Dark radiation signals in dark matter and neutrino experiments

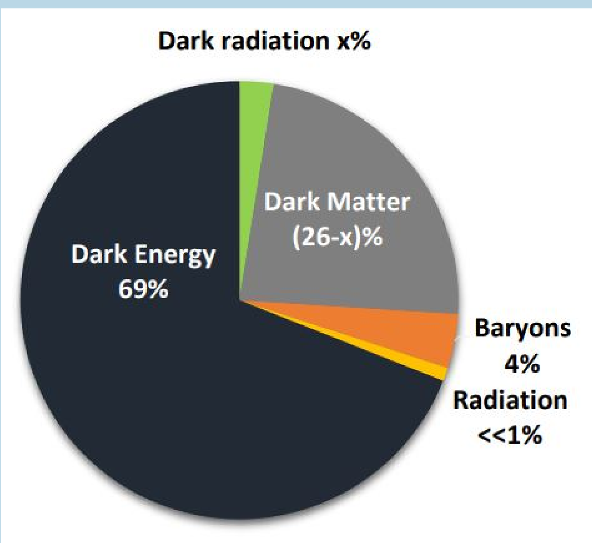
Marco Nikolic
marco.nikolic@oeaw.ac.at

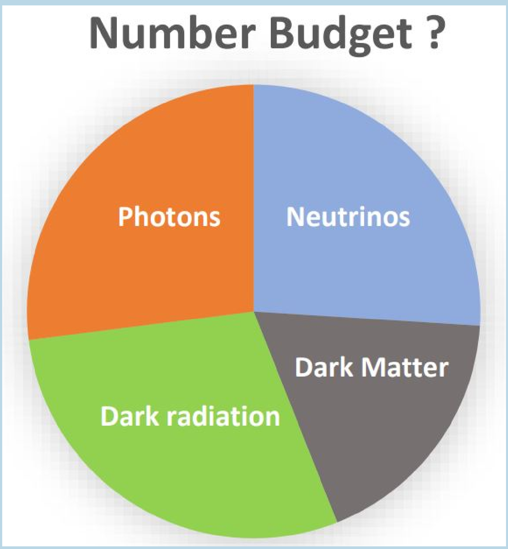
Motivation

Besides DM, the universe may also be filled in significant number with a new form of relativistic particles, dark radiation, that have escaped detection to date. Such dark radiation is assumed to be produced from dark matter decays. Assuming dark radiation in form of neutrinos, one way to look for such particles is by searching for nuclear recoil or electron events in direct detection experiments or in future experiments as PTOLEMY.

Basic Concept

- new form of relativistic particles produced by unstable dark matter (few % of total DM abundance) $\rightarrow$ dark radiation (DR)
- number budget unknown $\rightarrow$ large DR flux possible
- DR may leave a detectable signal in dark matter and neutrino experiments





Model

One simple model is to produce dark radiation by DM decays

$$X \rightarrow \nu\nu.$$

Dark radiation is described by the lifetime τ_X and mass m_X of the progenitor and the fraction of decaying DM f_X. The benefit of this scenario is that interactions of neutrinos are already known in experiments. We consider two possible neutrino nature:

- Standard Model neutrinos
- baryonic neutrinos which interact with baryon number through a new vector particle

References

[1] M. Nikolic, S. Kulkarni, J. Pradler, *The neutrino floor in the presence of dark radiation, arXiv: 2008.13557 [hep-ph]*

[2] K. Bondarenko, A. Boyarsky, M. Nikolic, J. Pradler, A. Sokolenko, *Probing sub-eV Dark Matter decays with PTOLEMY*, JCAP 03 (2021) 089, doi: 10.1088/1475-7516/2021/03/089, *arXiv: 2012.09704 [astro-ph.CO]*

Acknowledgements

MN and AS are supported by the FWF Research Group grant FG1. SK is supported by Elise-Richter grant project number V592-N27. JP is supported through the New Frontiers Program by the Austrian Academy of Sciences. KB and AB are supported by the European Research Council (ERC) Advanced Grant "NuBSM" (694896).

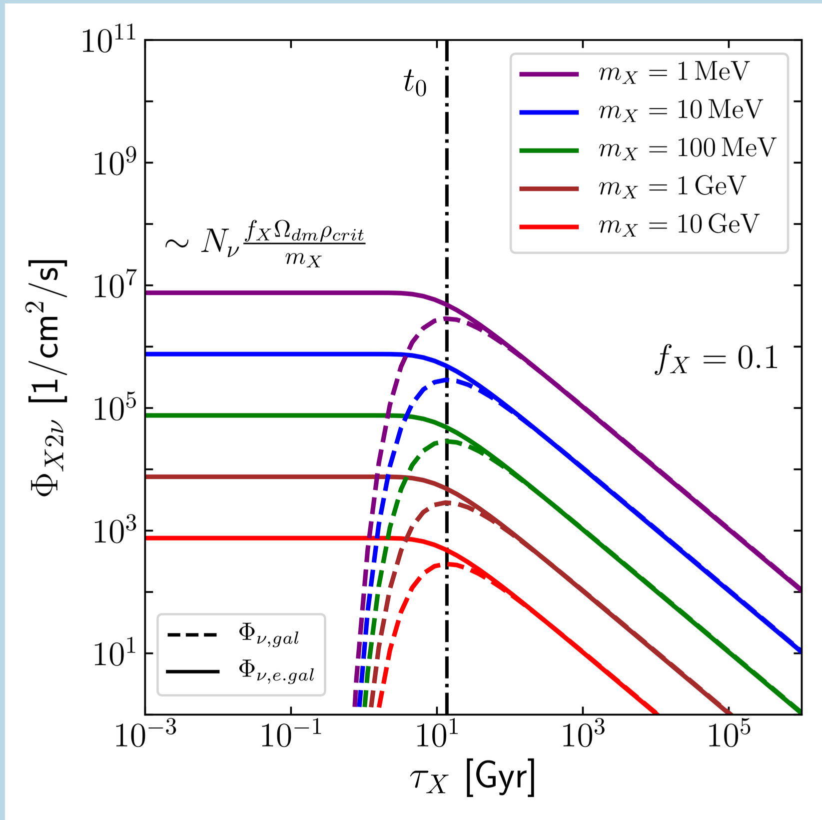
Dark radiation from dark matter decay

The DR flux arriving at the Earth is a combination of two components, the galactic flux Φ_{gal} and the extra-galactic flux Φ_{egal},

$$\Phi_{gal} = N_\nu \frac{f_X}{\tau_X m_X} e^{-\frac{t_0}{\tau_X}} r_\odot \rho_\odot \langle J_{\rm dec}(\theta)\rangle,$$

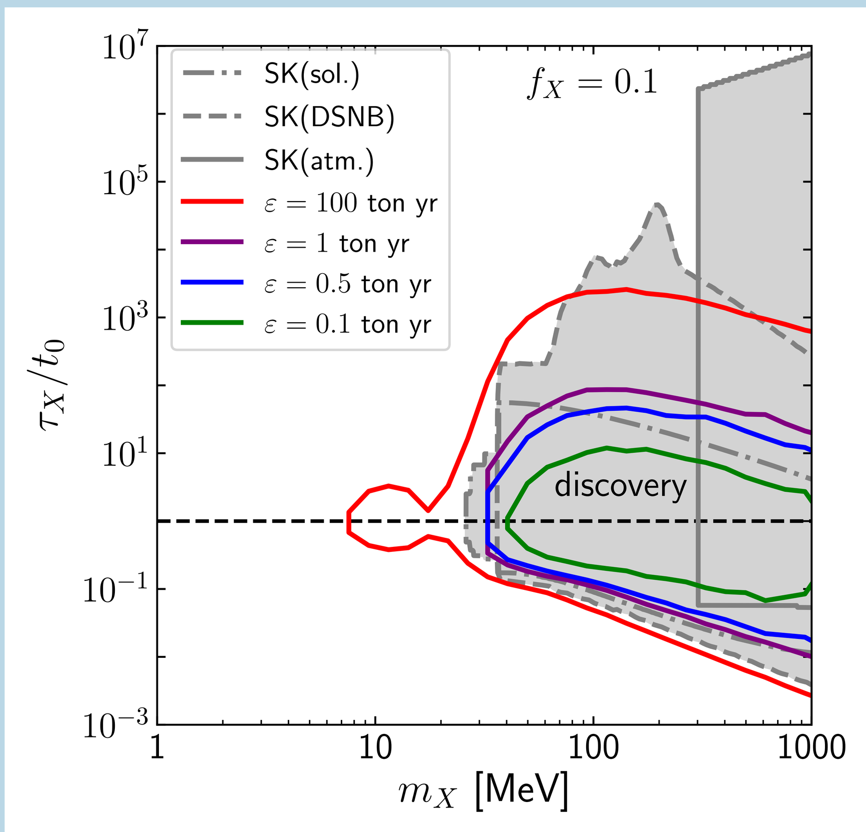
$$\Phi_{egal} \simeq N_\nu \frac{f_X\,\Omega_{\rm dm}\rho_{\rm crit}}{m_X} \times \begin{cases} 1 & \tau_X \ll t_0 \\ (H_0\tau_X)^{-1} & \tau_X \gg t_0 \end{cases},$$

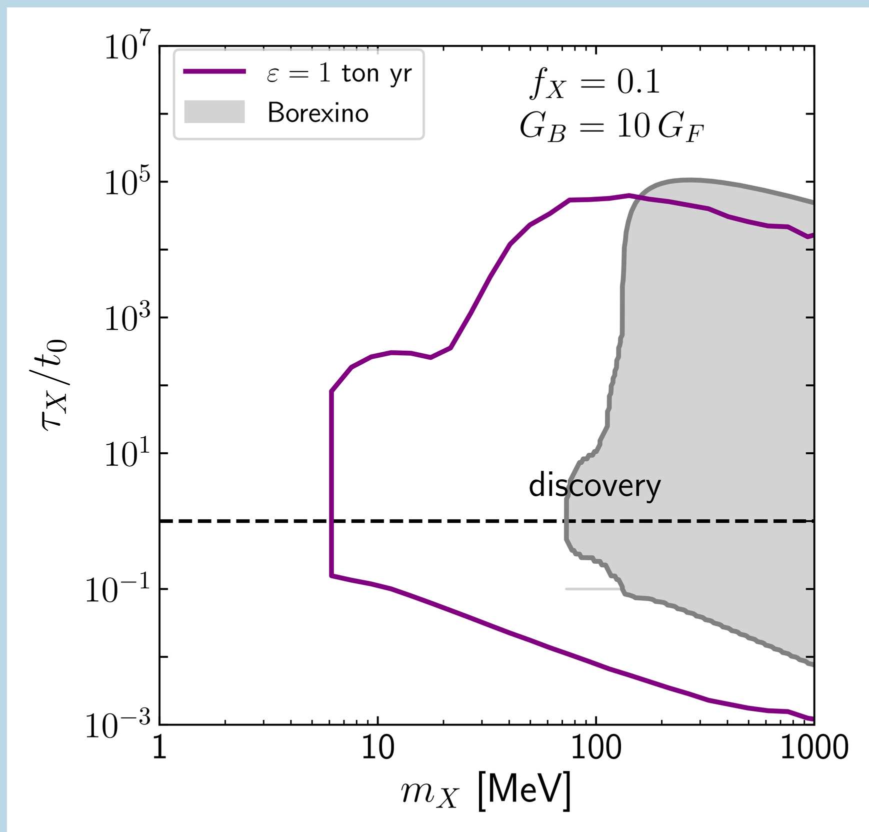
where $t_0 = 13.787 \pm 0.020$ Gyr is the age of the universe, $N_\nu = 2$ is the number of neutrinos in final state, $E_{\rm in} = m_X/2$ is the injection energy, $r_\odot = 8.33$ kpc is the distance between the observer at the Earth and the galactic center, $\rho_\odot = 0.3$ GeV/cm^3 is the local DM density and $\langle J_{\rm dec}\rangle \approx 2.19$ is the angular averaged J-factor obtained from an NFW profile. We set the density parameters $\Omega_{\rm dm}h^2 = 0.12$, $\Omega_M = 0.315$, $\Omega_\Lambda = 1 - \Omega_M$ consistent with the ΛCDM model of a flat Universe. $H_0 = 100h$ km/s/Mpc and $\rho_{\rm crit} = 3H^2/(8\pi G)$ are the Hubble parameter and critical density at the present time with $h = 0.674$.



Signatures of dark radiation

Discovery limits of dark radiation with a 3σ significance in presence of neutrino backgrounds (solar, atmospheric neutrinos and diffuse supernova neutrino background) in dark matter direct detection experiments.





Discovery limits of dark radiation with a 3σ significance in presence of neutrino backgrounds (beta background $\mathrm{T} \rightarrow {}^3\mathrm{He} + \mathrm{e}^- + \bar{\nu}_\mathrm{e}$ and tritium neutrino capture from cosmic neutrino baclground) in the future experiment PTOLEMY.