MAX-PLANCK-INSTITUT FÜR KERNPHYSIK

Laboratory limits on the annihilation or decay of dark matter particles

Tim Wolf

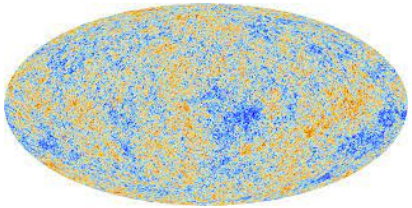
Max-Planck-Institut für Kernphysik

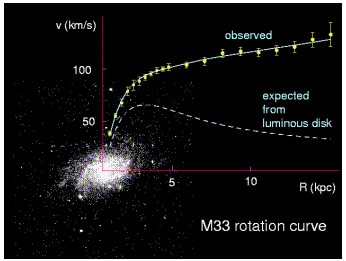
tim.wolf@mpi-hd.mpg.de

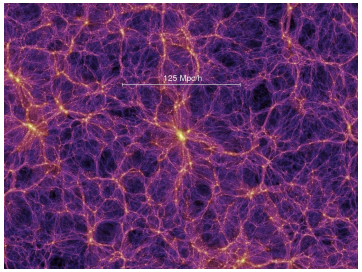
based on: arXiv:2107.05685

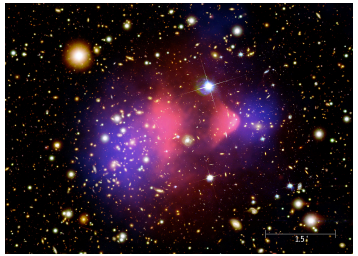
Why Dark Matter?

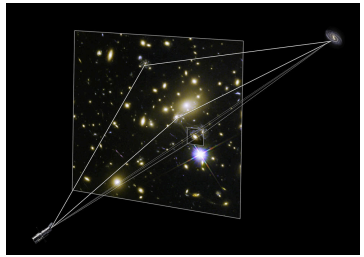
- Many different evidence for the existence of Dark Matter (DM)



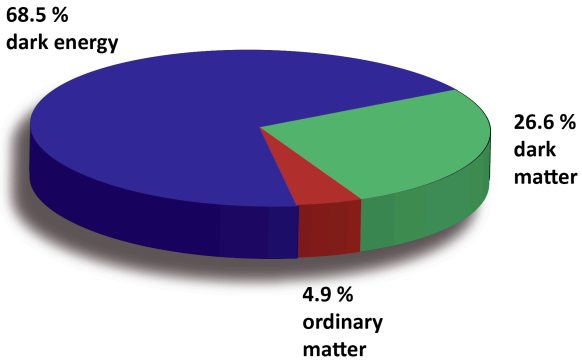








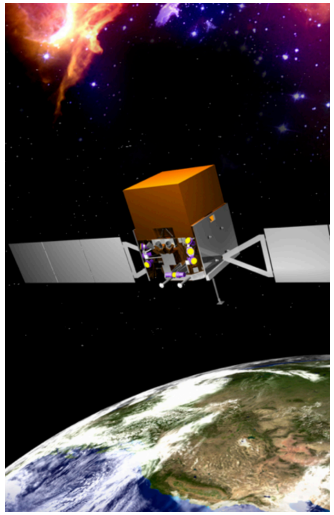
- ΛCDM describes all observations well
- Well motivated theory approach:
  Weakly **I**nteracting **M**assive **P**articles
  $\rightarrow$**WIMPs**



Nature of Dark Matter remains unknown!

Indirect detection

- Annihilation of DM might occur at the center of our galaxy sending out detectable signatures into the universe
- $\chi\chi \rightarrow e^+e^-, \chi\chi \rightarrow \gamma\gamma$



$$\frac{d\Phi_p}{dE} = \frac{\langle \sigma v \rangle}{4\pi 2 m_\chi^2} \cdot \frac{dN_p}{dE} \cdot J(\Delta\Omega) \qquad J(\Delta\Omega) = \int d\Omega \int \rho^2(\ell) d\ell$$

- DM annihilation typically targeted by:
  - satellites or balloons sensitive to charged particles, γs
  - Cherenkov telescopes and large neutrino observatories

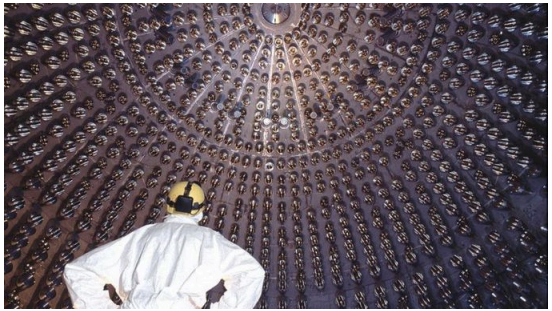
Direct Detection of DM

- Typically looking for DM interaction with ***nuclei*** and ***electrons*** of target material
- two phase time projection chambers are among the most sensitives (LZ, XENON, PandaX, Darkside, ArDM, …)

see Tuesday 10:00 - Michelle Galloway

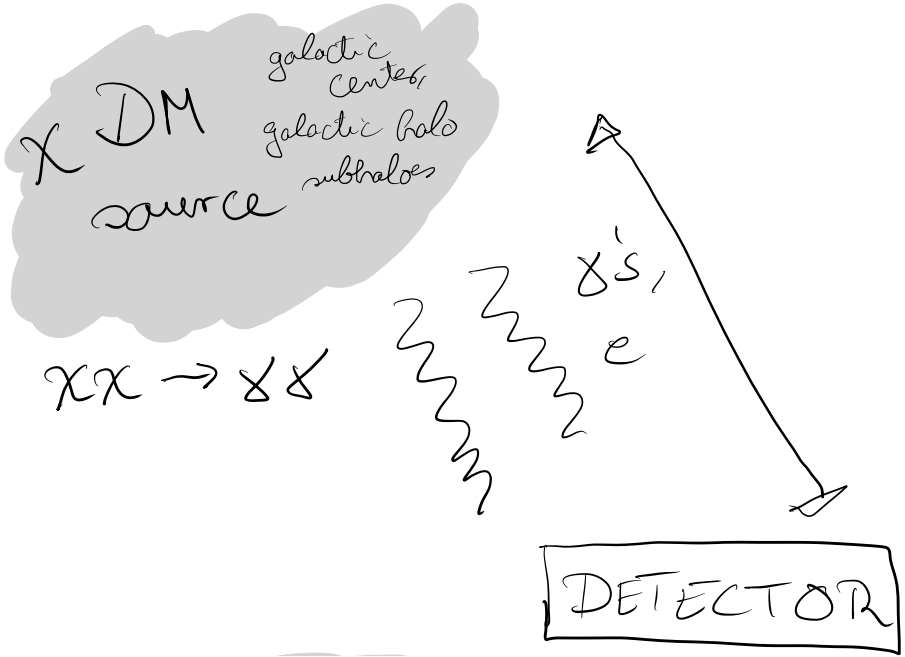

XNEONnT

- **Key point:**
  - sensitive to energy depositions between a few keV to a few MeV
  - energy spectrum allows so carry out searches


Not a DM detector (Borexino)

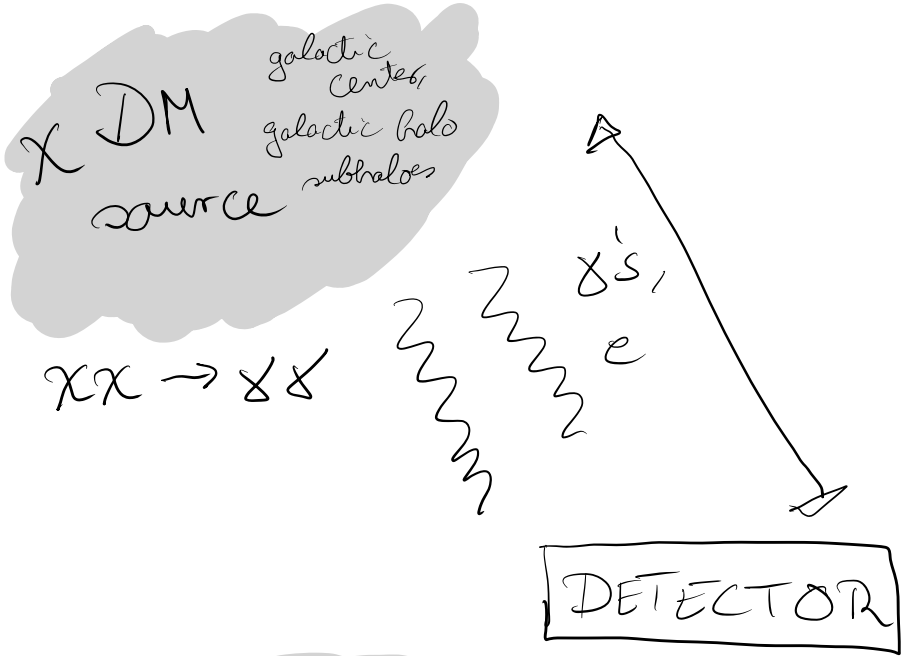
New perspective on laboratory experiments

classical indirect search for DM:

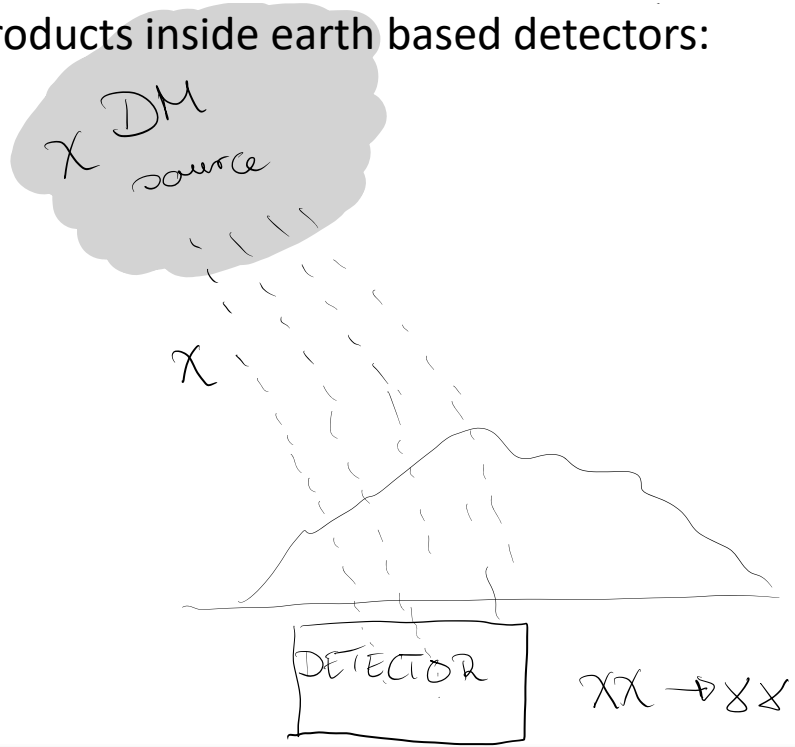


New perspective on laboratory experiments

classical indirect search for DM:



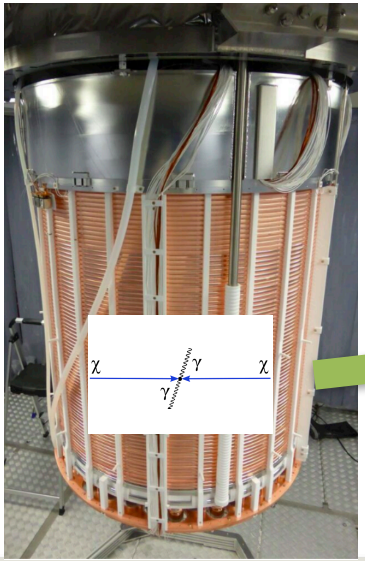
new idea to search for annihilation products inside earth based detectors:



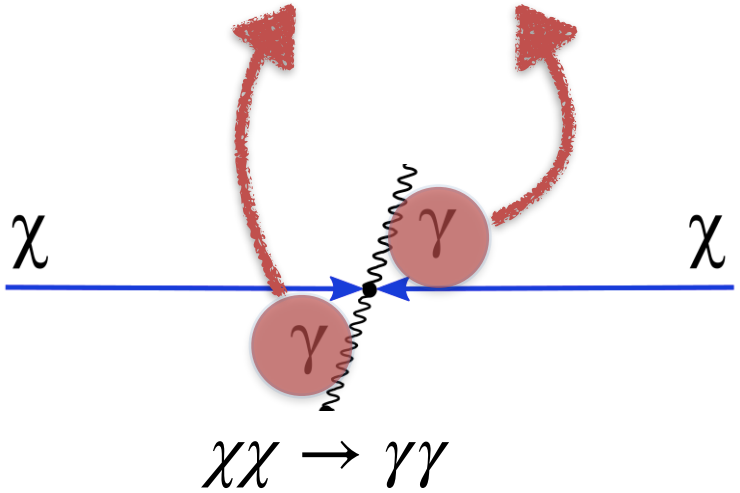
New perspective on laboratory experiments

- Study of sensitivity to annihilation taking place **inside earth based detectors**

Photomultiplier tubes
at top and bottom!



Not detectable by photo-sensors

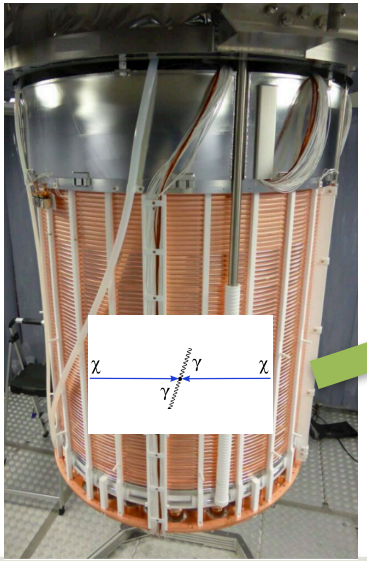


$$\chi\chi \rightarrow \gamma\gamma$$

New perspective on laboratory experiments

- Study of sensitivity to annihilation taking place **inside earth based detectors**

Photomultiplier tubes at top and bottom!



electrons detectable:
“S2” signal

Compton scattering

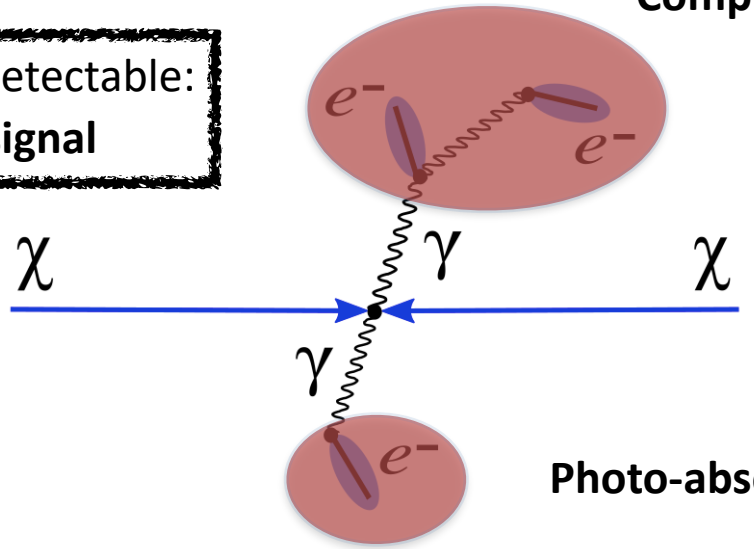


Photo-absorption

$\chi\chi \rightarrow \gamma\gamma$

New perspective on laboratory experiments

Annihilation rate: $\mathcal{R} = \frac{\langle \sigma v \rangle}{2} n_{\mathrm{DM}}^2 = \frac{\langle \sigma v \rangle}{2 m_\chi^2} \rho_{0,\mathrm{DM}}^2$

Signature: peak at $2m_\chi$

- No dependence:
  - J-factors
  - SM processes in complex objects do not matter
- Considered volume much smaller: detector vs. center of galaxy…

New perspective on laboratory experiments

Annihilation rate: $\mathcal{R} = \frac{\langle \sigma v \rangle}{2} n_{\rm DM}^2 = \frac{\langle \sigma v \rangle}{2 m_\chi^2} \rho_{0,\rm DM}^2$

Signature: peak at $2m_\chi$

- No dependence:
  - J-factors
  - SM processes in complex objects do not matter
- Considered volume much smaller: detector vs. center of galaxy…

Argument also applies for DM decay

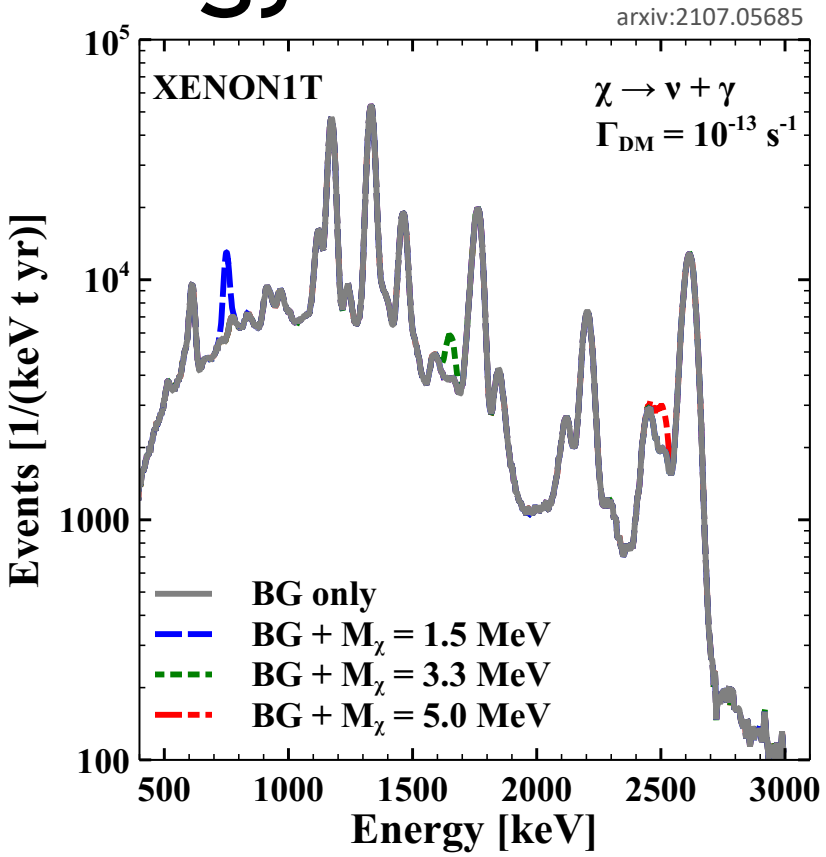
$\mathcal{R} = \Gamma_{\rm DM}\, n_{\rm DM} = \frac{\Gamma_{\rm DM}}{m_\chi} \rho_{0,\rm DM}$

$\chi \to \gamma\gamma,\ \chi \to e^+e^-,\ \chi \to \nu\gamma$

peak at $\frac{1}{2} m_\chi$

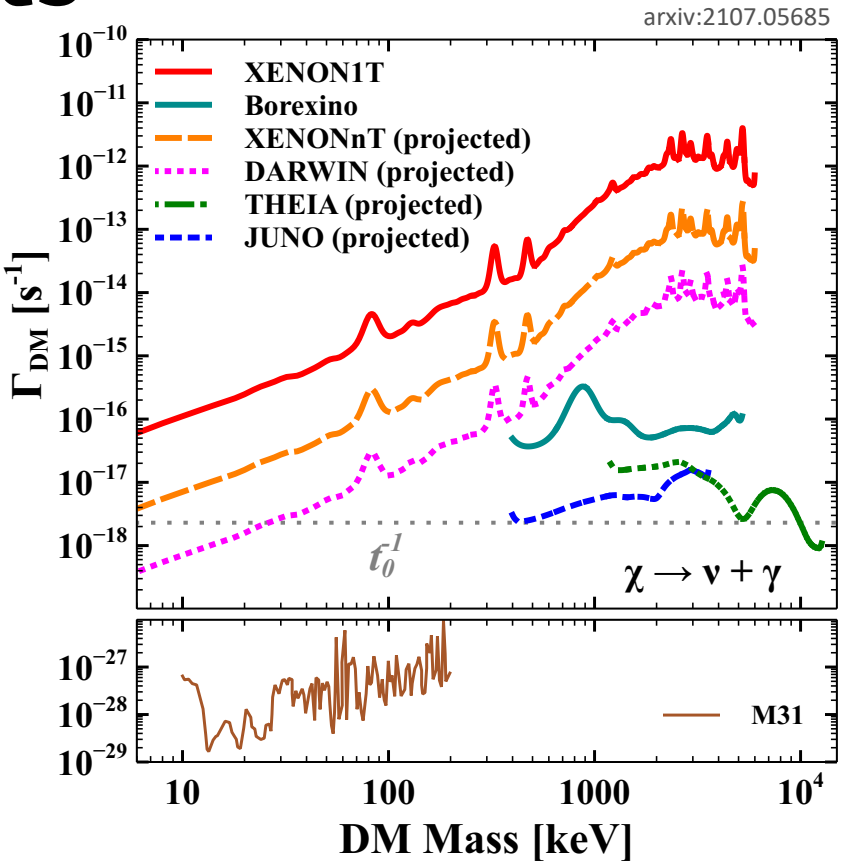
Analysis strategy

- look at high energy spectra of electronic recoil energy depositions
- observed rate at a given energy allows to constrain annihilation cross-section / decay rate respectively



Results

- Considering liquid xenon TPCs (XENON1T) but also organic scintillators (Borexino) and planned experiments
- Limits from M31 10 to 12 orders of magnitude better —> larger annihilation volume



Summary

- Novel idea to use earth based detectors to constrain:
  - DM annihilation rate → $\langle \sigma v \rangle$
  - DM decay rate → Γ_{DM}
- Limits are not competitive with astronomical experiments
- Complementary probe of DM properties
- Analysis which should be rather straightforward to perform once calibration up to higher energies is successful
- Bigger detectors as planned by XLZD will provide better limits