Magnetically-levitated Superconductors for Dark Matter Searches

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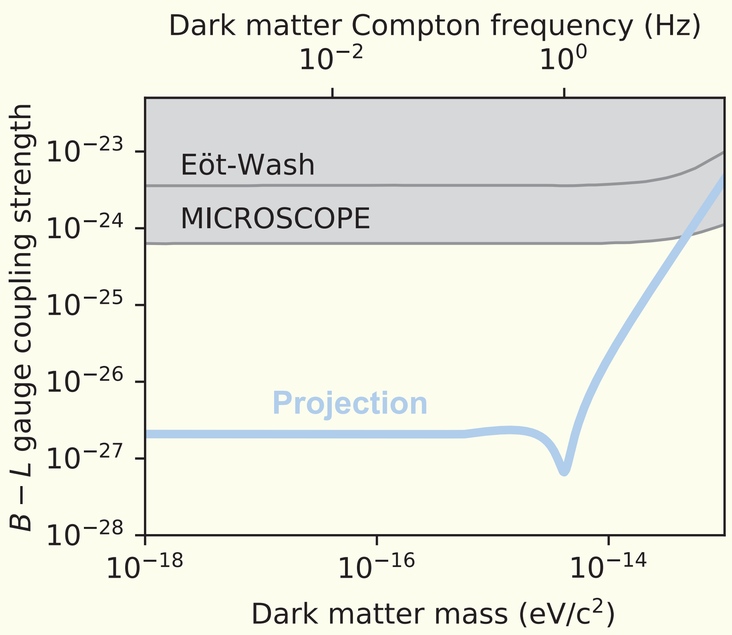
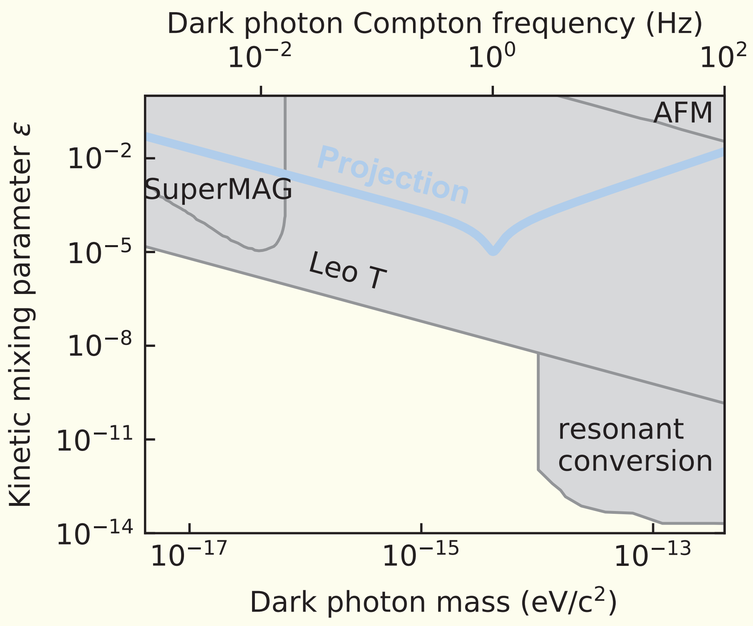
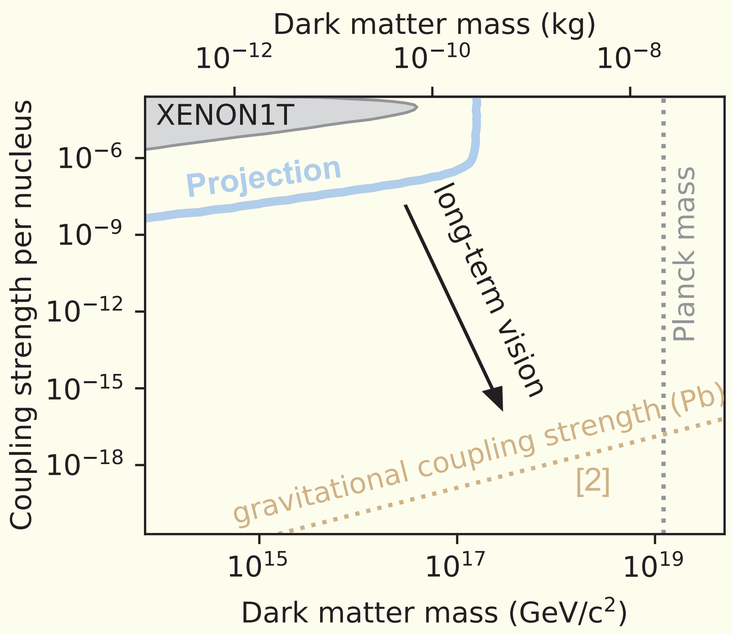
Projected sensitivity

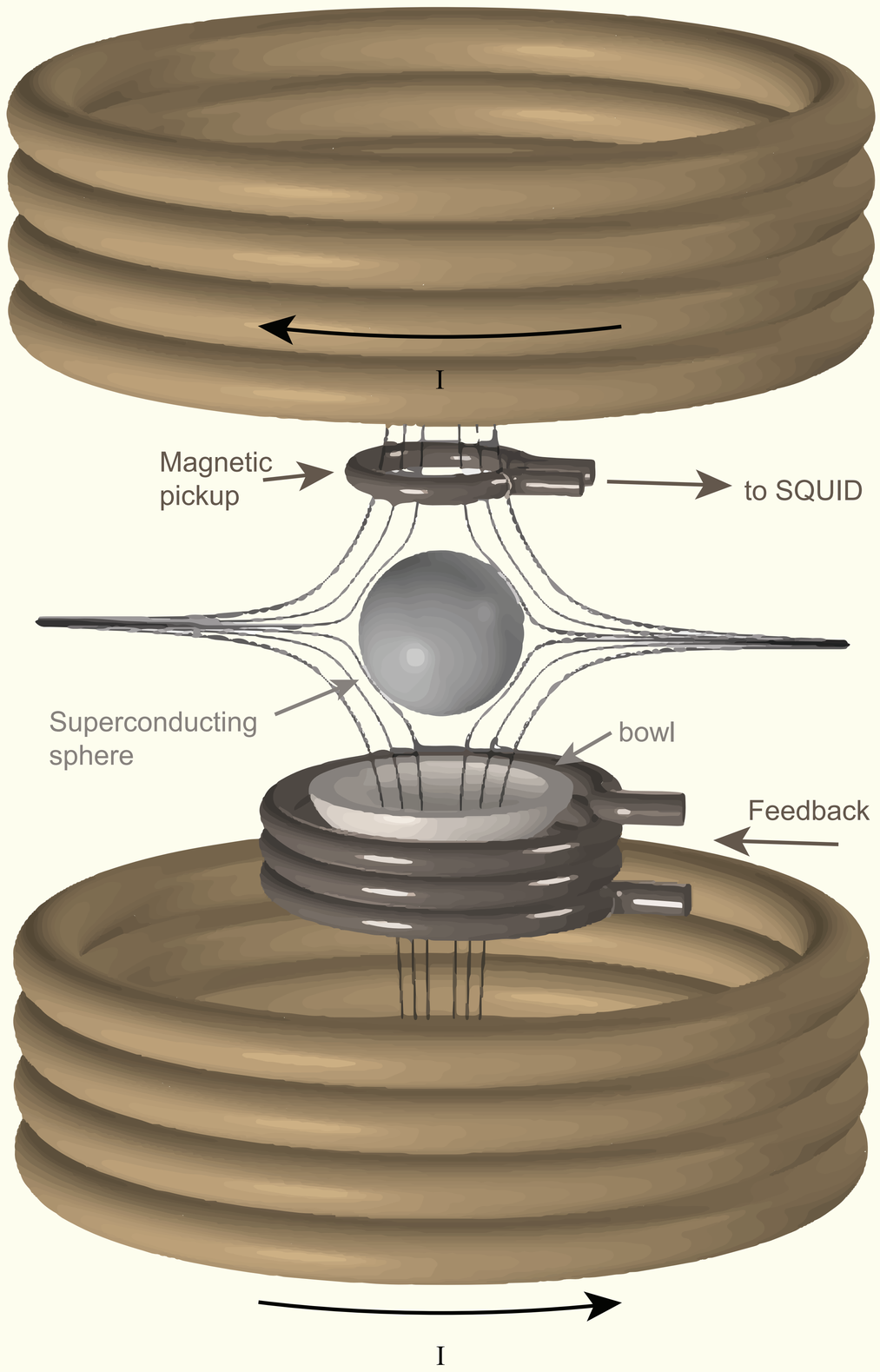
Mechanical sensors are powerful tools for precision tests of physics beyond the Standard Model [1]. Magnetically-levitated superconductors can act as ultra-sensitive mechanical sensors, for searching for both ultralight and ultra-heavy dark matter candidates.





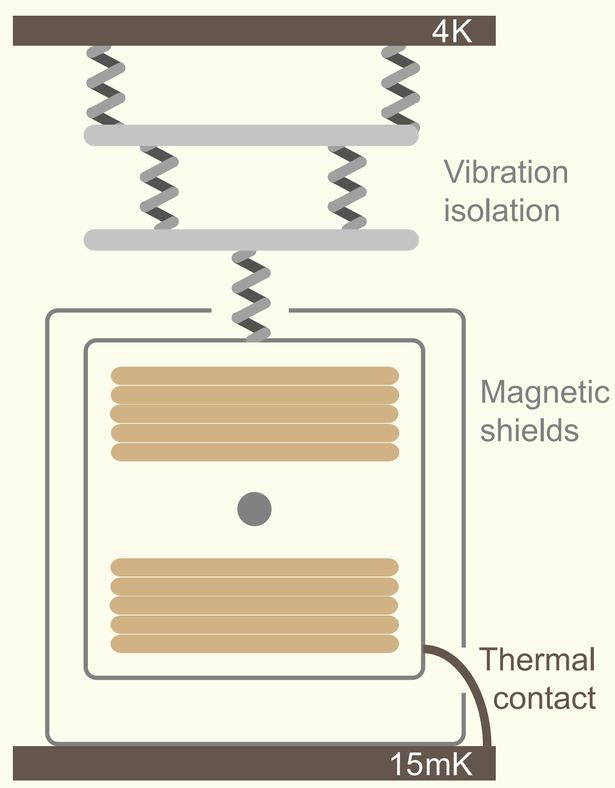


Projections prepared with Dorian Amaral (Rice University), Saarik Kalia (University of Minnesota) and Juehang Qin (Rice University).



Extreme isolation

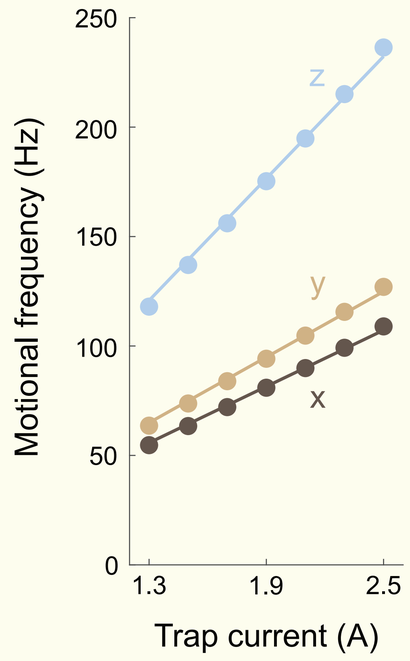
The particle is far from any surfaces, in ultrahigh vacuum, and its surroundings are at millikelvin temperatures. Magnetic shielding and vibration isolation mitigate magnetic field noise and vibrational noise.



Magnetic trapping

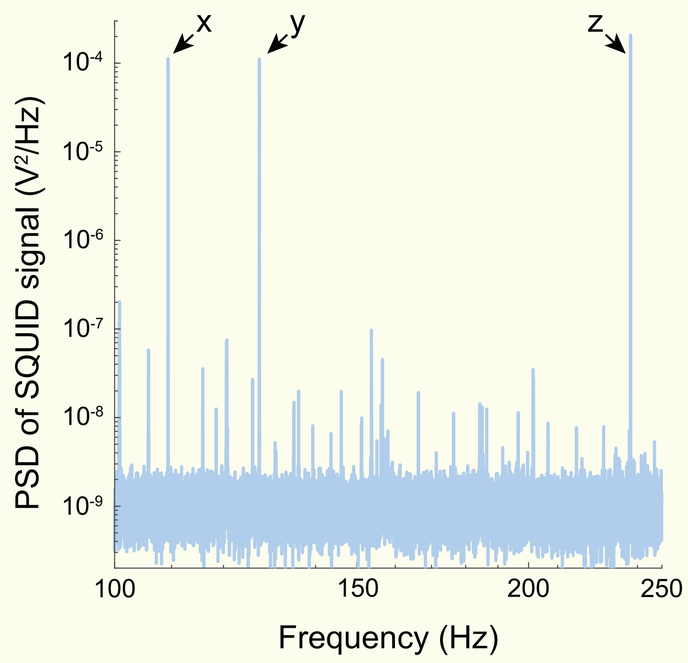
Superconductors act as ideal diamagnets, and can be stably confined in the magnetic field minimum between current-carrying coils.

The trap can be tuned via the coil current.



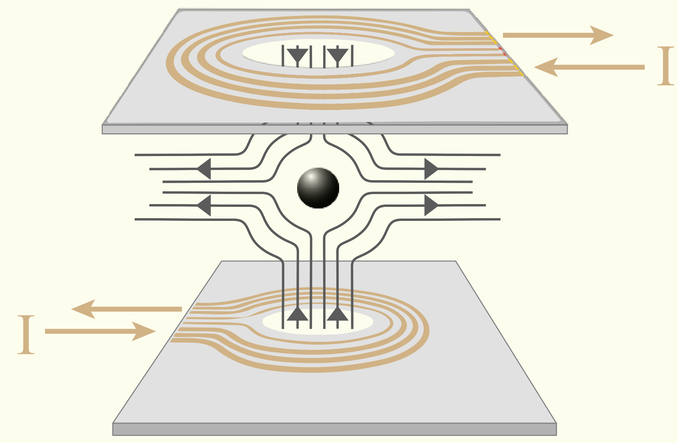
Precise readout

The particle motion can be precisely measured using superconducting quantum circuitry [3-5]. The trapping field bends around the superconductor. As the superconductor moves, the flux threading a pickup loop changes, inducing a current in the loop. This current is precisely measured using e.g. a SQUID.



Scaling-up

The coils can be microfabricated on chips [5-6]. This allows the setup to be miniaturised, and will enable a densely-packed sensor array.



References

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2. D. Carney et al., Phys. Rev. D 102, 072003 (2020) — Prospect of detecting dark matter via its gravitational interaction
3. O. Romero-Isart et al., Phys. Rev. Lett. 109, 147205 (2012)
4. J. Hofer et al., Phys. Rev. Lett. 131, 043603 (2023)
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} Levitated superconducting microspheres for fundamental quantum physics tests in the macroscopic domain

Related systems:

J. M. Goodkind, Rev. Sci. Instrum. 70, 4131 (1999) — Superconducting gravimeter
C. E. Griggs et al., Phys. Rev. Appl. 8, 064024 (2017) — Superconducting gravity gradiometer