Hunting dark matter with MeerKAT

First Pan-African Particle Physics Workshop

Geoff Beck & Sphesihle Makhathini
University of the Witwatersrand
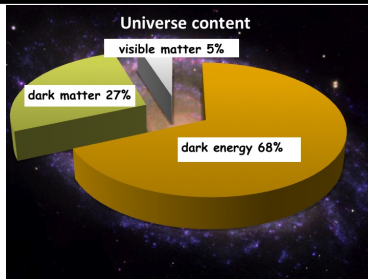
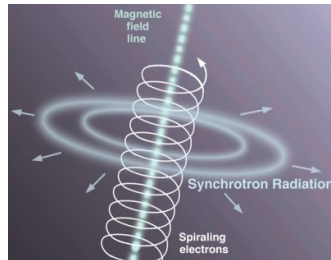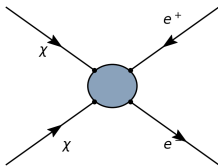UNIVERSITY OF THE
WITWATERSRAND,
JOHANNESBURG

21-23 March 2021
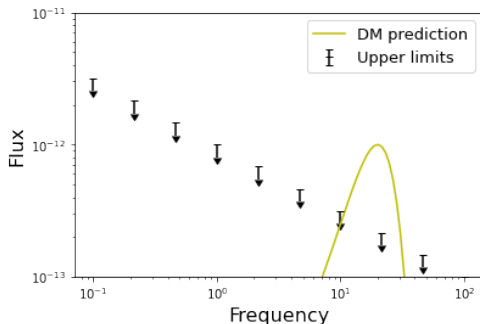
What's the matter with Dark Matter?

INDIRECT DARK MATTER SEARCHES IN RADIO

- ▶ DM particles annihilate to intermediate state
  ($b\bar{b}$, $\tau^+\tau^-$, $\mu^+\mu^-$)
    - ▶ Annihilation rate $\langle \sigma V \rangle$
- ▶ These decay to produce electrons and positrons
- ▶ Magnetised halo environments result in synchrotron emission

INDIRECT DARK MATTER SEARCHES IN RADIO

- ► Compare DM flux to observations: data or upper limits
- ► Either discover DM or limit properties
- ► Non-observation limit: if we saw no signal, what is the largest allowed $\langle \sigma V \rangle$?

EXISTING SEARCHES

- ▶ Pushing below the dashed line eliminates relevant models
  - ▶ Required rate to produce cosmic abundance "today"
- ▶ ATCA (right) can already compete with Fermi!
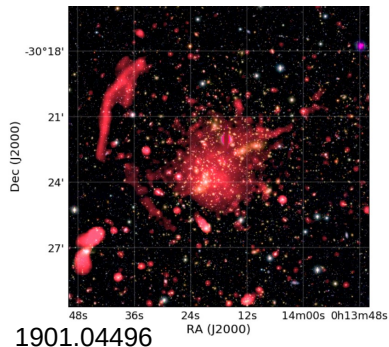 (1703.09921)
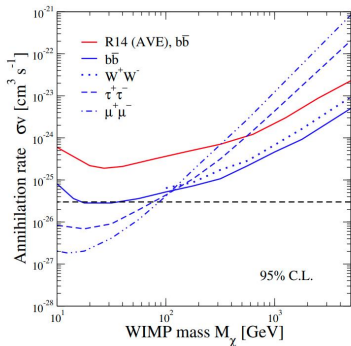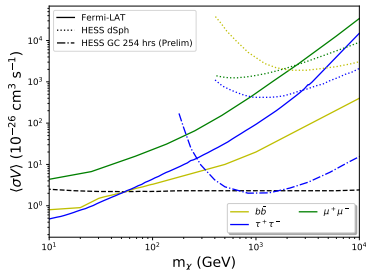
MEERKAT

- ▶ SKA precursor with 64 dishes
- ▶ Interferometer: measures via inter-dish correlations
- ▶ Frequencies of $\sim$ 0.6 to 1.6 GHz
- ▶ At least twice as sensitive as ATCA

SOME RADIO ASTRONOMY

1901.04496

- ▶ Point source: bright dot of emission
- ▶ Diffuse emission: cloud with no discernable origin

Dark matter emission will be diffuse (halo)

SOME RADIO ASTRONOMY

So how do we focus sensitivity on diffuse emission?

- ► A 'taper' allows us to select which scales we care about
- ► Scale corresponds inversely to dish spacing
- ► Diffuse emission → large scales → small spacing

One easy trick: Assign small weights to correlations at large spacing.
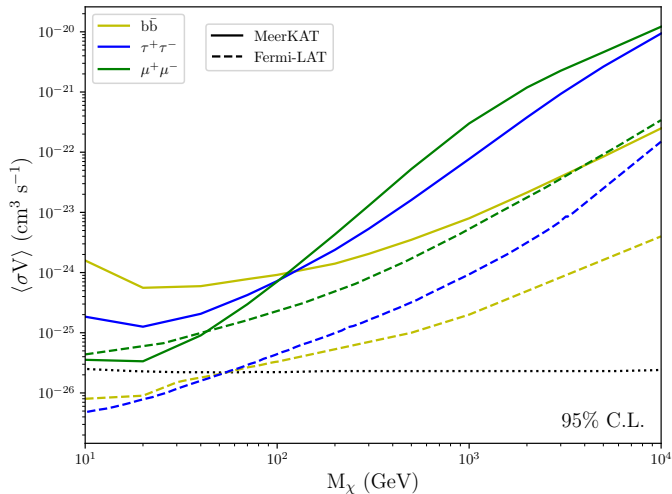
THE TRAIN TO THE DARK SIDE

- ▶ We make use of the software Stimela (train in isiZulu)
- ▶ Sky model NVSS, use -30° DEC
- ▶ Simulate MeerKAT observations via CASA
- ▶ RFI channels are masked out with RFIMasker
- ▶ Calibration (Meqtrees) and cleaning (WSClean)
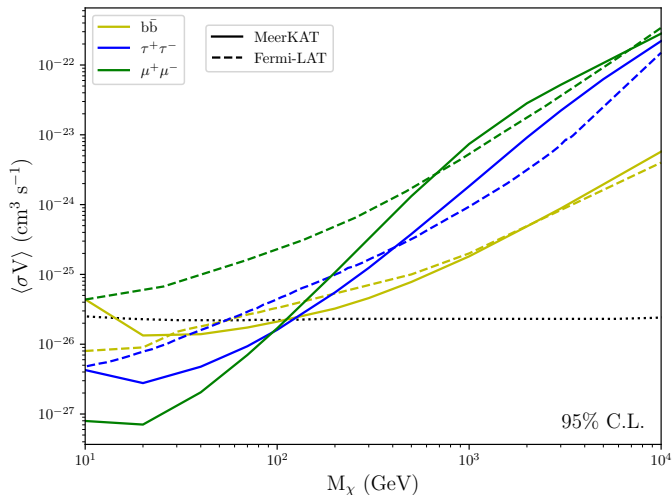- ▶ Goal: rms noise of image

MEERKAT- FLUX WITHIN 20′

- ▶ 20 hours of observation time
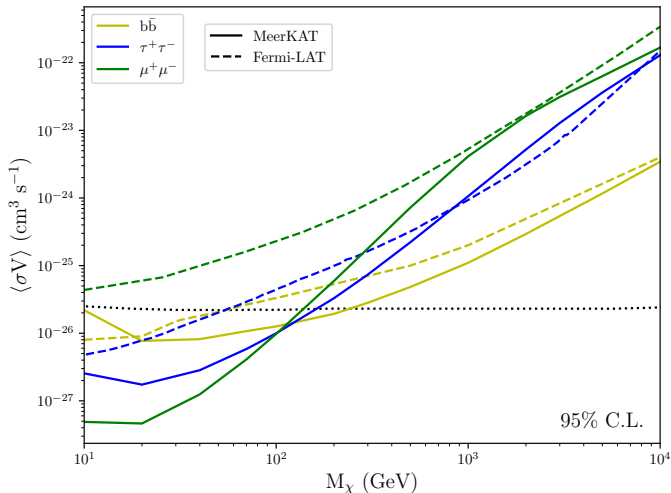- ▶ Integrated noise vs flux

MEERKAT- SURFACE BRIGHTNESS

- ▶ 20 hours of observation time
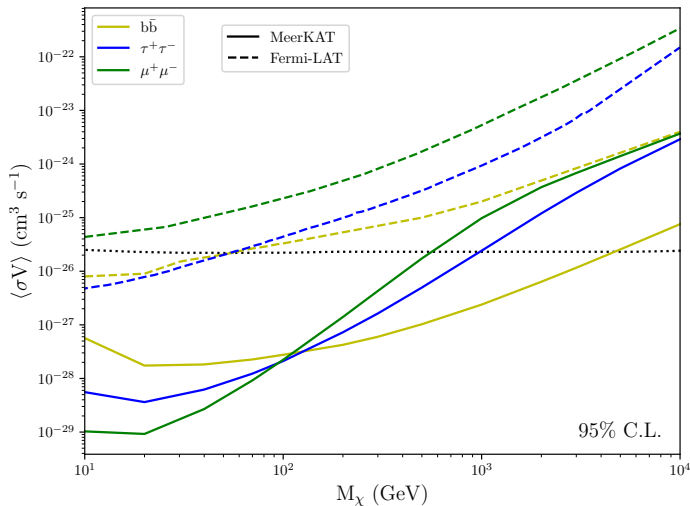- ▶ Binned noise vs radial flux distribution

MEERKAT - 15″ TAPER - FLUX INSIDE 20′

► 20 hours of observation time
► Integrated noise vs flux

MEERKAT - 15″ TAPER - SURFACE BRIGHTNESS

▶ 20 hours of observation time
▶ Binned noise vs radial flux distribution

CONCLUSIONS

- ▶ ATCA WIMP radio constraints compete with Fermi
- ▶ MeerKAT is twice as sensitive as ATCA already
  - ▶ MeerKAT will be getting an upgrade!
- ▶ Projected constraints up to an order of magnitude better
  - ▶ Tapering has a large effect
- ▶ Radio has potential to lead indirect searches
- ▶ There are caveats:
  - ▶ Magnetic field uncertainties
  - ▶ Halo geometry matters for radio
  - ▶ Effect of source subtraction?