Supax — a superconducting axion search experiment

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Introduction — Supax

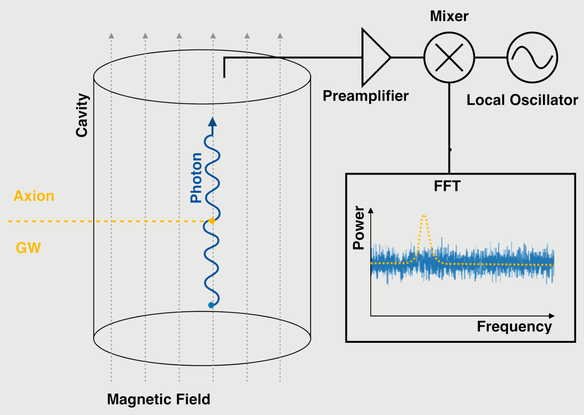
Axions are hypothetical fundamental particles that could explain *smallness of electric dipole moment* of the neutron, and is a **dark matter candidate**. Axions are expected to be low-mass particles, for which **haloscope** is a well matched approach. Supax aims at axions detection using **Primakoff effect**: axion $\rightarrow \gamma$ conversion in static magnetic field.

$$P_{\mathrm{sig}} = |g_{\alpha\gamma\gamma}|^2 \, \rho_\alpha \, \frac{\beta}{\beta+1} \, \frac{1}{m_A} \, B_0^2 \, V \, C \, Q_{\mathrm{eff}} \, \eta \, \hbar^2 c^5 \varepsilon_0$$

Nearly identical experiment design can be used for **high frequency gravitational waves** (HFGW) detection via **inverse Gertsenshtein** effect.

Detection approach

- cryostat 10 mK
- magnet 12 T
- low-noise amplifier (TWPA, JPA)
- frequency $\mathcal{O}$(1 GHz)



Supax — Results

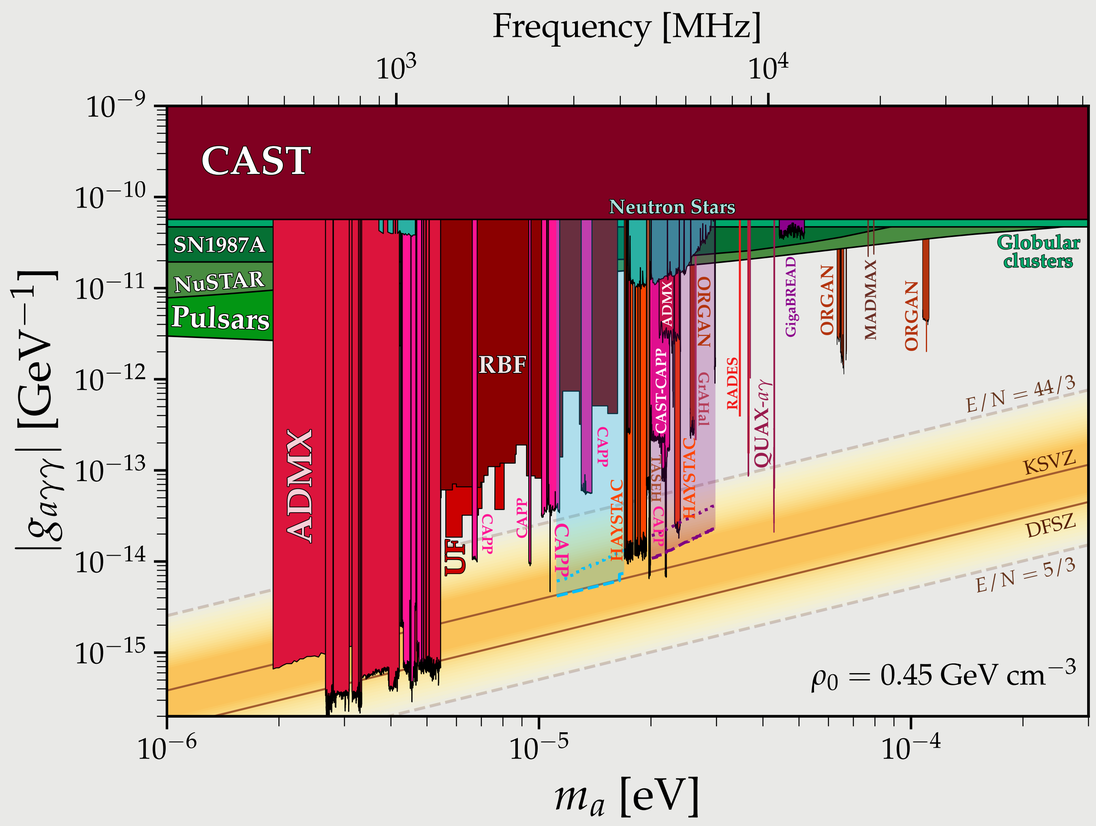
Prototype:

- resonant frequency 8.47 GHz $\rightarrow$ $m_A \approx 34\,\mu$eV
- $T_{\mathrm{cav}} = 2$ K, $B_0 = 12.1$ T, $Q_0 = 50,000$
- mass range: 0.0006 µeV (1.4 MHz) around 34 µeV
- **axion-photon coupling larger than $|g_{\alpha\gamma\gamma}| > 1.6 \times 10^{-13}$ excluded at 95% confidence level**

Supax — Outlook

Assumptions:

- 2.7 GHz $< f_0 <$ 7.2 GHz $\longrightarrow$ 11 µeV $< m_A <$ 30 µeV
- $Q_0 = 45{,}000$, $T_{\mathrm{cav}} = 10$ mK, $t_{\mathrm{meas}} = 40$ weeks



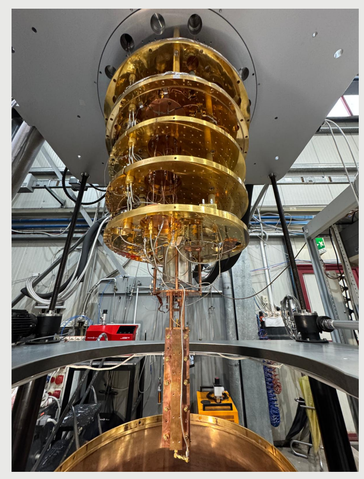
GW search — GravNet

- extension of axion search experiment
- focus on inspiral phase of **primordial black holes** (PBH) merger
- no constraints on the fraction of DM composed of PBHs in mass range: $10^{-16} - 10^{-10} M_\odot$, masses within sensitivity range
- **network** of $\mathcal{O}$(1 GHz) cavities + 250 MHz cavity
- signal detection in network — suppressed background event count
- EM signal **power**:

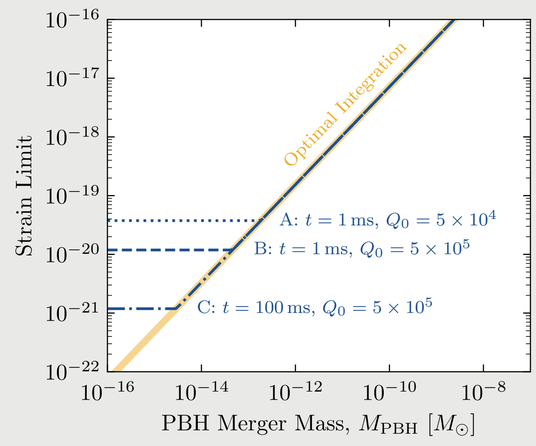
$$P_{\mathrm{sig}} \simeq \omega_g \, h^2_{\times,+} \, \langle B_0^2 \rangle \, Q_l \, C_{\mathrm{GW}} \, V$$

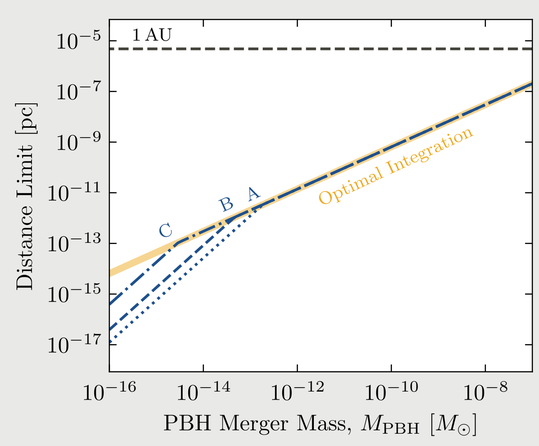
Experimental setup

- **commercial cryostat**, same as for axion search
- **tunable cavity**, $\Delta f_0 \approx 60$ MHz (sapphire tuning rod)
- **quantum limited noise readout line** (TWPA amplifier)
- dipole antenna for readout

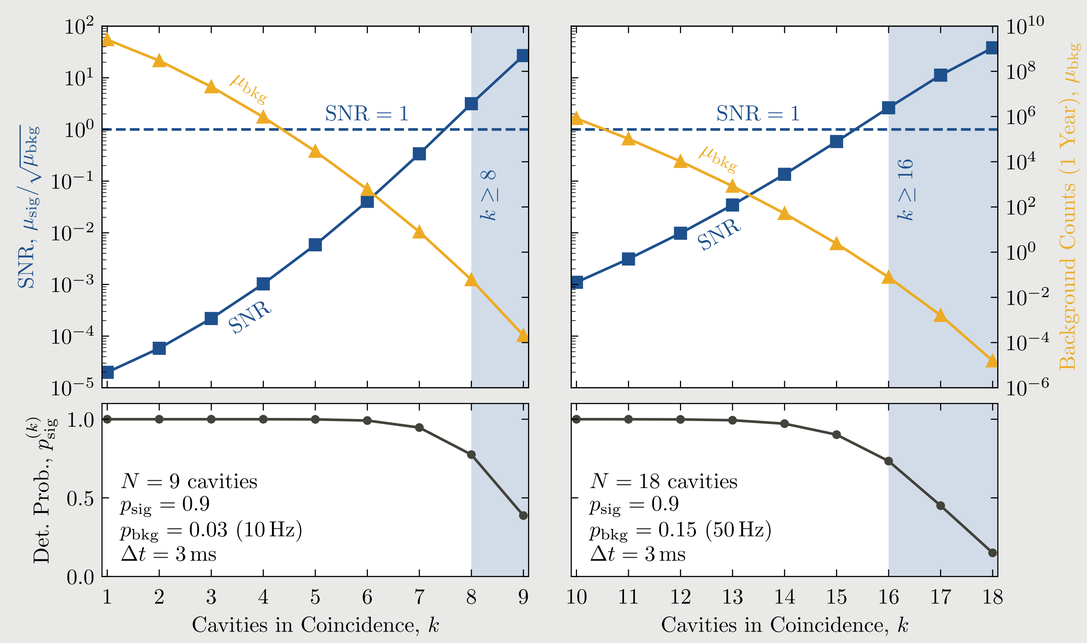


Sensitivity + one photon distance limit





Network performance



References

- **Supax CDR:** arXiv:2505.07541
- **GravNet CDR:** arXiv:2603.24645
- **GravNet Collaboration website:** www.pi.uni-bonn.de/gravnet

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