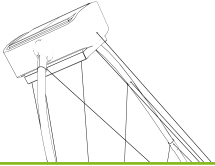
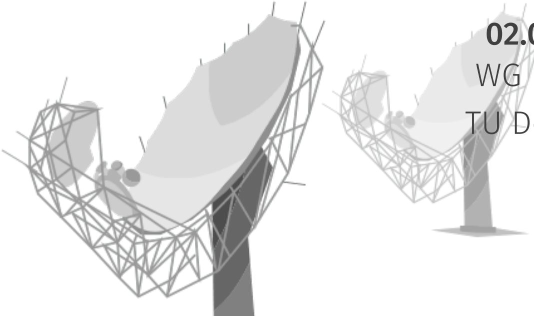
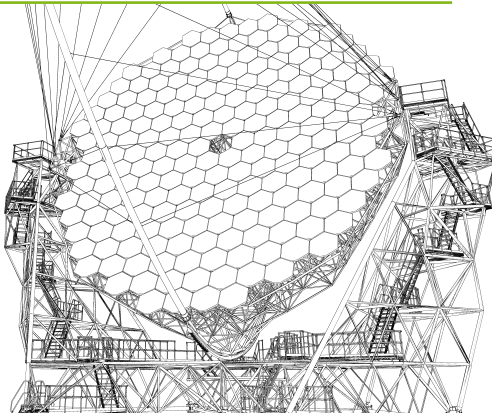
technische universität dortmund



DM search: γ+radio





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02.06.2022

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What is Radio Interferometry?

Radio Astronomy

- Ground based telescopes
- Wavelength: millimeter to meter
- **But:** Limited by Rayleigh criterion

Credit: NRAO/AUI/NSF

Radio Astronomy

Credit: Jacobs/Arecibo Observatory

Radio Interferometry

- **Solution:** Correlate multiple telescopes pairwise
- Measure one visibility per antenna pair
- Radio interferometer measurement equation (**RIME**)

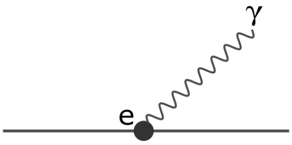
$$V_{\mathrm{pq}} = G_{\mathrm{p}} \left(\iint_{\mathrm{lm}} \frac{1}{n} E_{\mathrm{p}} B E_{\mathrm{q}}^{\mathrm{H}} e^{-2\pi i (u_{\mathrm{pq}} l + v_{\mathrm{pq}} m + w_{\mathrm{pq}} (n-1))} \, \mathrm{d}l \, \mathrm{d}m \right) G_{\mathrm{q}}$$

Credit: NRAO/AUI/NSF

Radio DM Search

Radio DM Search

- Target: dwarf spheroidal galaxies
  → significant magnetic field strength possible
- DM annihilation into leptons ($e^{\pm}$)
- Synchrotron radiation in magnetic field
  → 150 MHz



Radio DM Search

- Injection rate

$$s(r, E_{e^\pm}) = \frac{1}{2m_{\mathrm{DM}}^2}\rho^2(r)\frac{\mathrm{d}\langle\sigma v\rangle}{\mathrm{d}E_{e^\pm}}$$

- Electron/positron production

$$\frac{\mathrm{d}\langle\sigma v\rangle}{\mathrm{d}E_{e^\pm}} = \sum_{f^+f^-} BR(f^+f^-)\langle\sigma v\rangle\frac{\mathrm{d}N_{f^+f^-\to e^\pm+X}}{\mathrm{d}E_{e^\pm}}$$

Radio DM Search

- Electrons in magnetic field ⇒ **synchrotron radiation**
- Propagation using diffusive-loss-equation

$$\nabla[D(r,E)\nabla n_{e^\pm}] + b(r,E)\frac{\partial n_{e^\pm}}{\partial E} + s(r,E) = 0$$

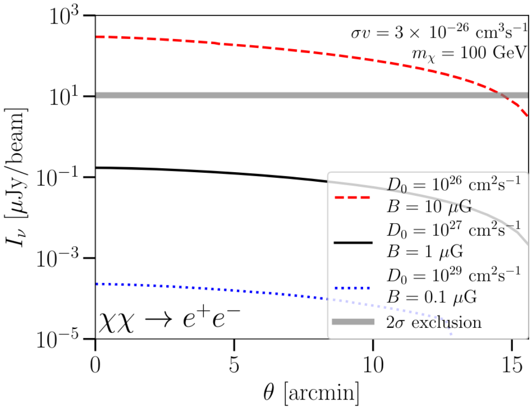
⇒ solve this for electron number density $n_{e^\pm}$

Radio DM Search

- Finally calculate radio continuum intensity:

$$I_\nu = \int_{\mathrm{l.o.s}} \int 2n_e(r,E) P_\nu(E,B)\,\mathrm{d}E\,\mathrm{d}l$$

⇒ This sky brightness is decoded in our measured radio visibilities!

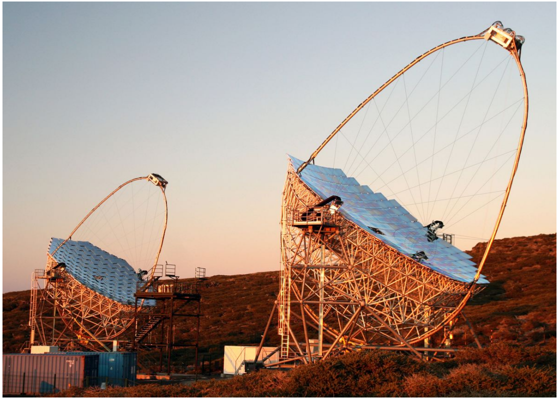


"Radio constraints on dark matter annihilation in Canes Venatici I with LOFAR", 2020, Vollmann et al., arxiv:1909.12355)

γ DM Search

MAGIC Telescopes

- Two 17 m telescopes @ La Palma
- γ induced atmospheric showers
  ⇒ Cherenkov light
- Stereo imaging of shower footprint



Credit: Robert Wagner/MAGIC Collaboration

γ DM Search

- Energy dependent events
- Binned likelihood

$$L = \prod_{j=1}^{N_{\mathrm{bins}}} \frac{(g_{ij}(\langle\sigma v\rangle) + b_{ij})^{N_{\mathrm{ON},ij}}}{N_{\mathrm{ON},ij}!} e^{-(g_{ij}(\langle\sigma v\rangle)+b_{ij})} \times \frac{(\tau_i b_{ij})^{N_{\mathrm{OFF},ij}}}{N_{\mathrm{OFF},ij}!} e^{-(\tau_i b_{ij})} \times \ldots$$

- Depends on free parameter $\langle\sigma v\rangle \Rightarrow$ use **gLike**

γ + Radio

Likelihood

- Normal distributed visibilities
- Combine γ + radio likelihood

$$L = \prod_{j=1}^{N_{\text{bins}}} \frac{(g_{ij}(\langle\sigma v\rangle) + b_{ij})^{N_{\text{ON},ij}}}{N_{\text{ON},ij}!} e^{-(g_{ij}(\langle\sigma v\rangle)+b_{ij})} \times \frac{(\tau_i b_{ij})^{N_{\text{OFF},ij}}}{N_{\text{OFF},ij}!} e^{-(\tau_i b_{ij})}$$

$$\times \frac{1}{(2\pi\sigma^2)^{\frac{N}{2}}} e^{-\frac{\sum_{i=1}^{N}(V_i(\langle\sigma v\rangle)-V_{i,\text{meas}})^2}{2\sigma^2}} \times \ldots$$

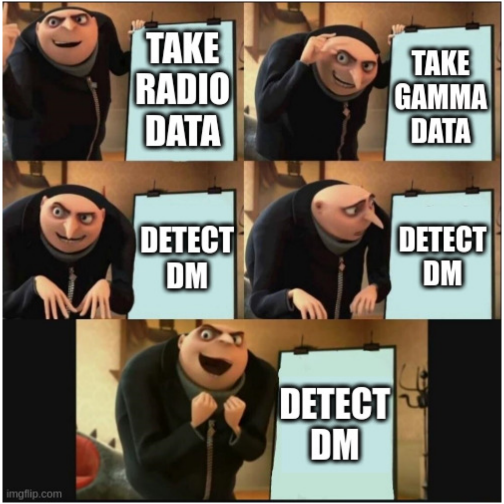
Outlook

Open questions

- Is it possible to maximize the likelihood?
- Use LOFAR sky survey release, but lots of visibilities $\mathcal{O}(10^6) \rightarrow$ averaging?

Next steps

- Implement radio likelihood class in gLike
- Calculate new DM spectra with PPPC 4 DM (Cirelli et al.)
- Test new extended likelihood method



Thank you!