ADMX “Phase 2” Upgrade: Answering the Axion Dark Matter Question

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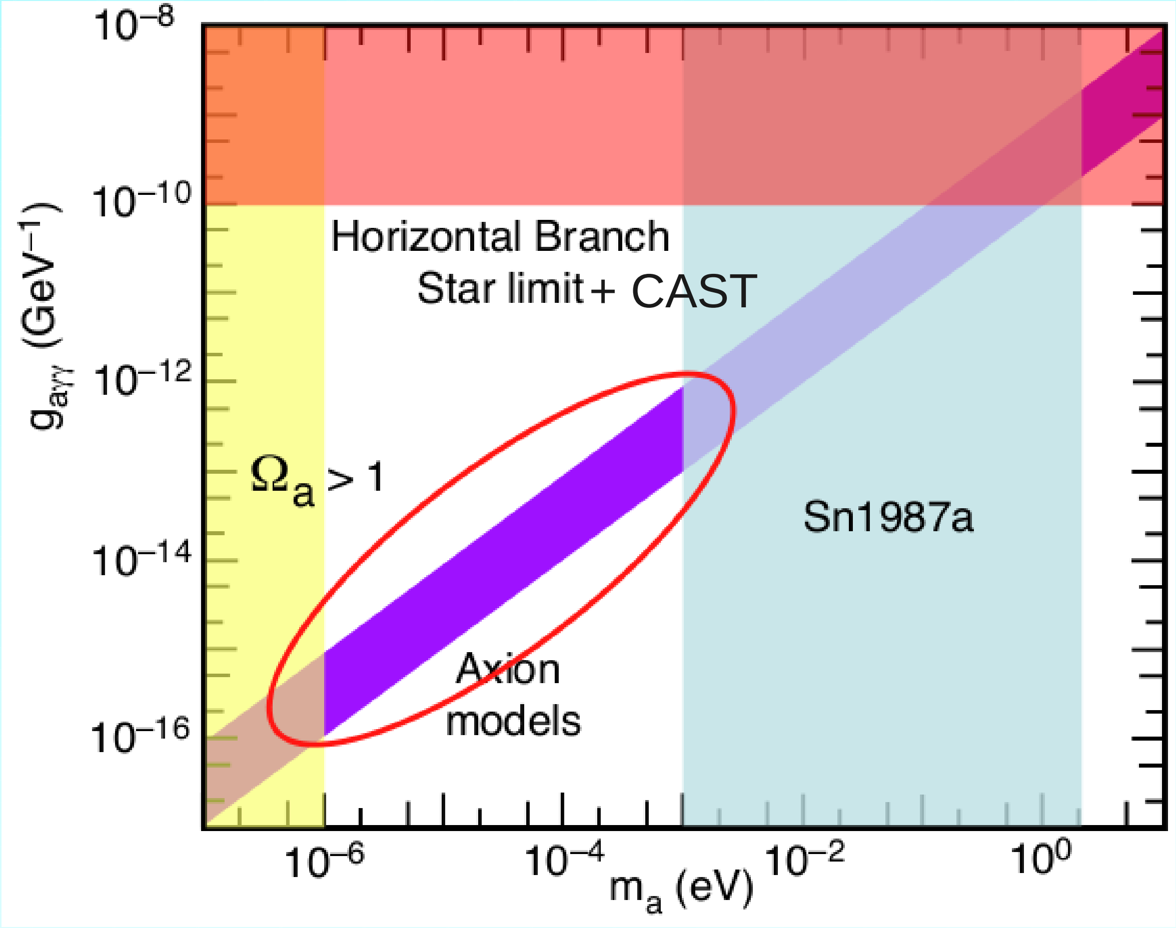
Review: Why Haven't We Found Axions Yet?



Likely axion dark matter models span three orders of magnitude

ADMX has scanned about 3% in 1 year of running, and not at all couplings

At this rate, scanning all reasonable axion space will take 100+ years

We need to scan faster

How Do We Scan Faster?

Run Colder

1) Scan speed improves quadratically with inverse temperature. If we can run 10x colder, we can run 100x faster (or 10x faster and be sensitive to 3 times weaker couplings)

-Dilution refrigerator will lower the physical temperature
-SQUID amplifier has low noise temperature

Run Smarter

2) Look for several axion masses at once

-A second antenna can explore axion coupling to higher modes

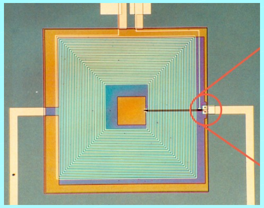
Dilution Refrigerator Upgrade

Old cooling (pumped liquid helium) allowed us to have a noise temperature of ~2K

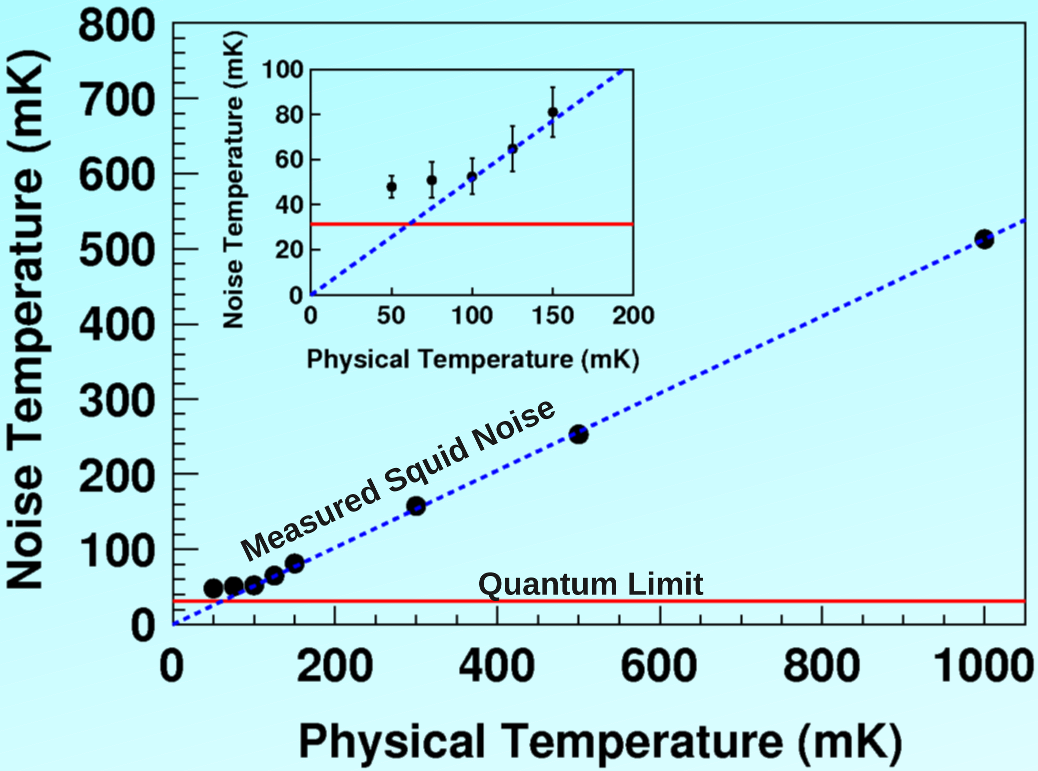
An $^{3}He/^{4}He$ dilution refrigerator can achieve temperatures as low as 2 mK (we'll aim for 100 mK)

Requires a significant redesign of experiment cryogenics, but factor speedup well worth the cost.

Why not cool to nanokelvins?



SQUID Amplifier



Amplifier noise will become the dominant source of noise

SQUID amplifiers (demonstrated in the last phase) approach the quantum limit, which is ~50 mK at this frequency

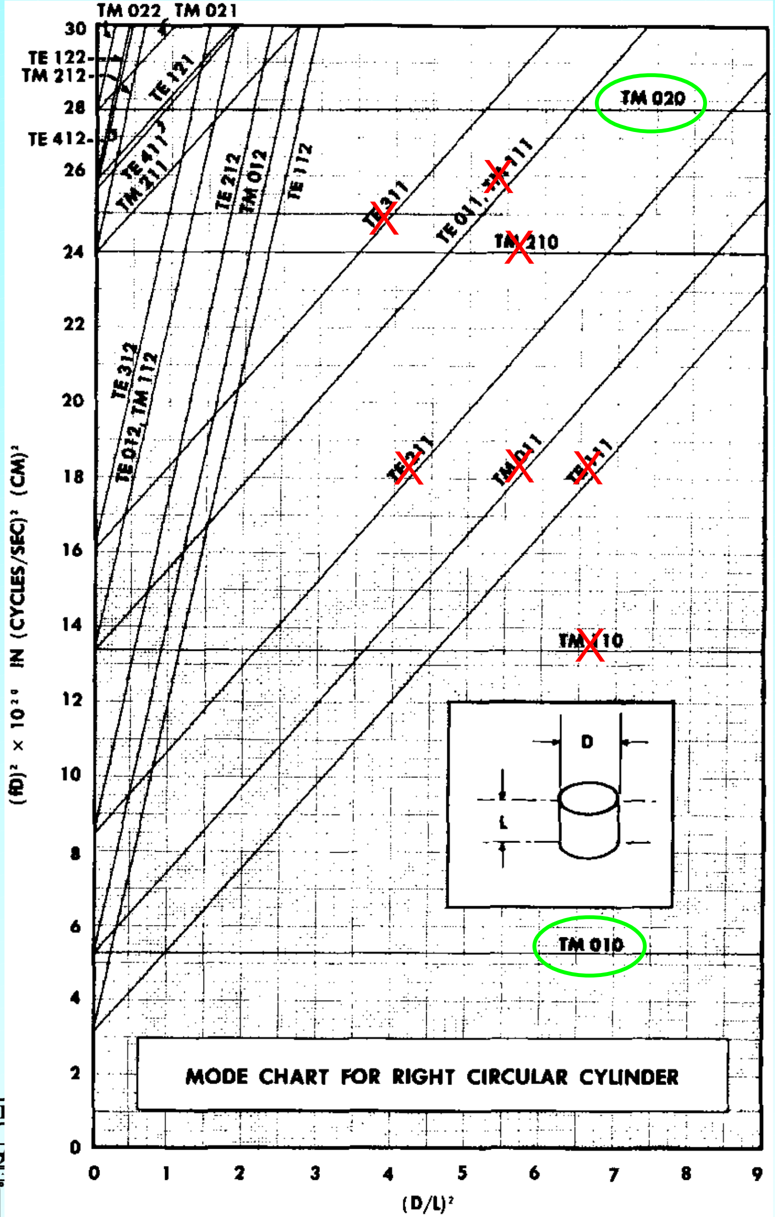
Best possible noise of this system = 50 mK @ 0K physical temperature

(Noise temperature last time ~3K)

Expected Final Noise Temperature: 100mK Physical + 50 mK SQUID noise = 150 mK

*Scanning 100x+ faster doable. Any faster and time to move rods/change cavities will become the limiting factor.

High Frequency Channel



The TM010 cavity mode is the most strongly coupled to an axion dark matter signal

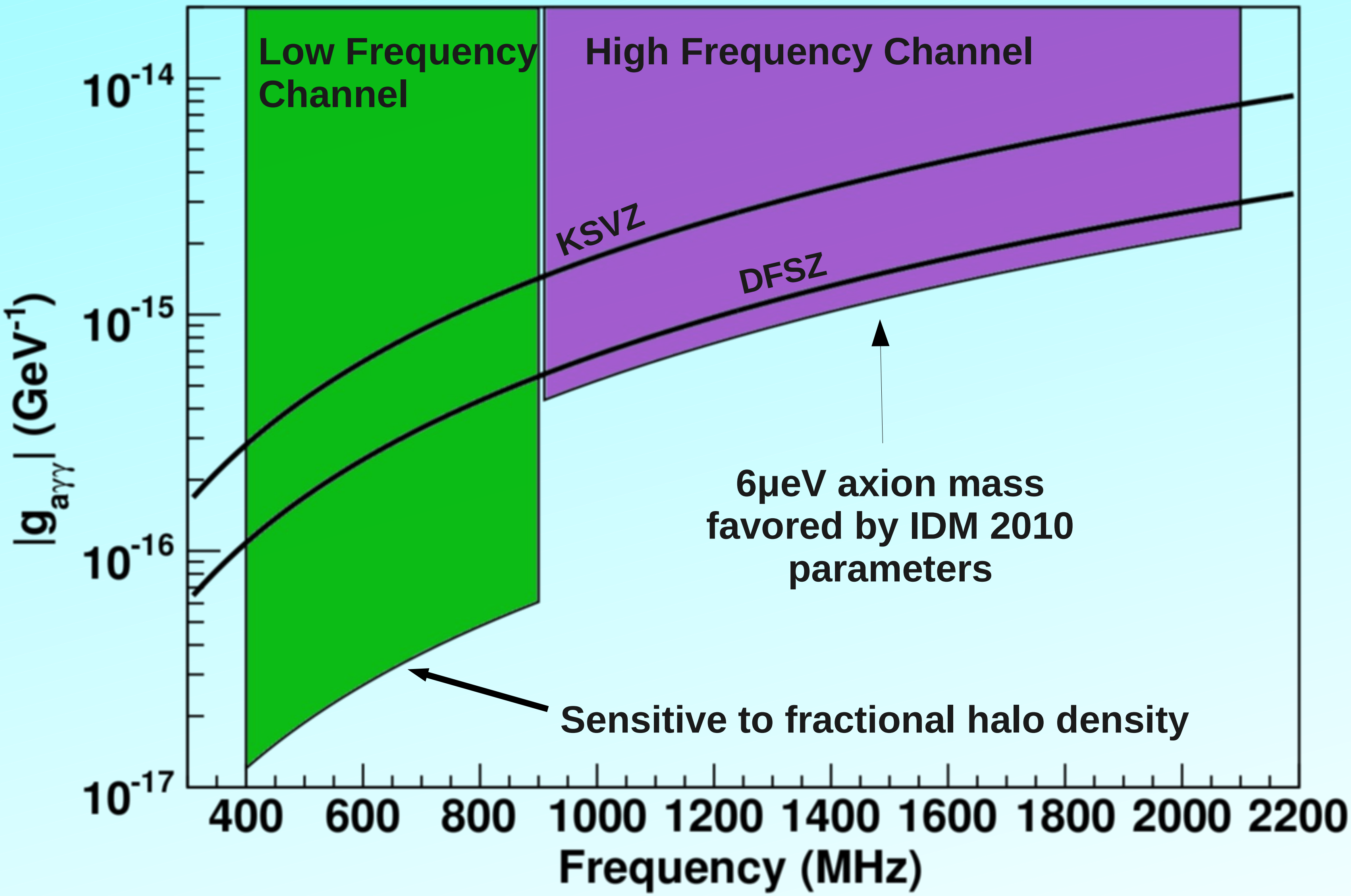
Most cavity modes are insensitive to axion signal (useful background elimination tool)

Some cavity modes are still sensitive but with worse coupling.

If we have spare sensitivity, we can use those modes to scan multiple axion masses at once

mode	relative frequency	first year tuning range (MHz)	relative power
TM_{010}	1.00	400-900	1.00
TM_{020}	2.30	920-2,100	0.41

Target Region



In one year of running, we expect to cover 1.5-9 μeV, roughly 25% of the reasonable axion dark matter mass range. (on a log scale)

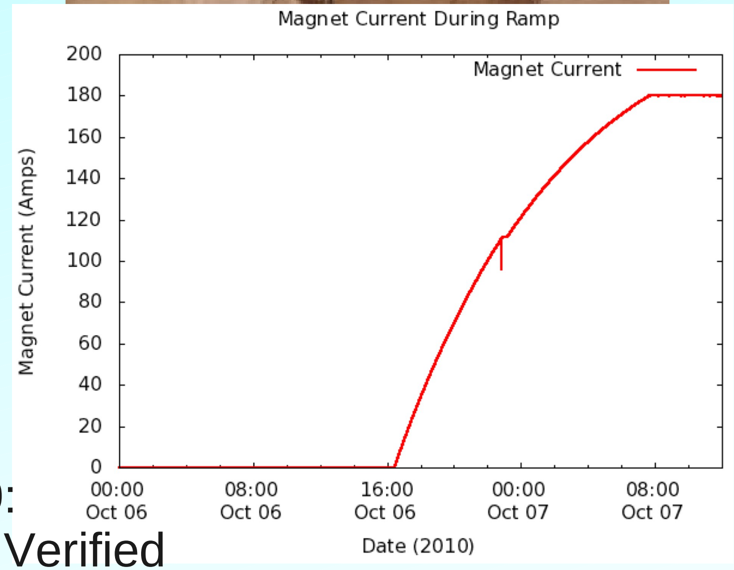
Other Technical Improvements

Helium Liquifier
Improved Cryogenics
Piezoelectric Rod Motion
Rod location Tracking
Improved Thermometry
Real-Time Analysis
Clean assembly Area
Better Cavity Modeling
New Paint Job
HFET Bias Monitor

Dynamic SQUID Gain Monitoring
In-Situ Noise Calibration Suite
Tunable SQUIDs
Improved Receiver Chain
Digital Filtering
Better Timing Standard
Cavity Plating Upgrade
All High Resolution Time Series Data
New Magnet Leads

ADMX Comes to UW

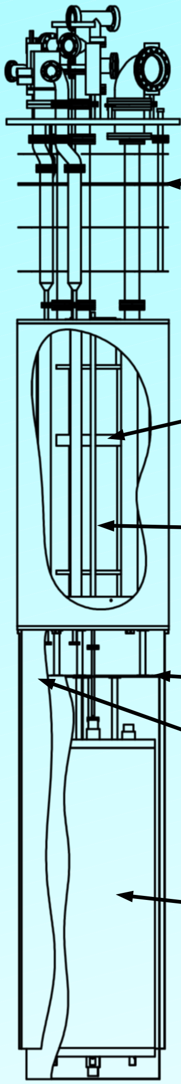
August 2010:
ADMX Moves to UW



October 2010:
Main Magnet Verified

May 2011:
Main Magnet Installed
in Experiment Area (CENPA)

Insert Design (Video)



Cryocooler improves helium consumption

Same field cancellation magnet as before

SQUID in zero field region, linked to dil fridge by cold finger

1K shield protects 100 mK space

Dilution refrigerator

New cavity, improved plating

Schedule

~~Summer 2010~~ ~~Winter 2010~~
~~Spring 2011~~ Summer 2011 – Funding Clears

2011-2012 Construct new insert

small axion search here

2012-2013 Commission new insert, order dilution refrigerator

2013-2014 Install dilution refrigerator, commission

2015+ Definitive Axion search

Even Higher Axion Masses

Yale

R&D on reaching higher axion masses continues at multiple ADMX institutions

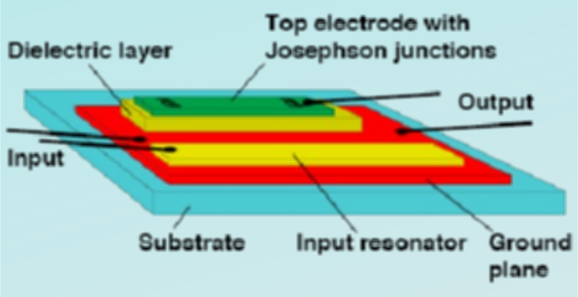
Axion-photon Coupling ~ m_a (good)

Cavity Volume ~ $1/m_a^2$

Quantum Noise Limit ~ m_a

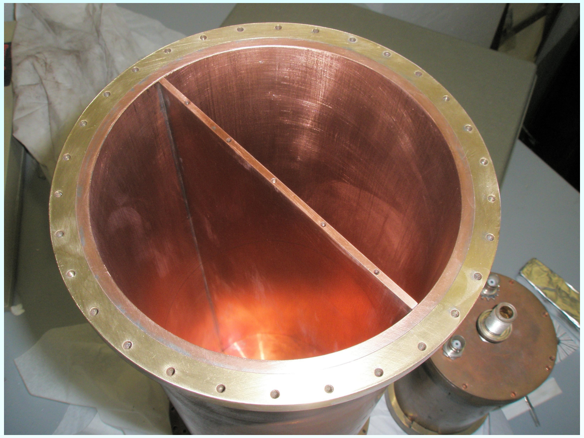
HF Testbed

Higher Frequency SQUIDs or new amplifier technology?



UC Berkeley

Multiple/Split Cavity Designs



U. Florida

Conclusions

ADMX Phase 2 is beginning construction

We are on track to exhaustively search the lower third of the reasonable dark matter axion mass range

Stay tuned in the next few years for exciting results!

Exotic Search Improvements