SEARCH FOR HIGH FREQUENCY DARK MATTER AXIONS

Ari Brill
Advisors: Gray Rybka and Leslie Rosenberg
University of Washington INT REU
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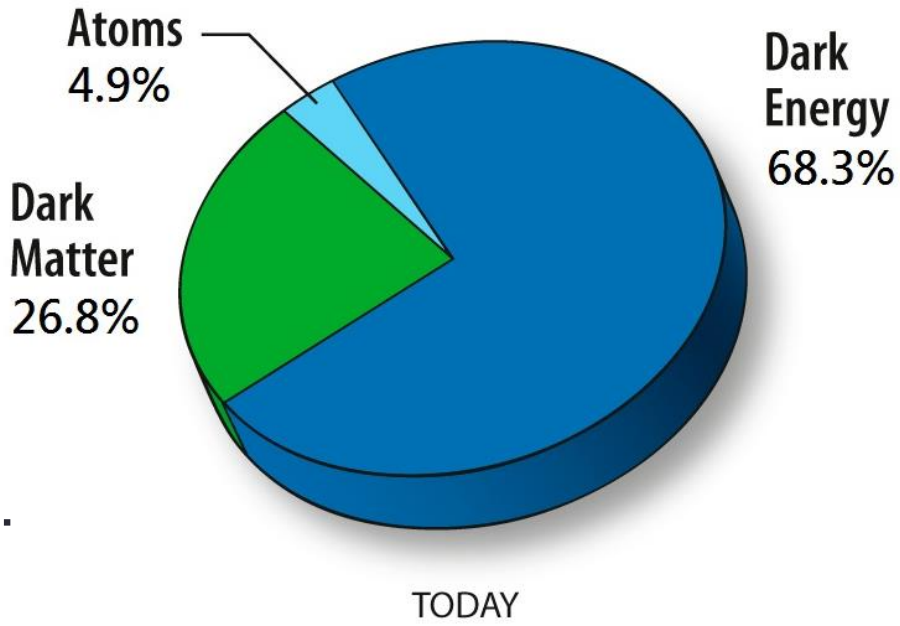
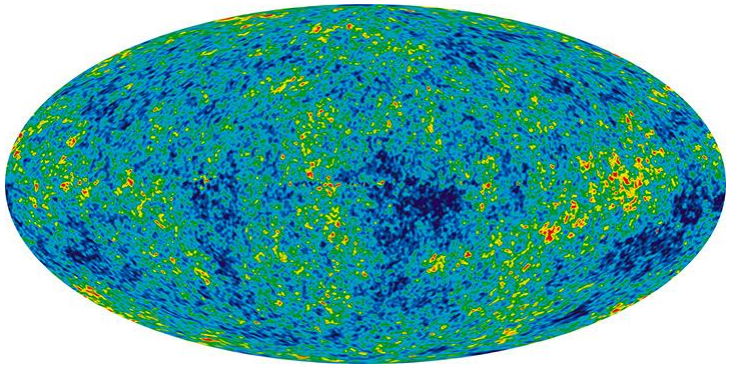
Dark Matter

Evidence across many length scales:

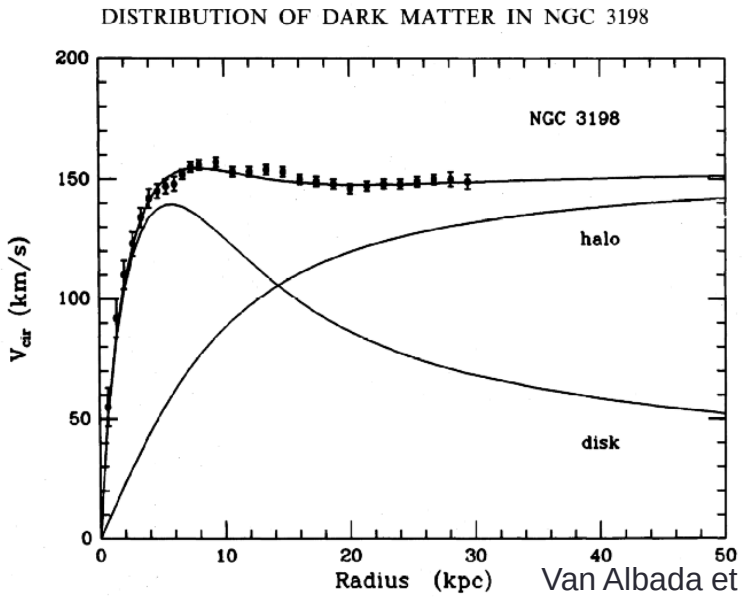


From oscillations in the CMB…



WMAP 9 Year, NASA

…to stellar velocities in galaxies.

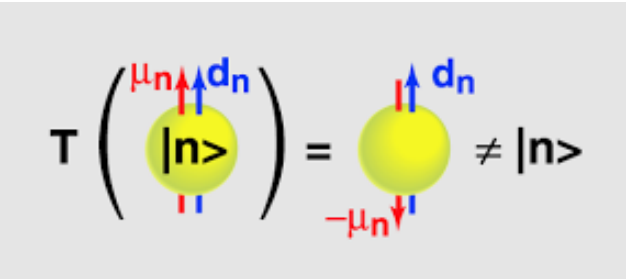


Van Albada et al.

Strong CP Problem

Theory of strong force contains several charge/parity symmetry violating terms of expected order 1.

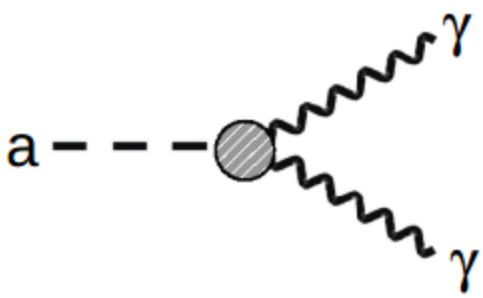
Measurements of neutron electric dipole moment reveal no violation, to order 10^{-9}.



The Peccei-Quinn Mechanism provides an answer.

The Axion

Weinberg, Wilczek: this implies a new particle, the axion!



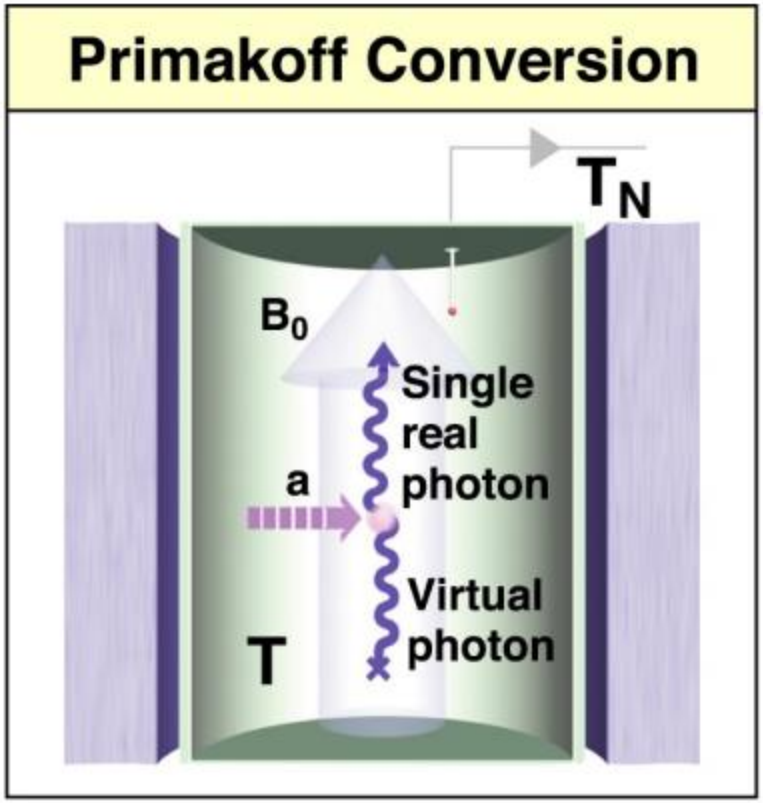
- Only decay is to 2 photons, lifetime ~10^{50} sec → Dark.
- Has a small mass → Matter.
- In general, predicted properties match cold dark matter.

Axion Haloscope

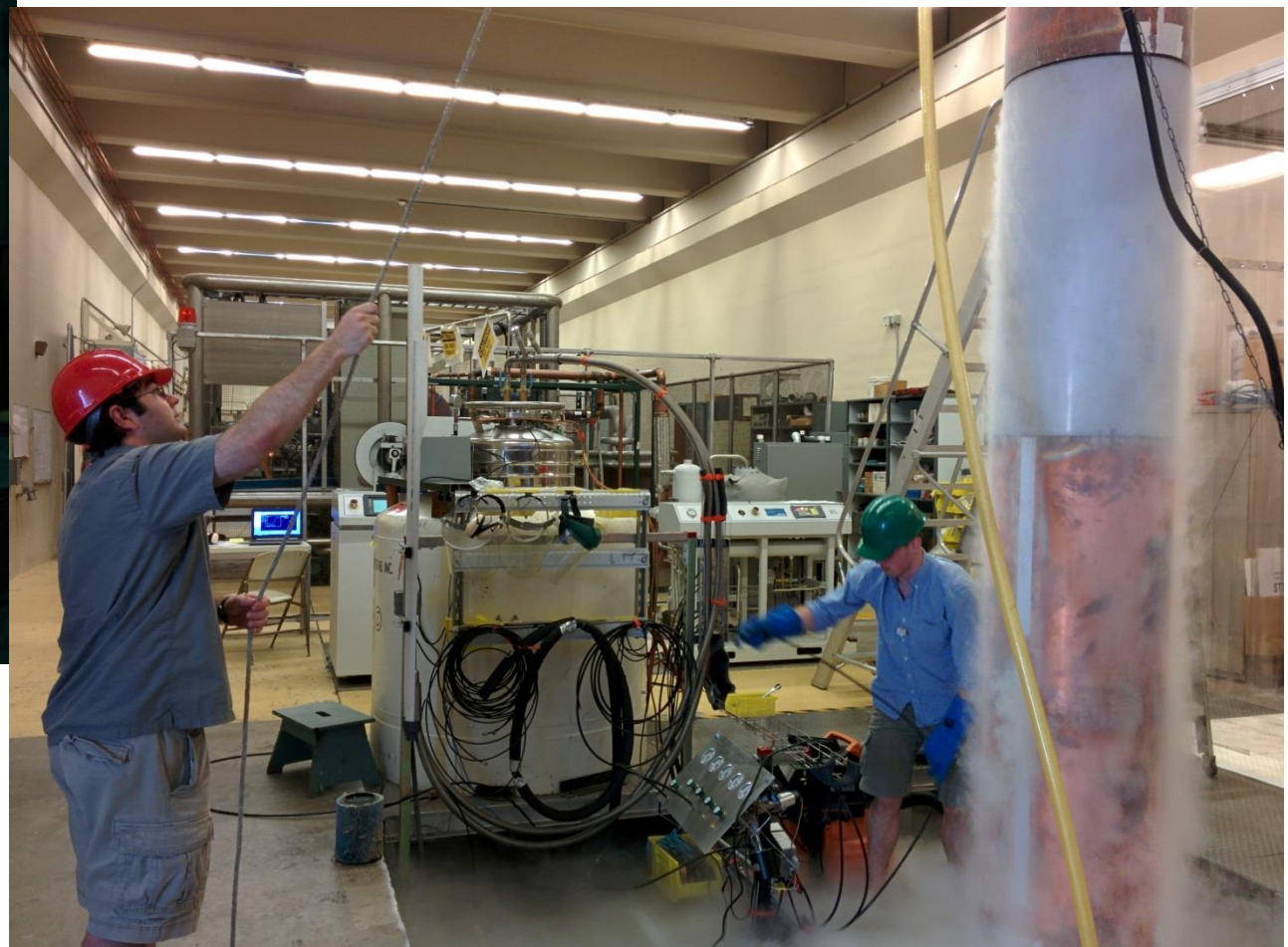
A strong magnetic field converts axions into detectable photons.

Enhance measurement by setting cavity resonance to axion frequency.

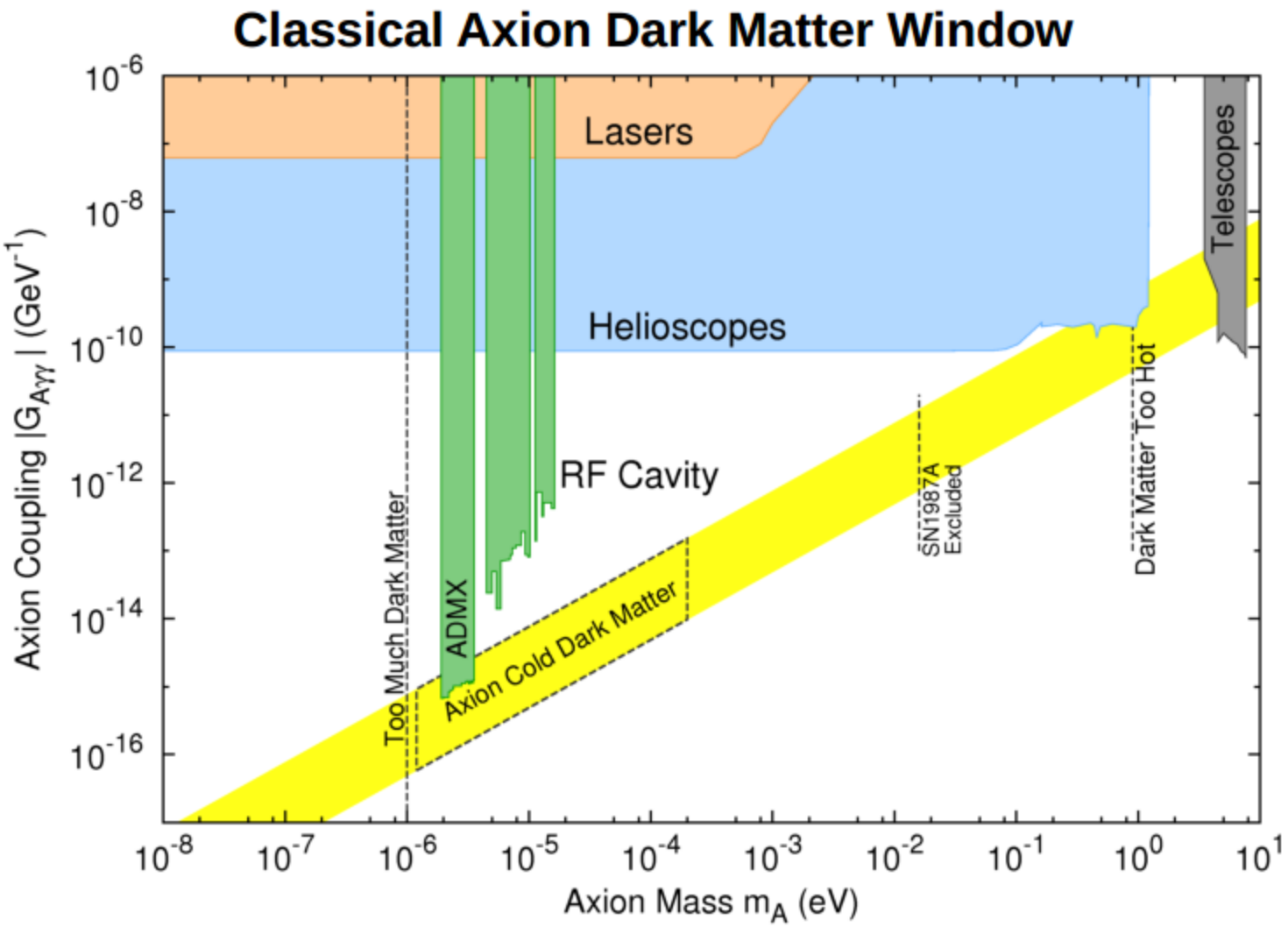
Enhanced coupling depends on **E**·**B** in cavity.



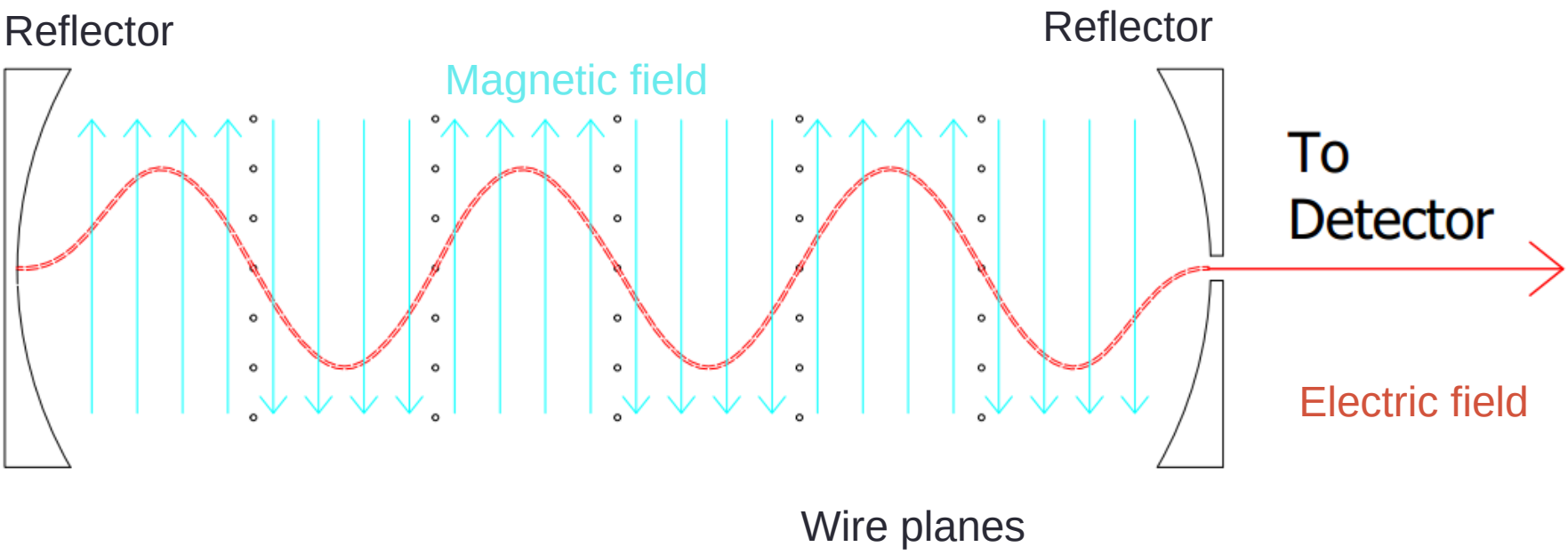
ADMX

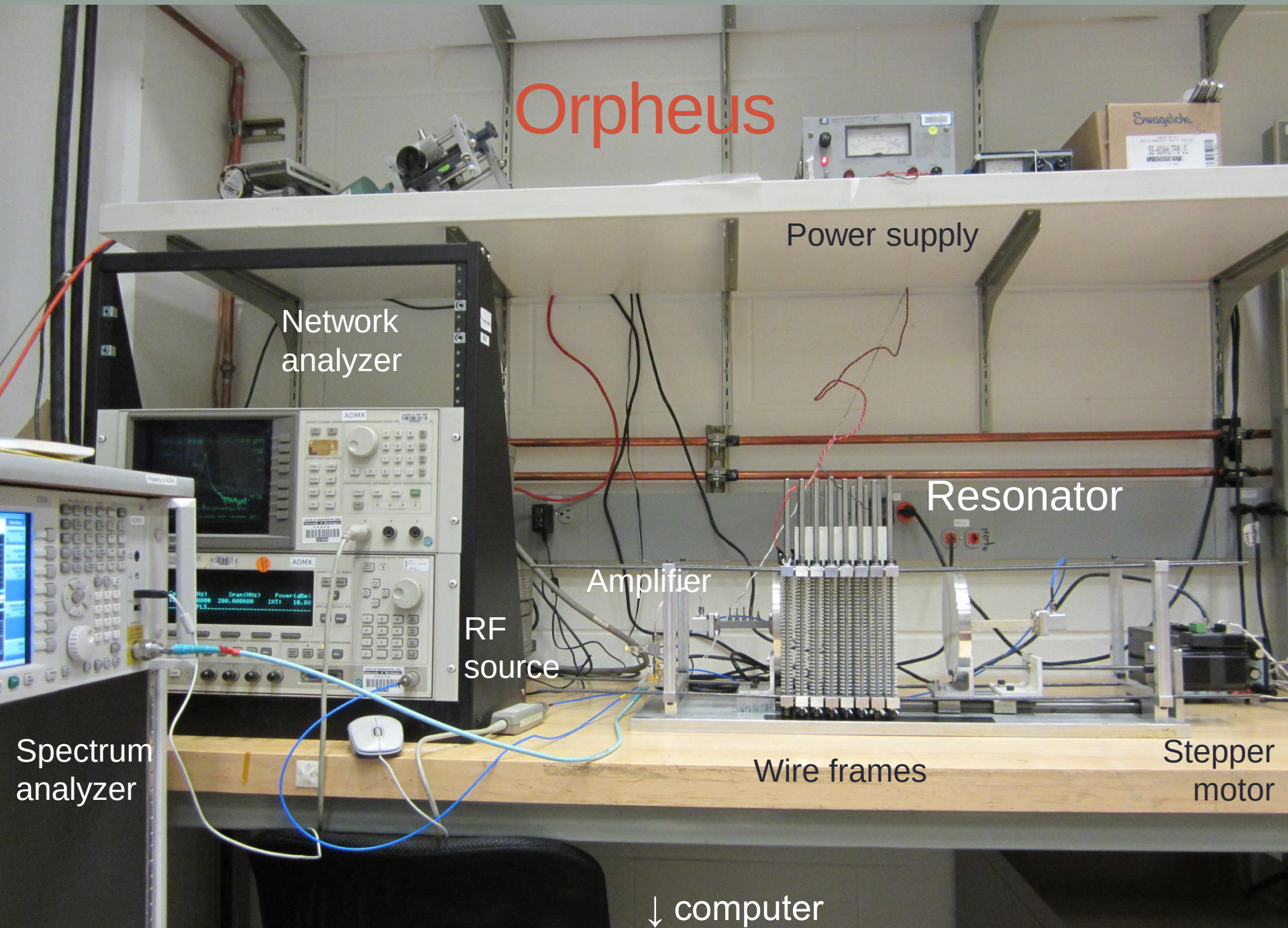


Axion Mass Window

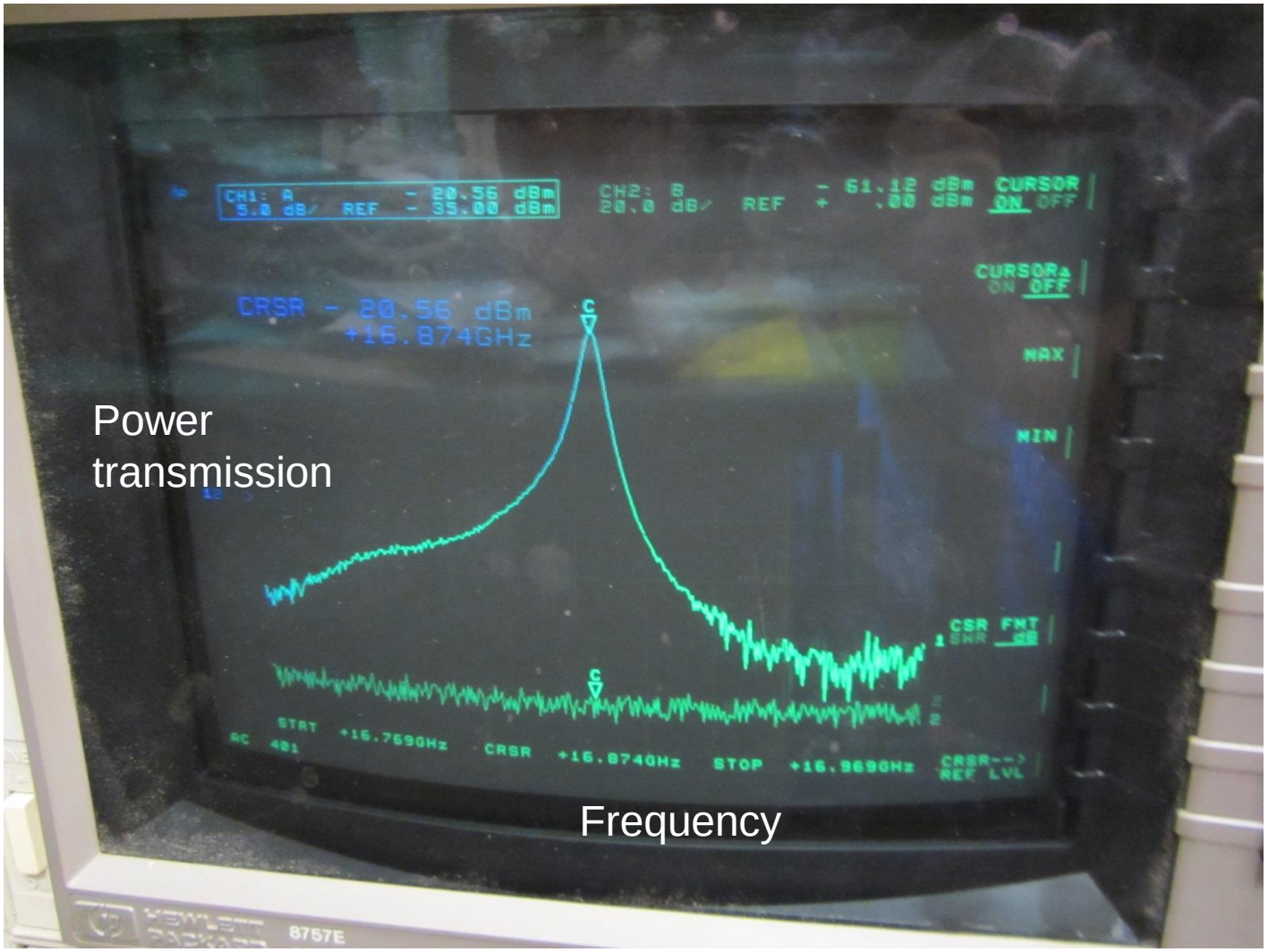


Open Resonators

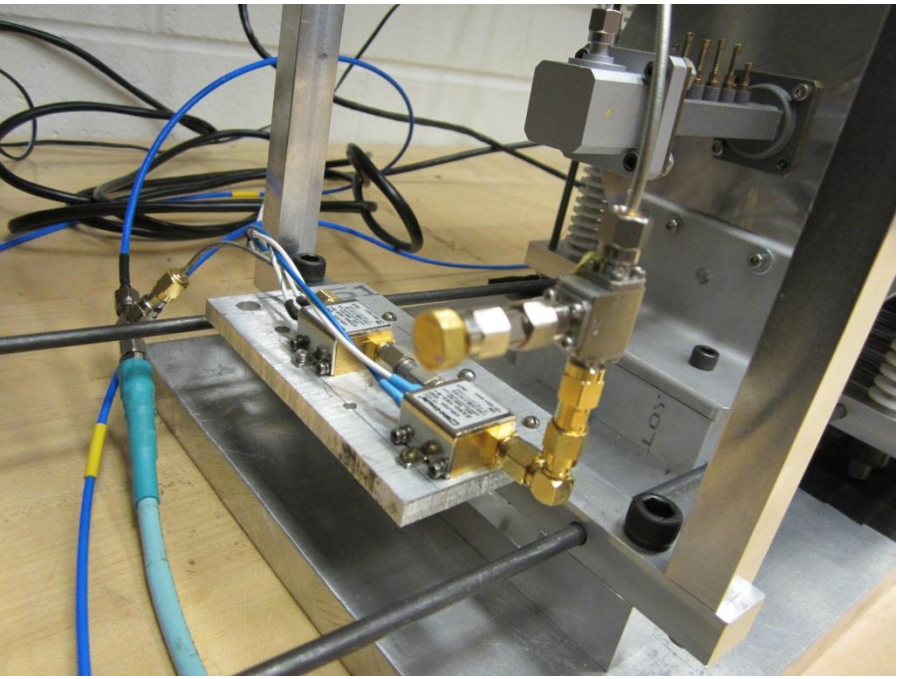


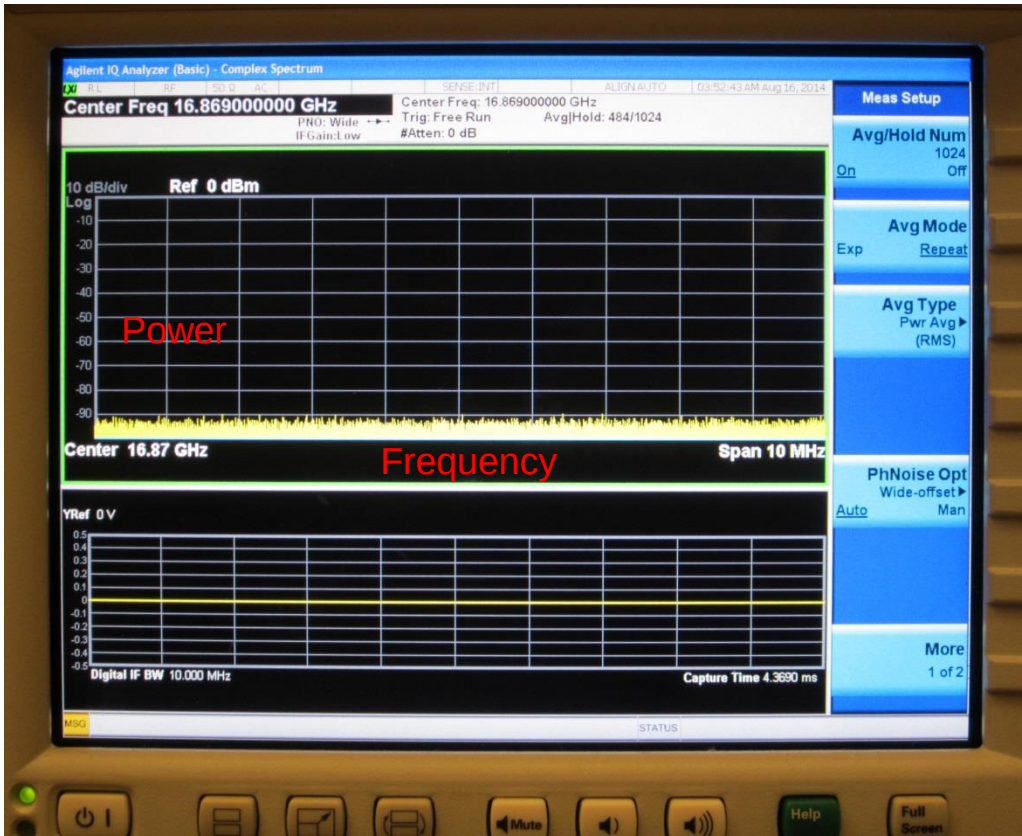

Orpheus
Power supply
Network analyzer
Resonator
Amplifier
RF source
Spectrum analyzer
Wire frames
Stepper motor
↓ computer

Resonance Tuning

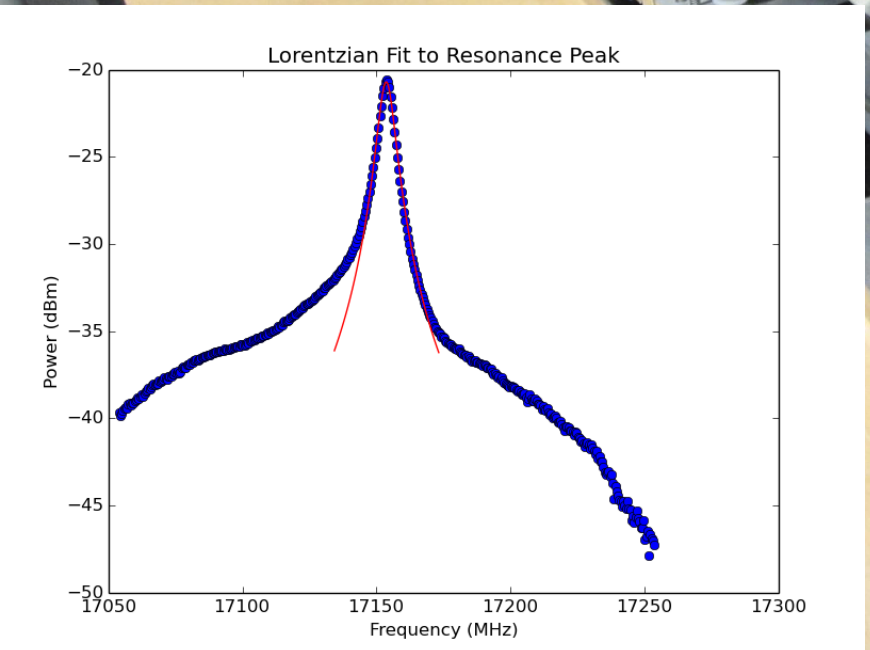


Data-Taking



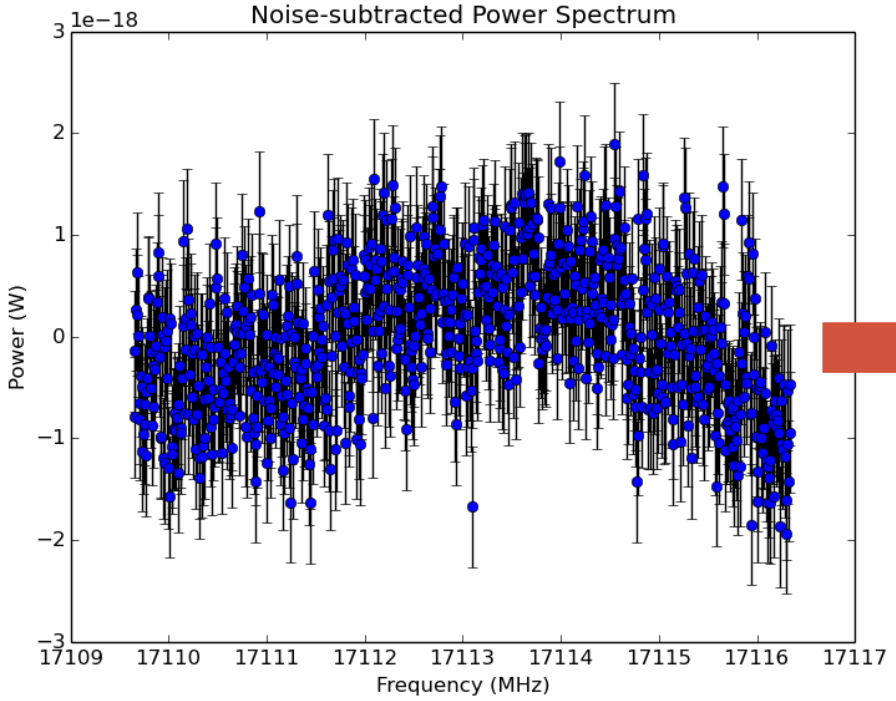

Agilent IQ Analyzer (Basic) - Complex Spectrum
Center Freq 16.869000000 GHz
Center Freq: 16.869000000 GHz
Trig: Free Run
Avg|Hold: 484/1024
#Atten: 0 dB
Meas Setup
Avg/Hold Num
1024
On
Off
Avg Mode
Exp
Repeat
Avg Type
Pwr Avg
(RMS)
10 dB/div
Ref 0 dBm
Log
Power
Center 16.87 GHz
Frequency
Span 10 MHz
PhNoise Opt
Wide-offset
Auto
Man
YRef 0 V
Digital IF BW 10.000 MHz
Capture Time 4.3690 ms
More
1 of 2
Mute
Help
Full Screen

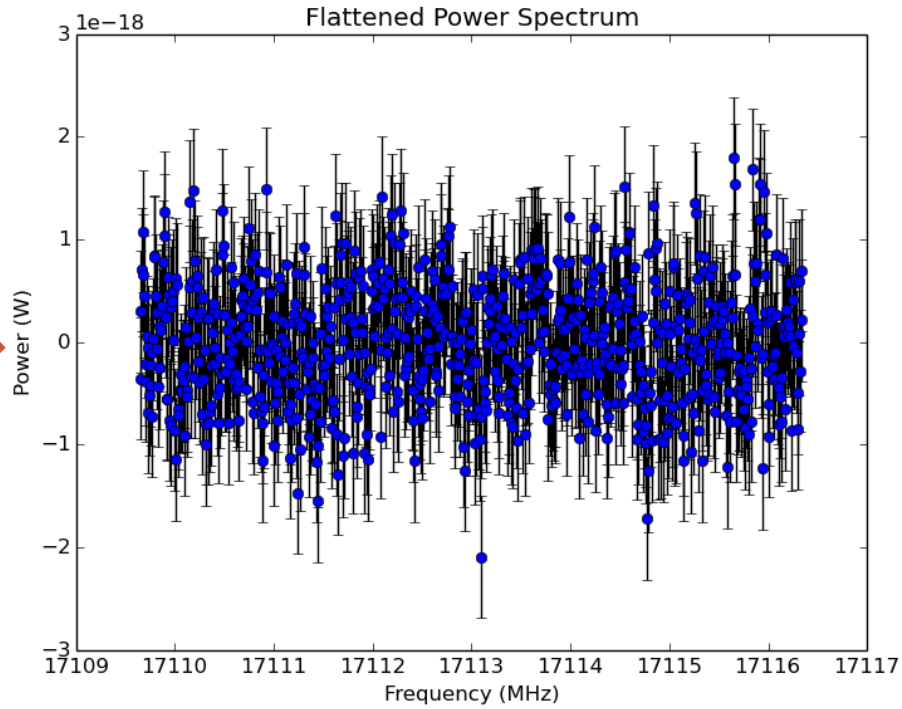
Automated Control



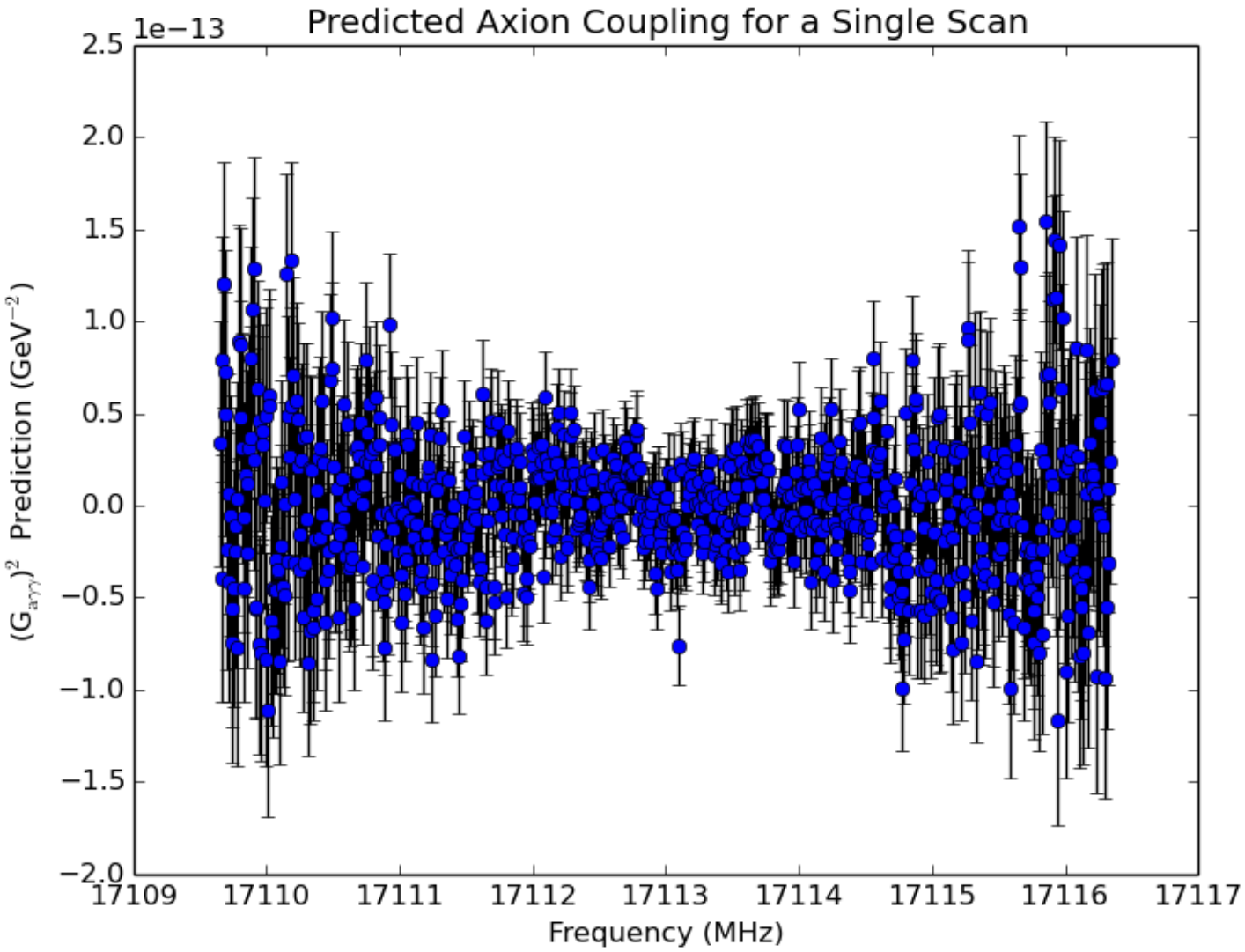
Analysis

Normalize power spectra and divide out structure:

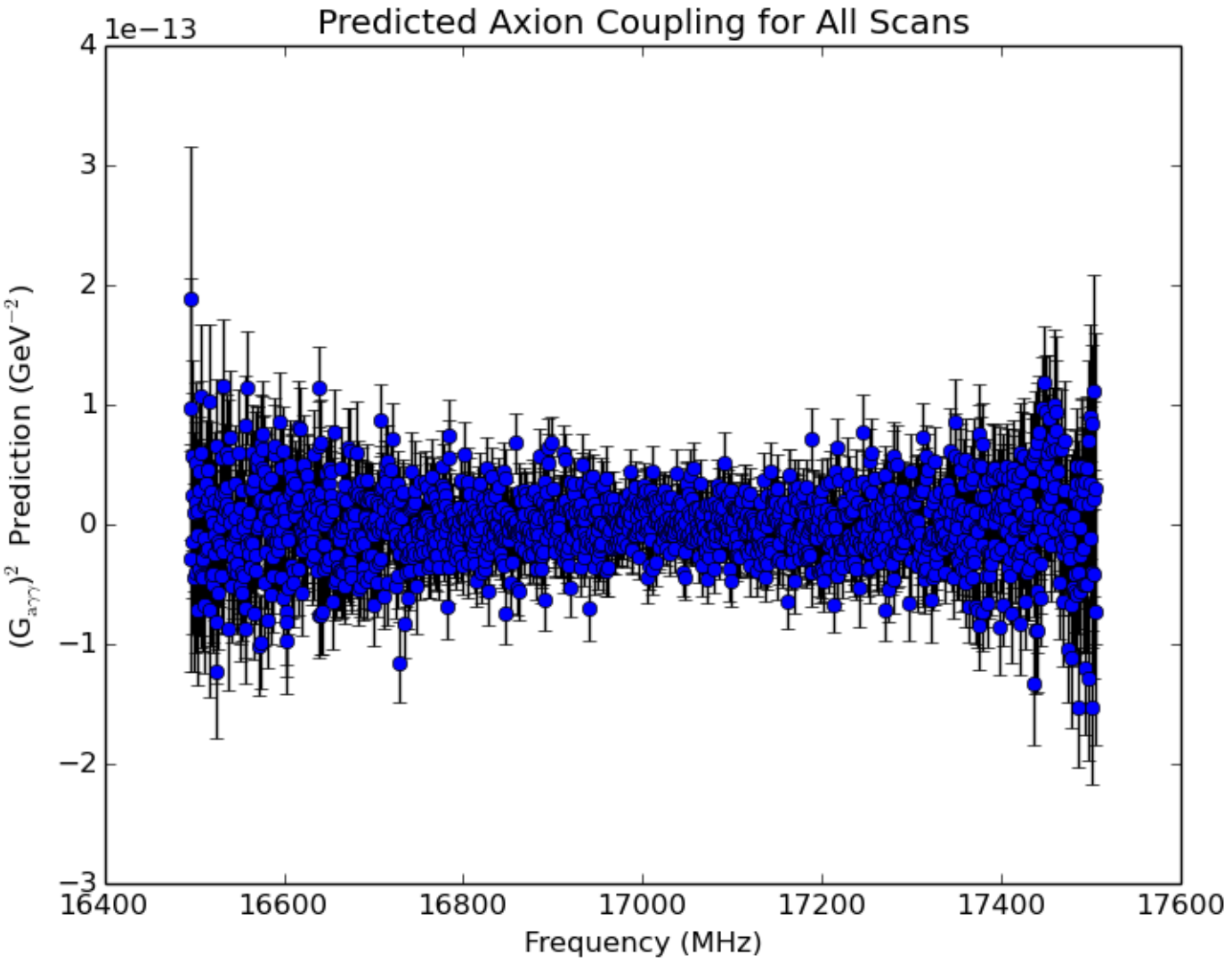




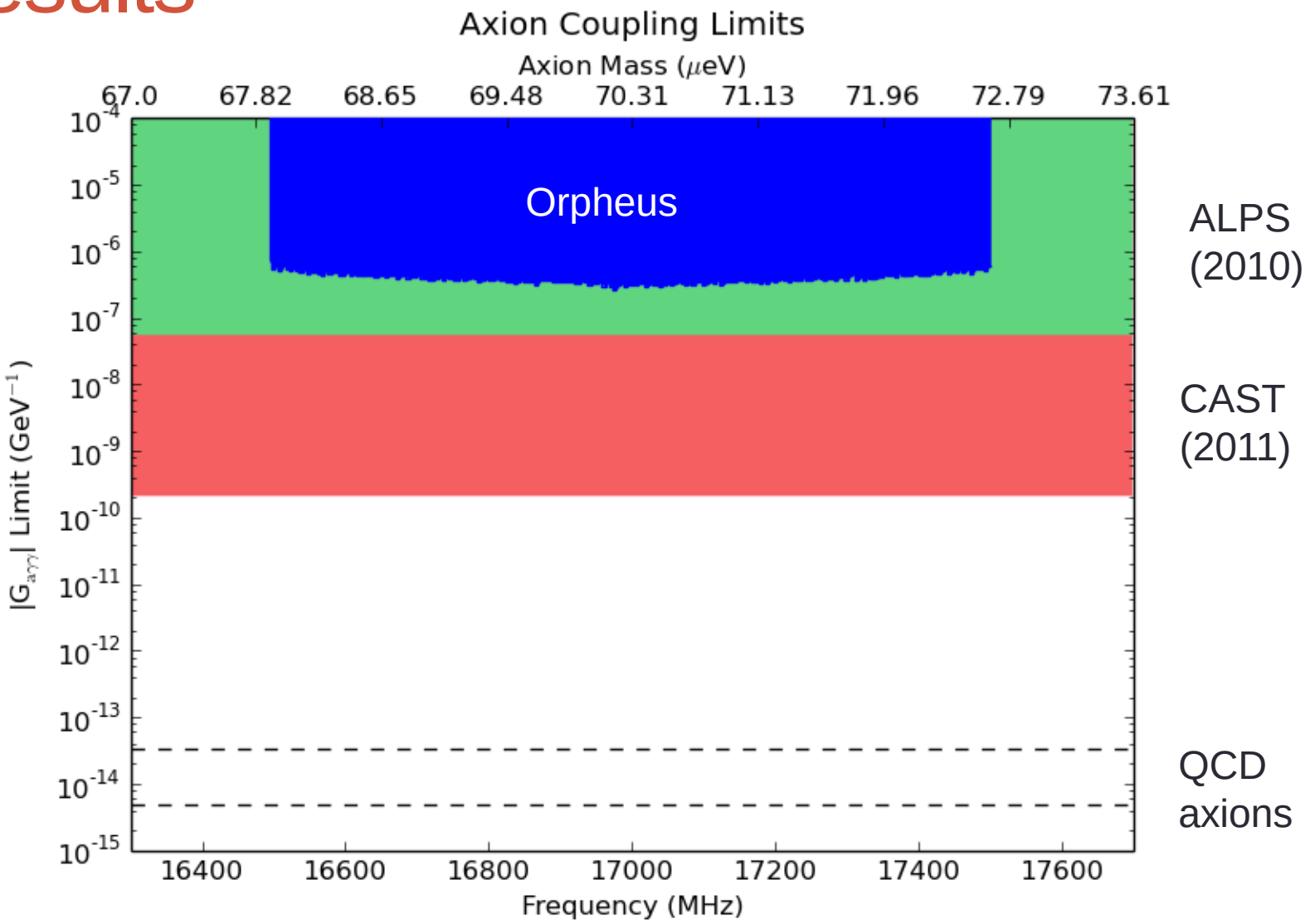
Analysis


Predicted Axion Coupling for a Single Scan
1e−13
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
$(G_{a\gamma\gamma})^2$ Prediction (GeV^{-2})
17109
17110
17111
17112
17113
17114
17115
17116
17117
Frequency (MHz)

Analysis

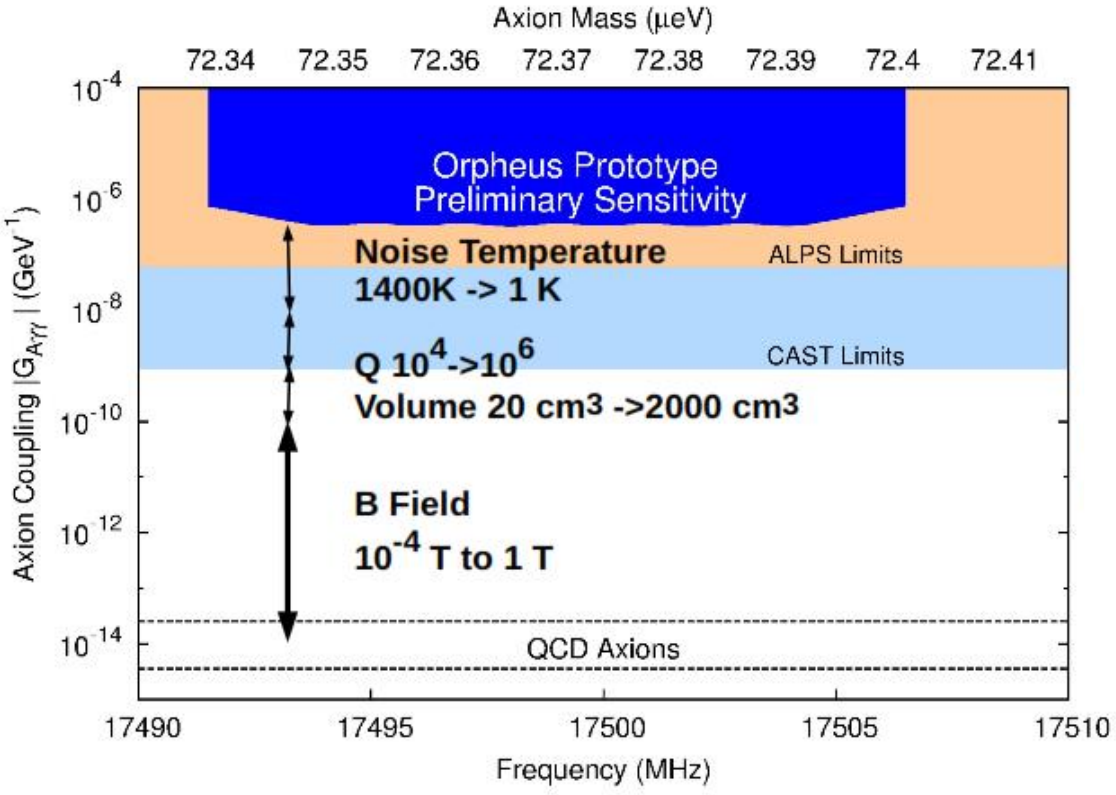

Predicted Axion Coupling for All Scans
1e−13
4
3
2
1
0
−1
−2
−3
$(G_{a\gamma\gamma})^2$ Prediction (GeV^{-2})
16400
16600
16800
17000
17200
17400
17600
Frequency (MHz)

Results


Axion Coupling Limits
Axion Mass (μeV)
67.0
67.82
68.65
69.48
70.31
71.13
71.96
72.79
73.61
Orpheus
ALPS (2010)
CAST (2011)
QCD axions
$|G_{a\gamma\gamma}|$ Limit (GeV^{-1})
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^{-14}
10^{-15}
16400
16600
16800
17000
17200
17400
17600
Frequency (MHz)

Further Work

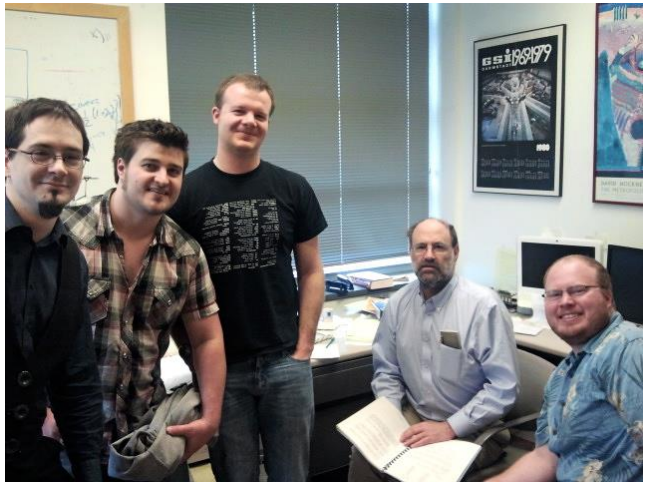
- Increase B field by using superconducting wire
- Decrease noise by operating at cryogenic temperature
- Increase cavity Q with better reflectors



Conclusions

- The axion, if real, explains two mysteries: dark matter and the strong CP problem.
- The open resonator technique extends ADMX's reach to higher frequencies.
- Initial Orpheus results constrain the axion – photon coupling to be under 6×10^{-7} for 68.2 – 72.4 μeV axions.
- With improvements, this technology can find or exclude high mass dark matter axions.

Thanks



- Dr. Gray Rybka
- Dr. Andrew Wagner
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