# Searching for Wavelike Dark Matter with SRF Cavities

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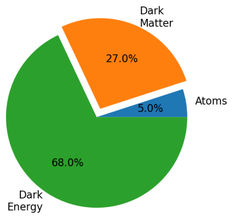
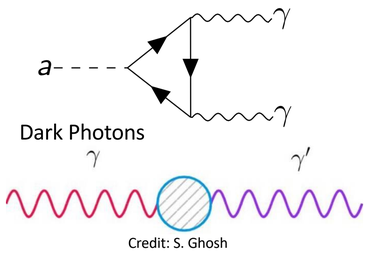
## What is Dark Matter?



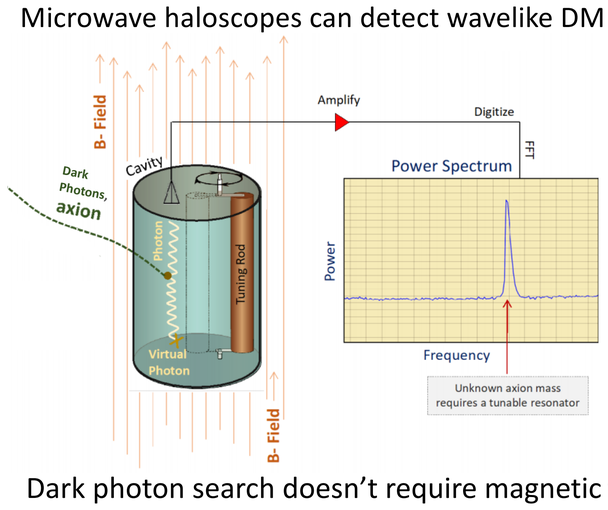

Can it be wavelike?

Axions



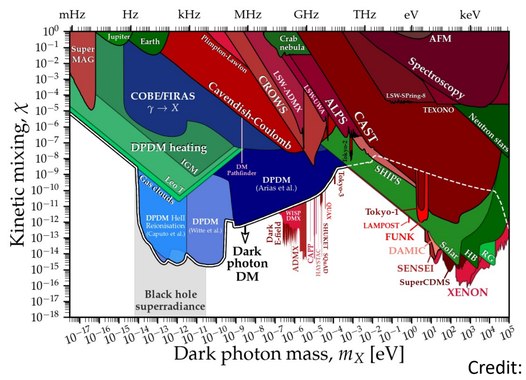

Credit: S. Ghosh

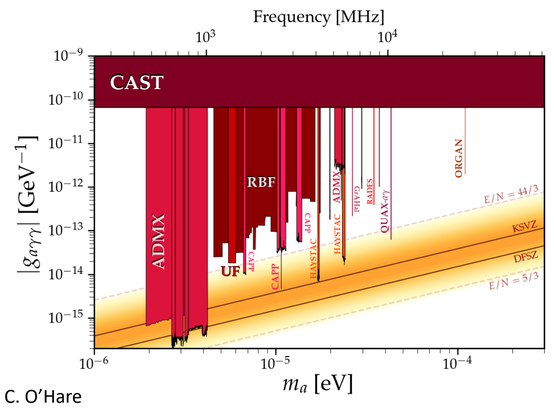
Microwave haloscopes can detect wavelike DM




Dark photon search doesn't require magnetic field.

**DM coupling strength, mass unknown.**
**Lots of unexplored parameter space.**



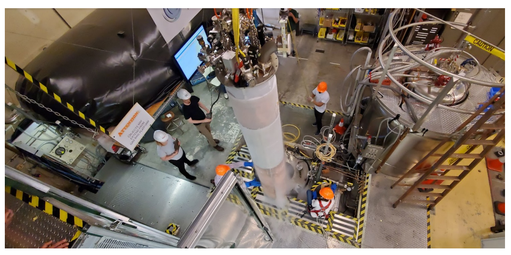




Credit: C. O'Hare

## Can We Speed Up DM Searches with SRF Cavities?

Benefits from longer coherence time.

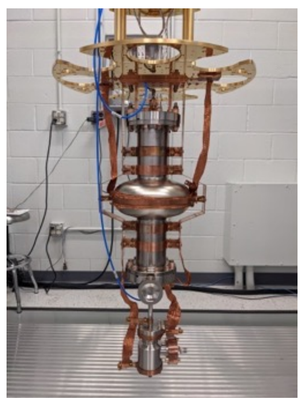
State of the art: ADMX



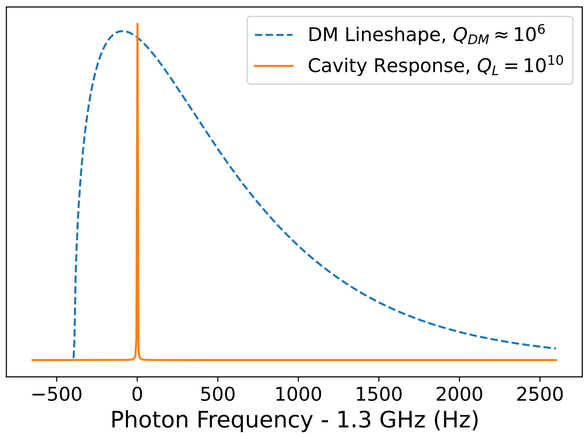
$Q_L \approx 8\times10^4$

Compare to

SRF Cavities



$Q_L \approx 8\times10^9$



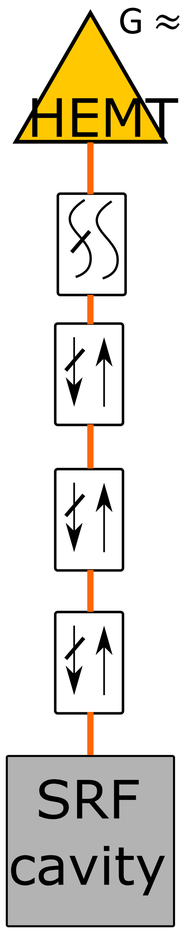

scan rate $\propto Q_L$
**if $Q_L \gg Q_{DM}$**

- Signal power constant with $Q_L$.
- Noise power reduces with $Q_L$.
- Cavity sensitive to distribution of possible DM rest masses.

Can SRF cavities increase instantaneous scan rate of haloscope experiments by a factor of 100,000?

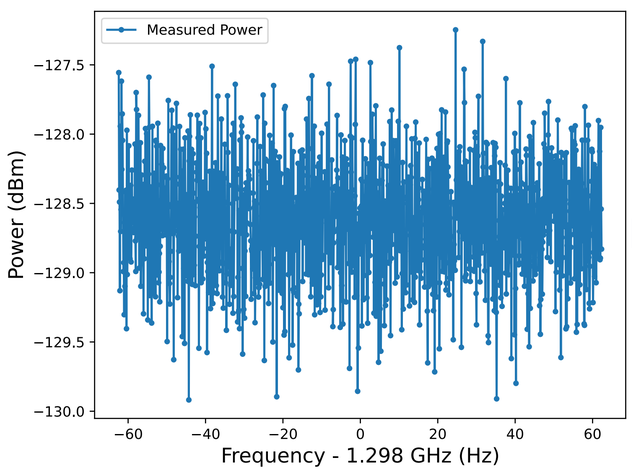
## Dark Photon Dark Matter Search with SRF Cavity

$T_a \approx 4.9$ K
G ≈ +37 dB



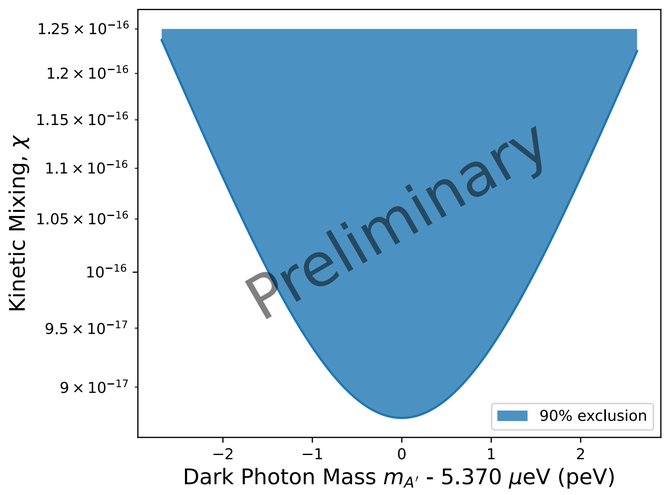

$T_c \approx 40$ mK
$Q_L \approx 8\times10^9$
$f_0 = 1.298$ GHz

Power Measured from Cavity



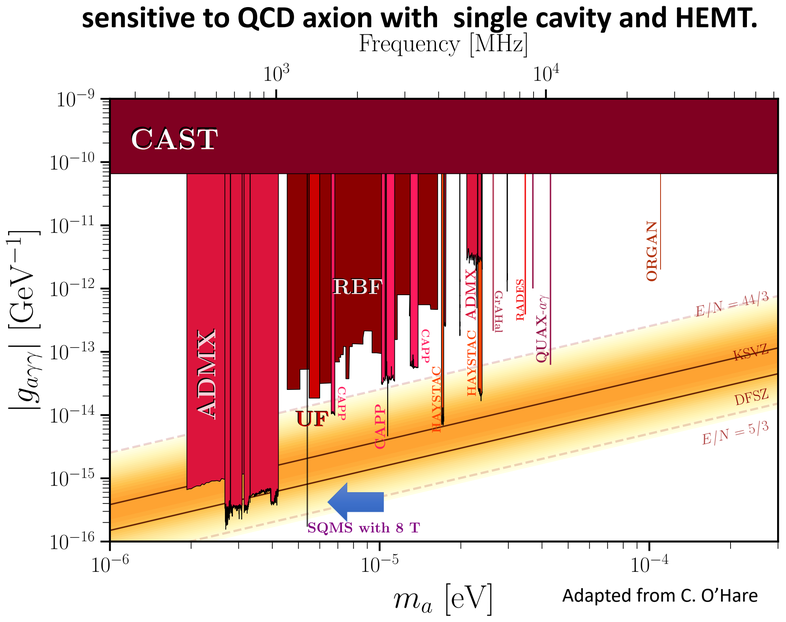

Just noise. No DP signal

**New Dark Photon DM Limits**



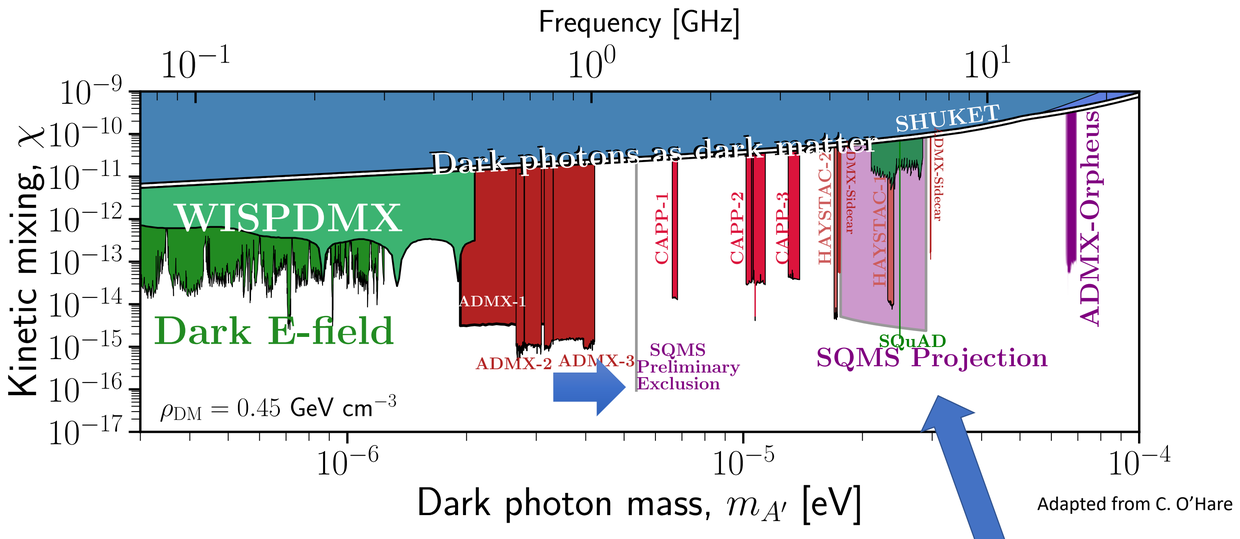

**SRF Cavities for Possible Axion Dark Matter Searches**

**If this worked in an 8 T magnetic field, would be sensitive to QCD axion with single cavity and HEMT.**

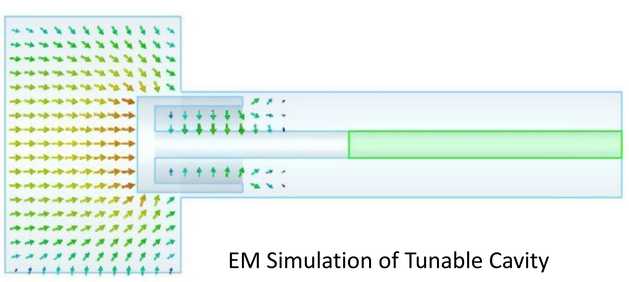



Adapted from C. O'Hare

## Most sensitive microwave DP haloscope



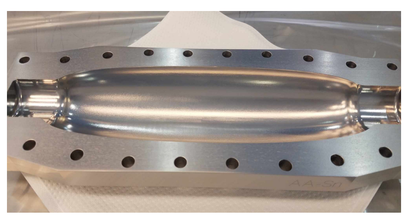

Adapted from C. O'Hare



EM Simulation of Tunable Cavity

Currently designing tunable 4.3-7 GHz SRF cavity for future DP search.
2nd phase will implement qubit-based photon counting to subvert SQL noise.

**Developing $Nb_3Sn$ SRF cavities in high magnetic fields**



Cigar-shaped $Nb_3Sn$ cavity

Performance so far:
$Q_L \approx 5\times10^5$
$f_0 = 3.9$ GHz
$B_0 = 6$T
https://arxiv.org/abs/2201.10733v2

## Take-home message

We have demonstrated that SRF cavities have unprecedented sensitivity to dark photon dark matter and have achieved the smallest excluded kinetic mixing for wavelike dark photons.
SRF cavities may be able increase the scan rate of dark matter searches by a factor of 100,000.
SRF cavities that are resistant to magnetic fields are being developed for axion searches.

## Acknowledgements

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