# A radio-frequency WIMP search with MeerKAT Galaxy Cluster Legacy Survey

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## Introduction

Dark matter (DM) indirect searches have previously been focused on gamma rays due to their low attenuation, high detection efficiency, and simplicity of the predicted signal. Advancements in radio astronomy techniques and technologies are beginning to overcome traditional obstacles, opening a powerful new avenue to probe dark matter through synchrotron radiation produced in annihilation events. **The MeerKAT array** [1], located in South Africa, is now one of the most powerful instruments of its kind. This instrument boasts a **high sensitivity** as well as excellent **resolution**. This allows us to **search for fainter diffuse synchrotron fluxes than ever before while simultaneously disentangling point source contributions**.

Figure 1:The MeerKAT array, photo by Donna Slater.

In contrast to earlier radio DM searches that have utilized dwarf galaxies, **we consider galaxy clusters**. By studying clusters of galaxies we benefit from reduced uncertainties in DM density and magnetic field profiles, as well as having negligible diffusion effects. We are then able to **constrain the DM parameter space by comparing predicted DM signals to what is measured in clusters with MeerKAT**.
Alongside generic WIMP annihilation channels, we probed 2HDM+S [2], a particle physics model proposed to explain multi-lepton anomalies at the LHC. This model interacts with the dark sector through a scalar mediator.

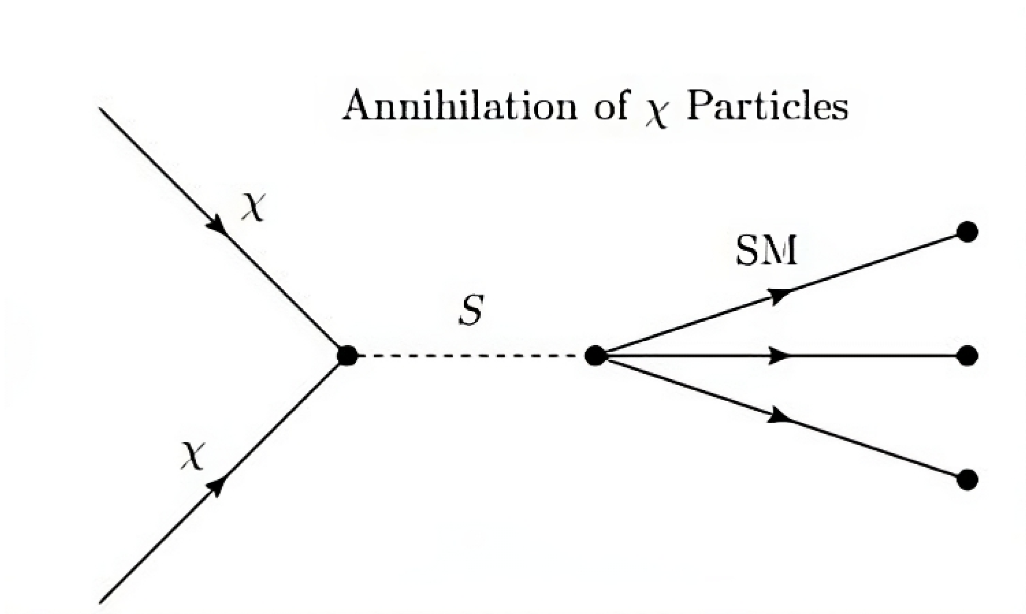


Figure 2:DM candidate annihilating through the scalar mediator S to standard model particles.

## MGCLS

We investigated a number of clusters from the **MGCLS catalogue** [3], with the selection being based on available data on the DM halo. More constraining results were found for clusters with faint mini-halos or with a non-detection of diffuse emission. The following steps were performed:

- Removal of point source contributions with `PyBDSF`.
- The residual image is used the reference flux/ surface brightness values.
- The modelled DM signal was convolved with the MeerKAT beam using `CASA`.
- The DM signal was injected into the residual image

## Methods

Two methods were considered to produce the DM upper limits. The first termed **pixel-by-pixel** [4], the surface brightness values are statistically analysed for each individual pixel. For the **integrated flux exclusion** method a $2\sigma$ exclusion was obtained for the integrated fluxes with half the scale radius of the DM halo.

## Results

We present the most constraining upper limits, determined for the galaxy cluster **Abell 4038**. Here the two methodologies can be compared.

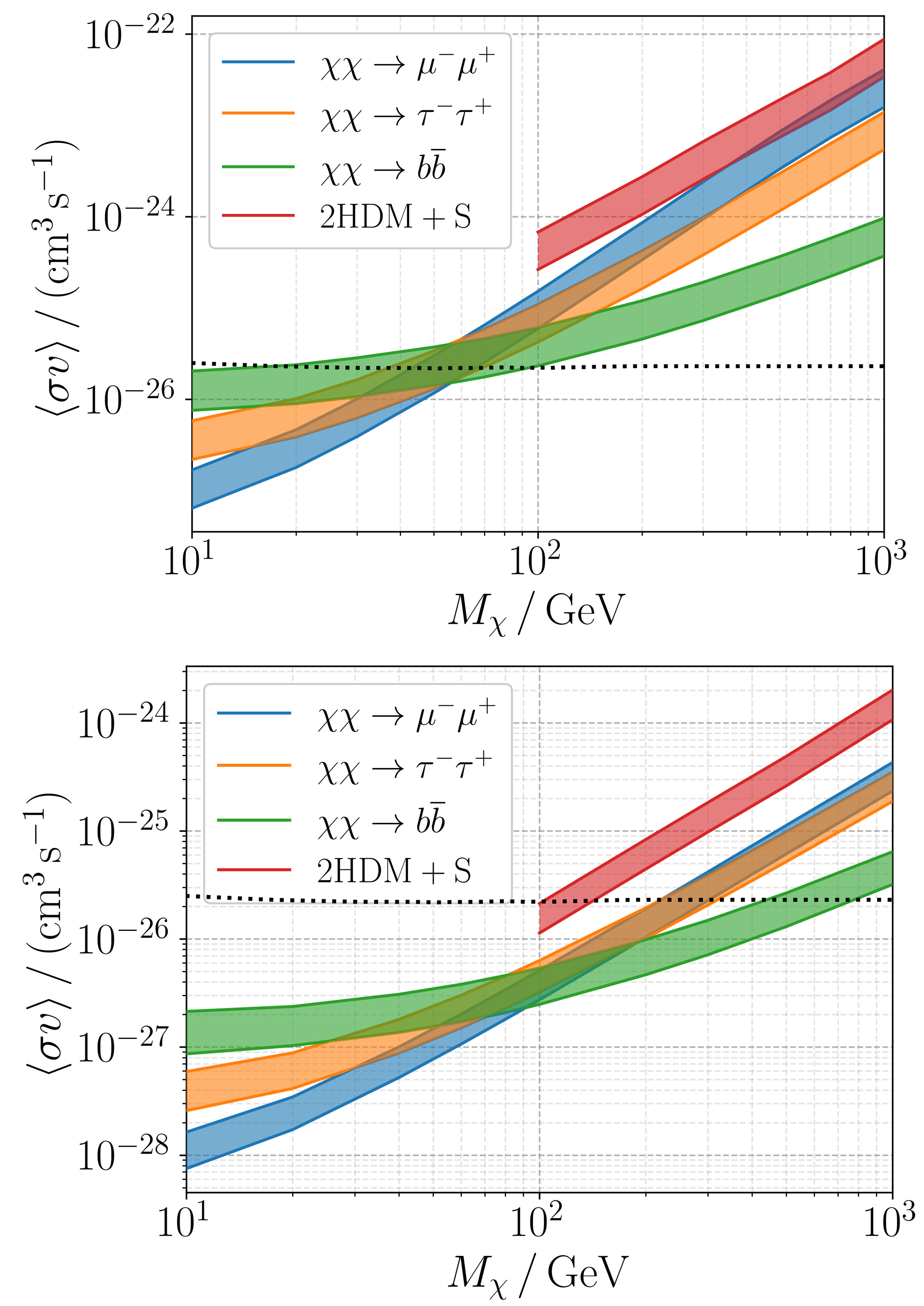


Figure 3:Upper limits ($2\sigma$) on the DM annihilation cross-section as a function of WIMP mass. The thermal relic cross-section is shown with the black dotted line, below which models can be excluded. The lower boundary of the uncertainty band is for an NFW ($\alpha = 1$) DM density profile, and the upper boundary represents the cross-sections obtained with the more shallowly cusped DM profile ($\alpha = 0.5$). The mass range for 2HDM+S is limited by the model. *Top*: Pixel-by-pixel *Bottom*: Integrated flux exclusions.

## Conclusion

This work shows that MeerKAT is a powerful tool for probing the dark matter parameter space. The most stringent results **exclude annihilation through bottom quarks for masses less than ~ 800 GeV**.

## References

[1] Booth R, De Blok W, Jonas J and Fanaroff B 2009 *arXiv preprint arXiv:0910.2935*

[2] Von Buddenbrock S, Chakrabarty N, Cornell A S, Kar D, Kumar M, Mandal T, Mellado B, Mukhopadhyaya B and Reed R G 2015 *arXiv preprint arXiv:1506.00612*

[3] Knowles K, Cotton W, Rudnick L, Camilo F, Goedhart S, Deane R, Ramatsoku M, Bietenholz M, Brüggen M, Button C *et al.* 2022 *Astronomy & Astrophysics* **657** A56

[4] Sarkis M, Beck G and Lavis N 2023 *arXiv preprint arXiv:2303.00684*

## Acknowledgements

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