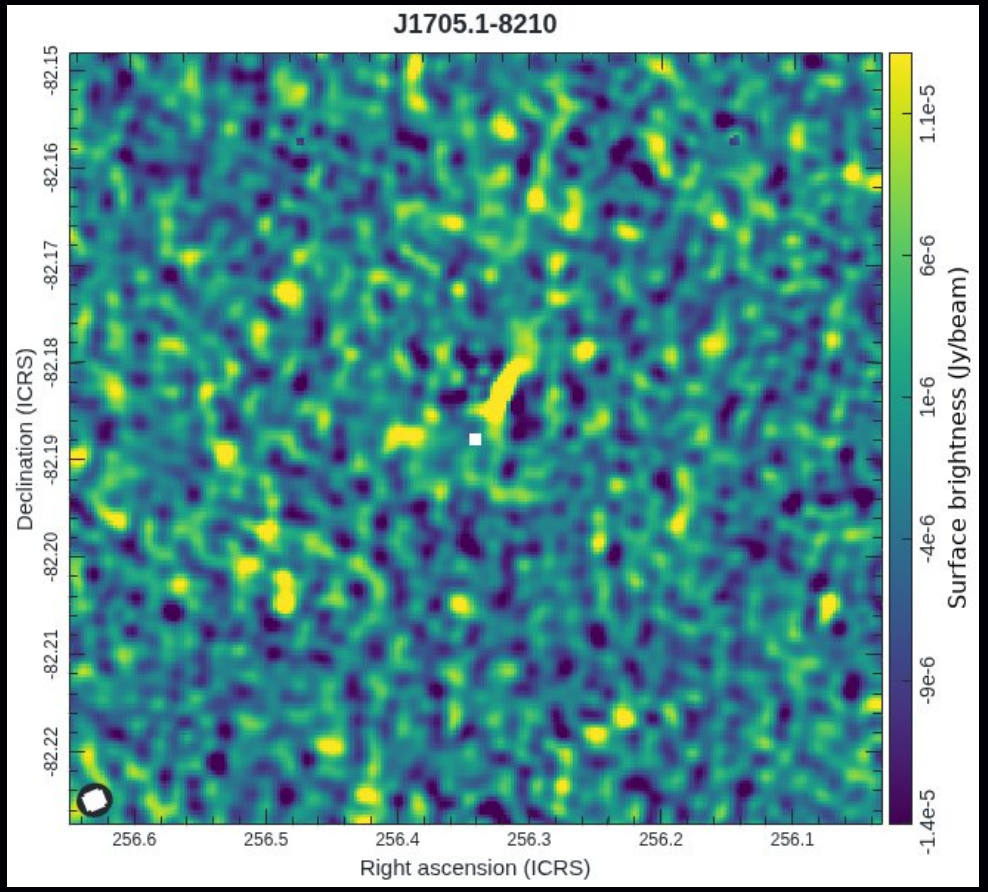
For each target we do the following:

- Subtract point sources (image plane only - PYBDSF)
- Compare residual map and DarkMatters map
- Perform MCMC search to get 95% confidence exclusion

- Targets:
  - Reticulum II (ultrafaint dwarf galaxy)
  - Large magellanic cloud (irregular dwarf galaxy)
  - J1705.1-8210 (galaxy cluster)

Results: J1705.1-8210

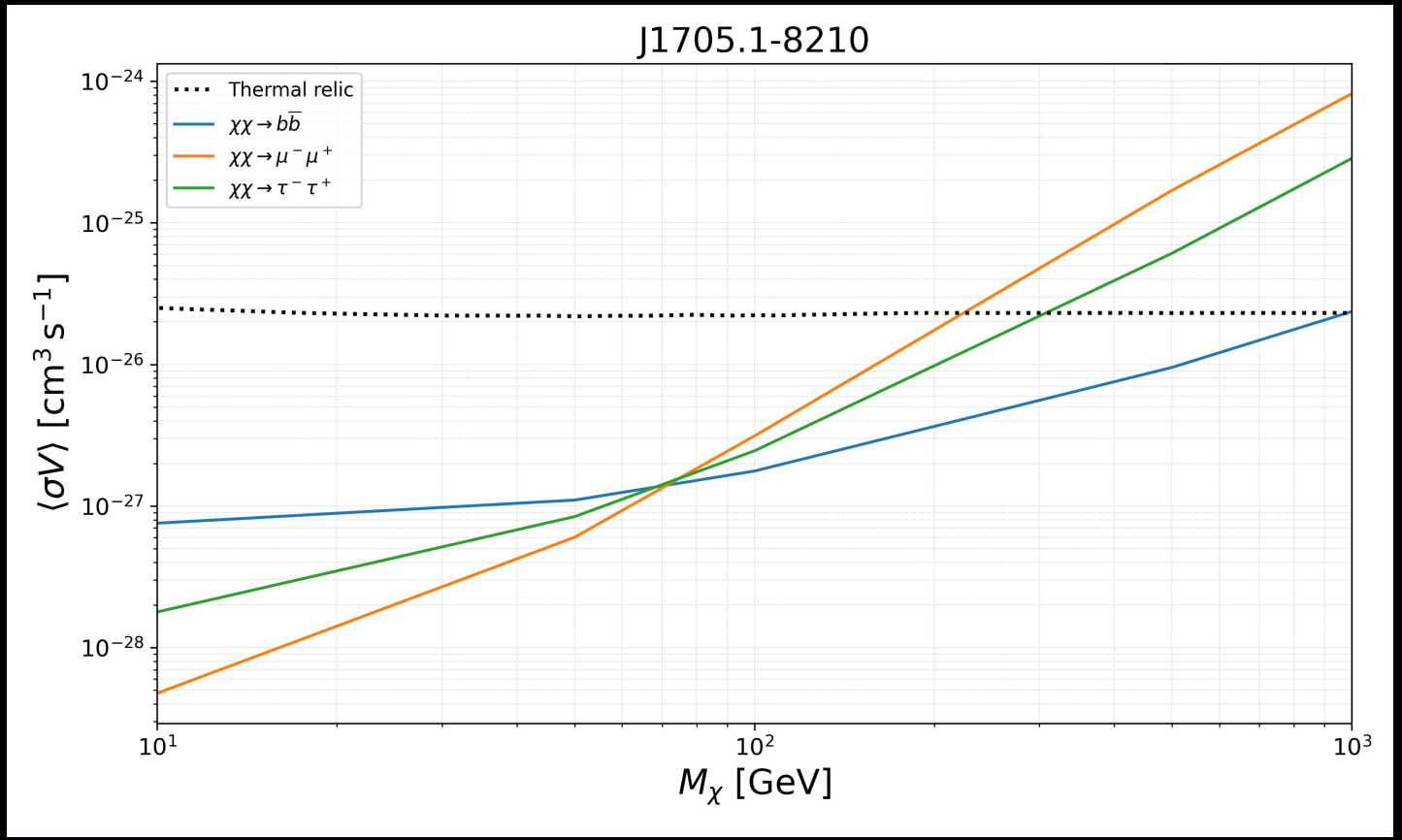
Lavis, Beck, & Knowles in prep



Competitive with best existing limits

Results: J1705.1-8210

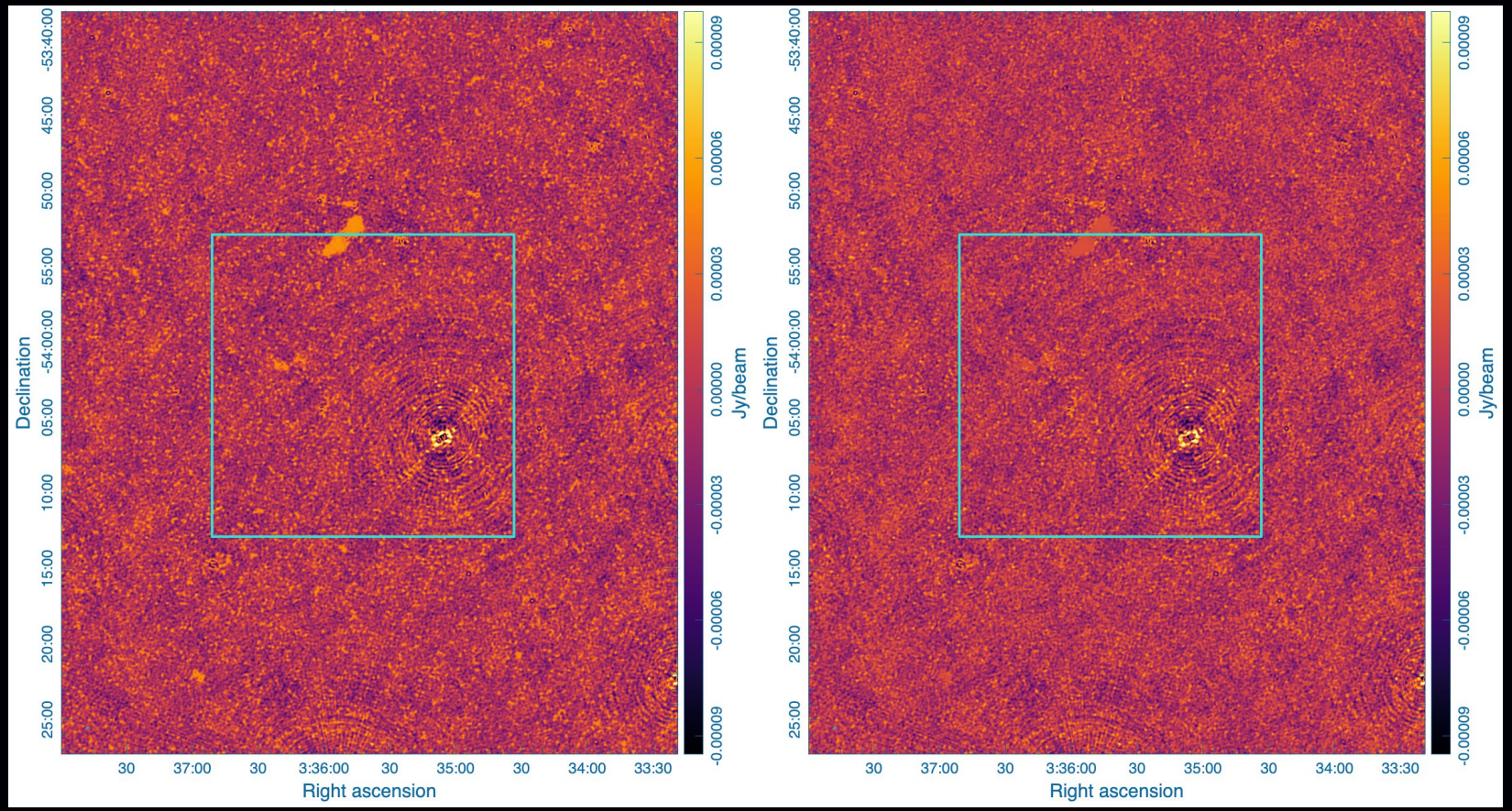
Lavis, Beck, & Knowles in prep



Competitive with best existing limits

Results: Reticulum II

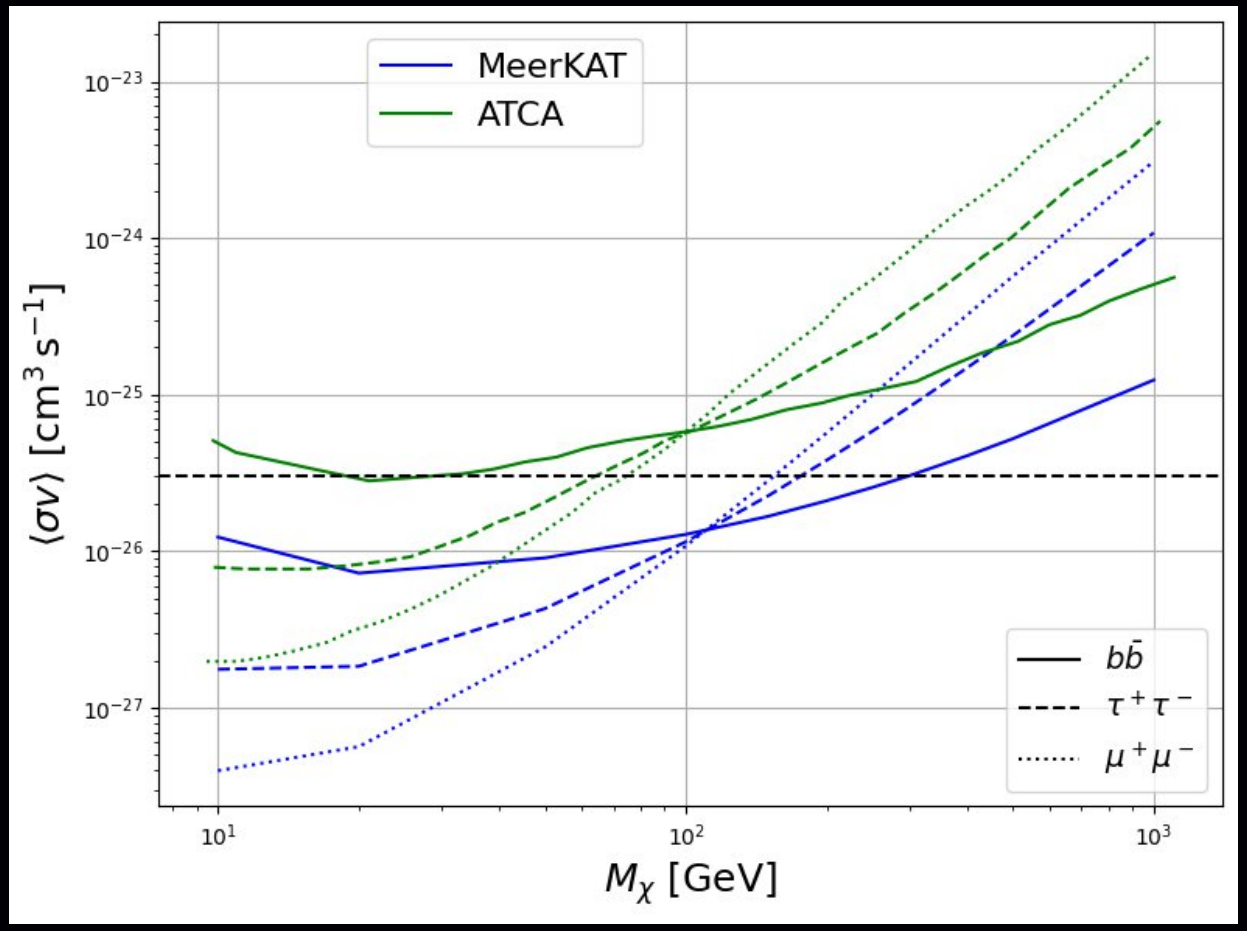
Semane et al, in review



Cleaned with multiple rounds of 3GC

Results: Reticulum II

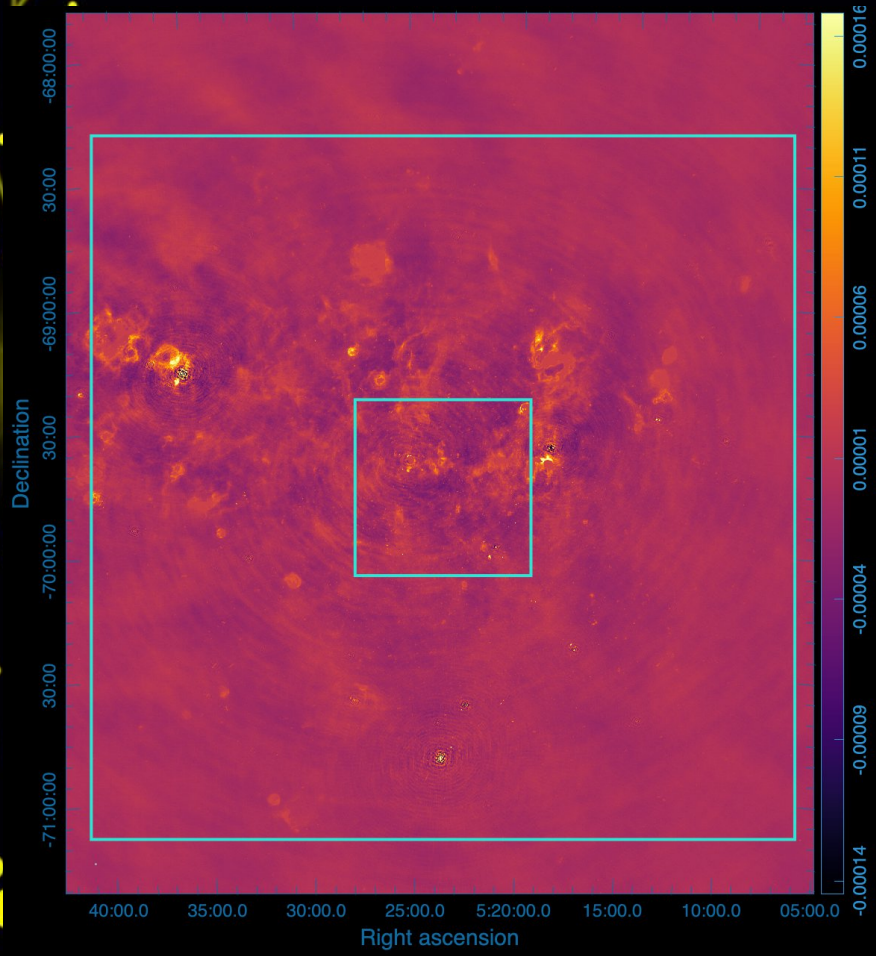
Semane et al, in review

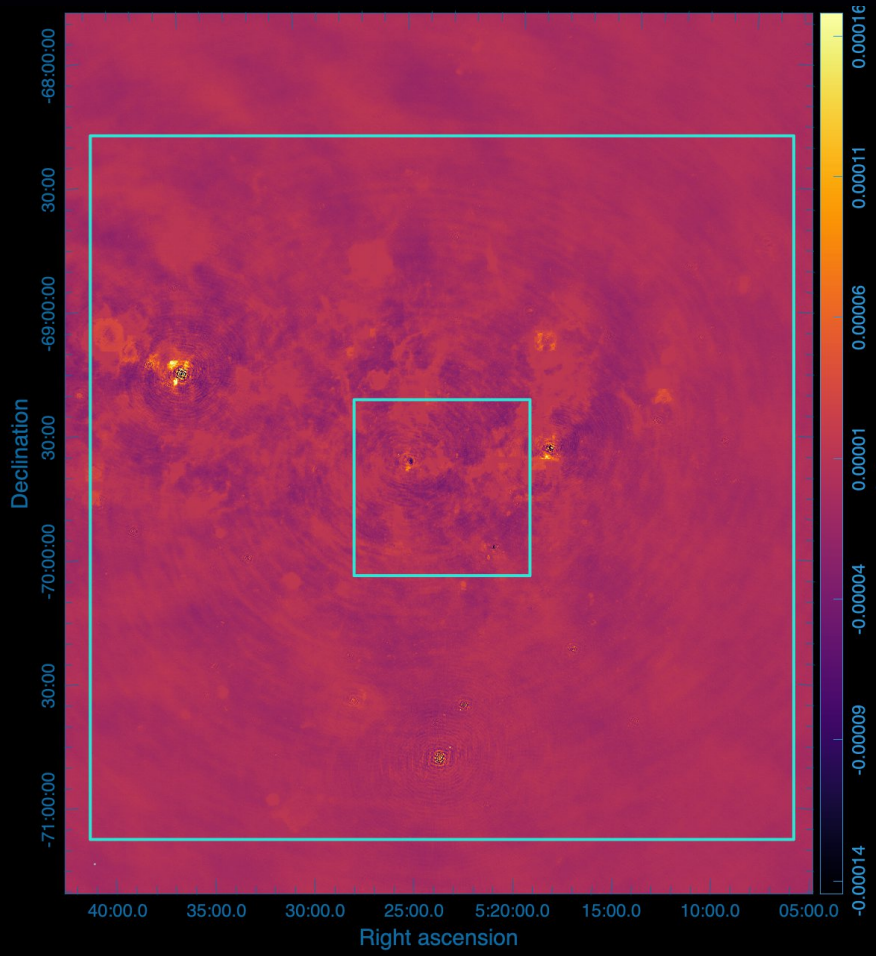


Substantial improvement over previous work in Ret II

Results: LMC

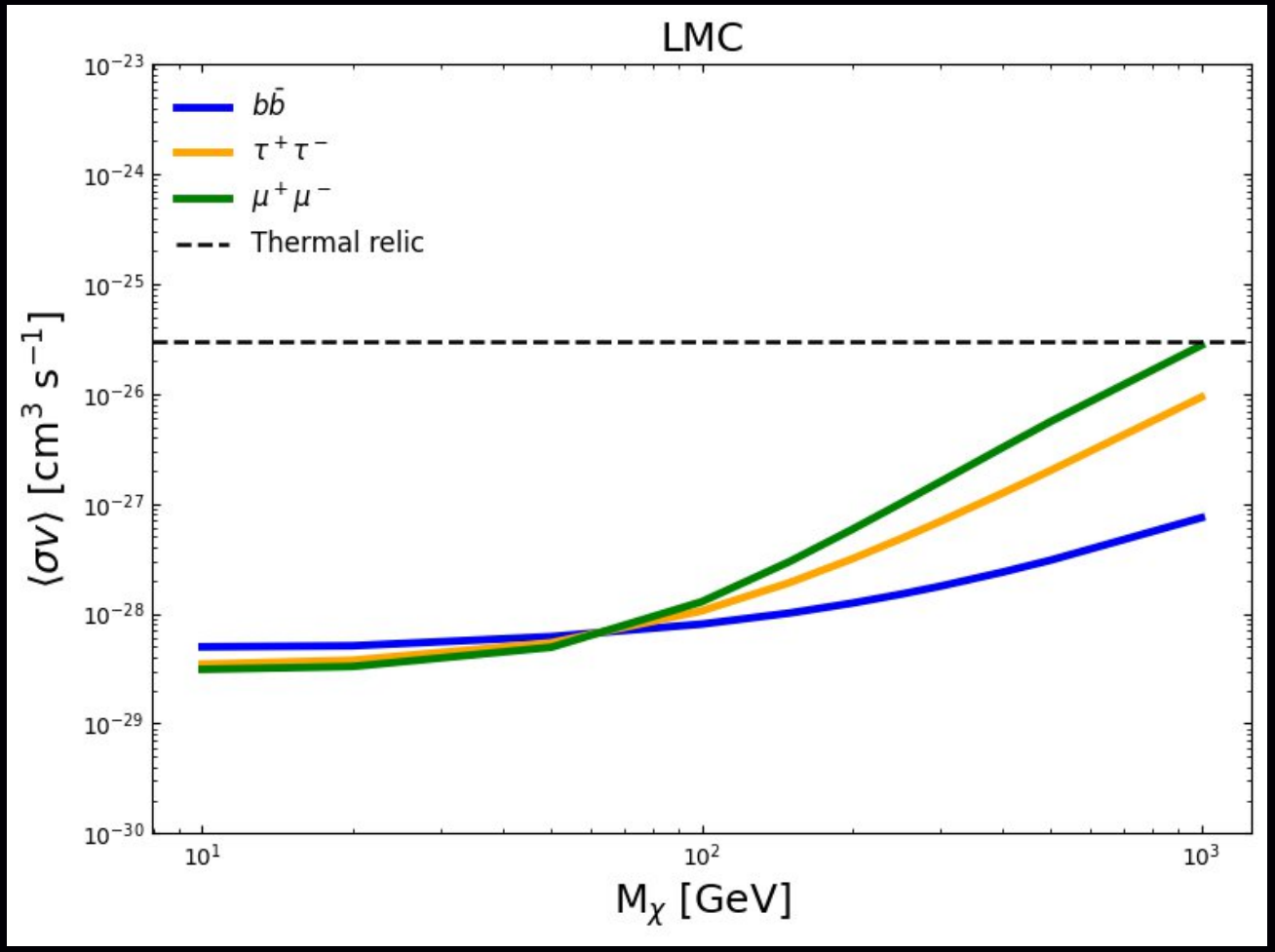
Semane, Makhathini, & Beck, in prep





Model a diffuse disk + dark matter

Results: LMC



Far exceeds other limits, even modeling in galactic disk

Conclusions and the future

- Powerful limits from MGCLS, competitive with best in literature
- Incredible limits from LMC
- Reticulum II not as strong a target as hoped

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