AXION DARK MATTER SEARCH

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The Other End of the Spectrum: μeV Particle Astrophysics

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Overview

- Properties of dark matter axions
- Axion detection in the galactic halo
- New result from the Axion Dark Matter eXperiment

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Axion Properties

The Peccei-Quinn (1977) solution to the **strong CP problem** gives us the **axion** (Weinberg, 1978; Wilczek, 1978).

New parameter: f_a, the Peccei-Quinn (PQ) symmetry breaking scale.

Small mass

$$m_a = 6\,\mu\mathrm{eV}\left(\frac{10^{12}\,\mathrm{GeV}}{f_a}\right) \tag{1}$$

$$m_a \sim 10^{-6} - 10^{-2}\ \mathrm{eV}$$

$$\Longrightarrow f_a \sim 10^{9} - 10^{13}\ \mathrm{GeV}$$

The parameter space is bounded - we know where to look!

Cold Axion Population

A cold population of axions has never been in thermal equilibrium with the rest of the universe.

- Axions from **vacuum realignment**

(Abbot & Sikivie, 1983; Preskill, Wise & Wilczek, 1983; Dine & Fischler, 1983)

- Initial momentum is of the order:

$$p_a(t_{QCD}) \sim \frac{1}{t_{QCD}} \sim 10^{-9} \text{ eV}.$$

- Hubble expansion until today:

$$p_a(t_0) \sim 10^{-21} \text{ eV}$$

$\Longrightarrow$ **Cold!**

- Generic couplings:

$$g_{aii} \propto \frac{1}{f_a}$$

$$f_a \sim 10^9 - 10^{13} \text{ GeV}$$

$\Longrightarrow$ **Weakly coupled!**

Axions make a good candidate for the cold dark matter.

Microwave Cavity Detection

Axion-electromagnetic field coupling:

$$\mathcal{L}_{a\gamma\gamma} = g_{a\gamma\gamma}\, a\mathbf{E}\cdot\mathbf{B}. \tag{2}$$

Resonant conversion of axion to photons is induced in a microwave cavity when the resonant frequency is equal to the axion energy.

(Sikivie, 1983)

ADMX Collaboration

(Axion Dark Matter eXperiment)

Lawrence Livermore National Laboratory:

S. J. Asztalos, C. Hagmann, D. Kinion, L. J. Rosenberg, K. van Bibber, D. B. Yu

University of Florida:

L. D. Duffy, P. Sikivie, D. B. Tanner

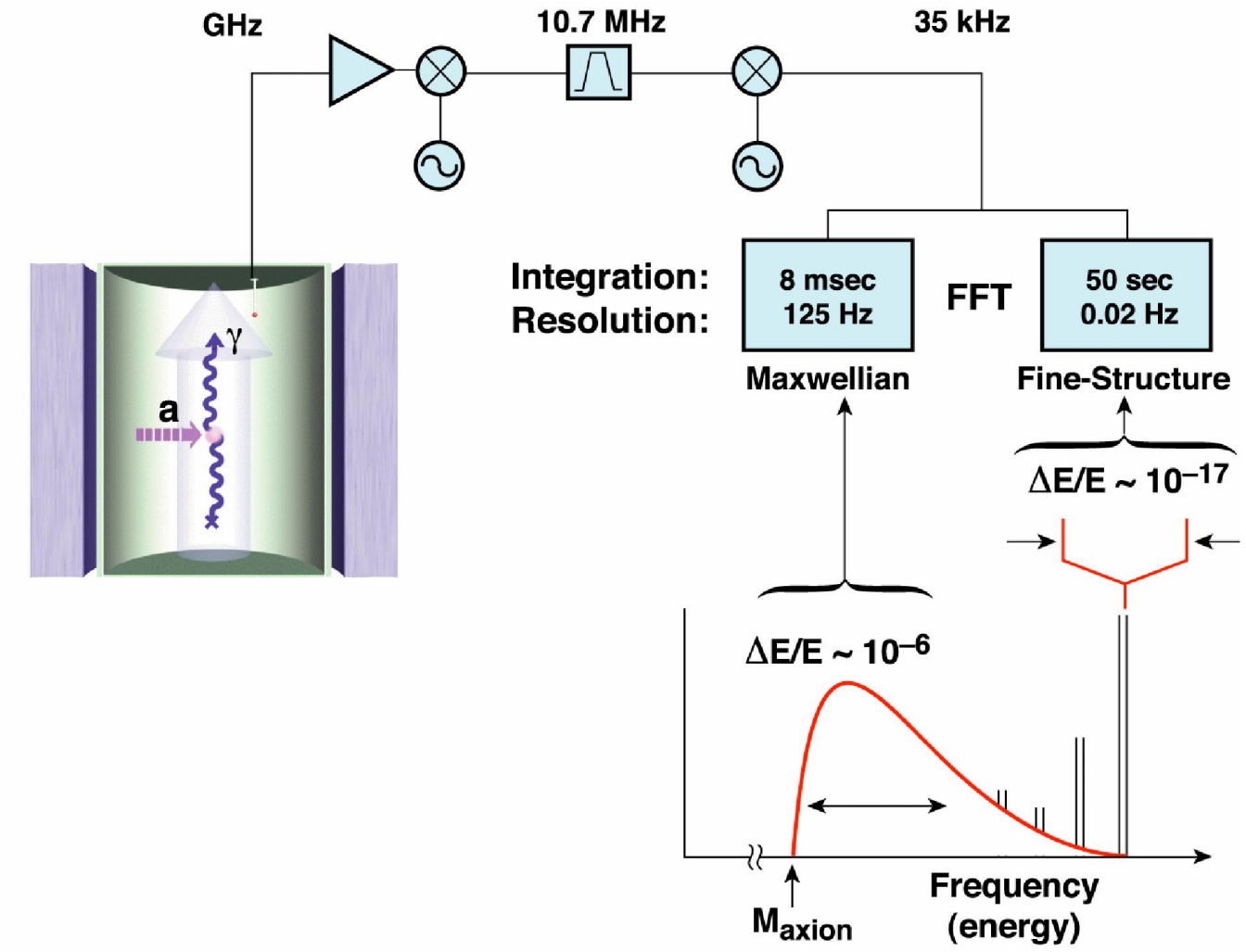
National Radio Astronomy Observatory:

R. F. Bradley

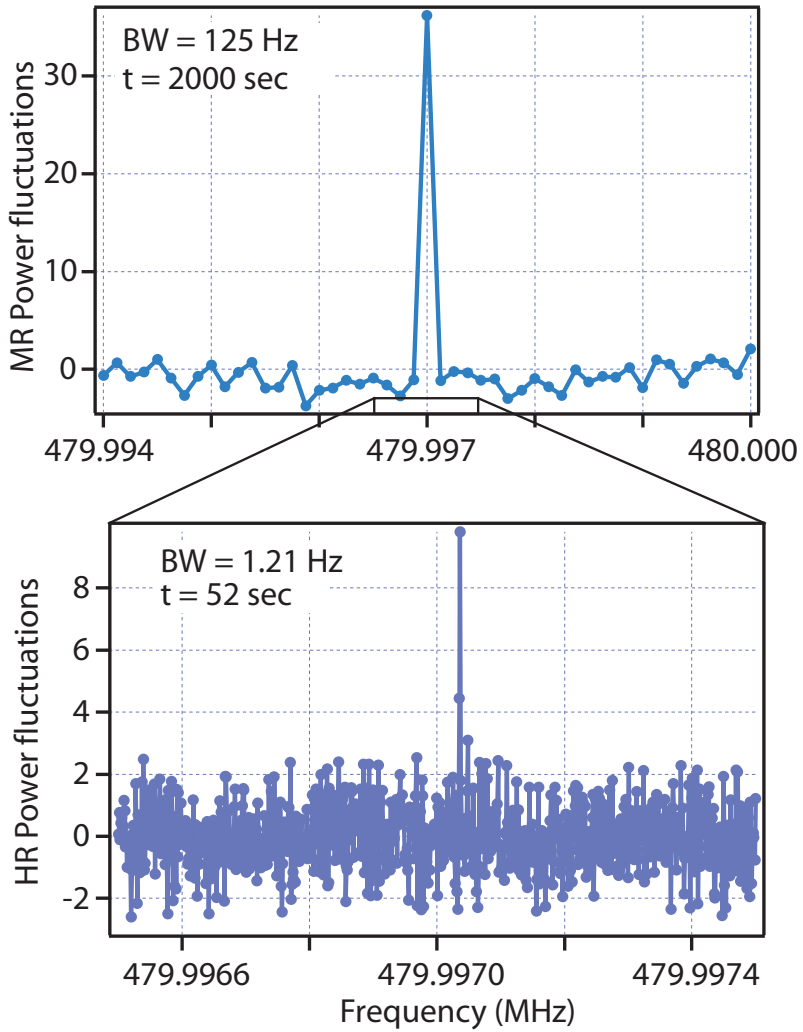
University of California (Berkeley):

D. M. Moltz

The ADMX Detector



Cross-channel Comparison



High Resolution Search

Hypothesis: There exist steady flows of dark matter axions with small velocity dispersion that will result in fine structure in the spectrum taken with a microwave cavity detector.

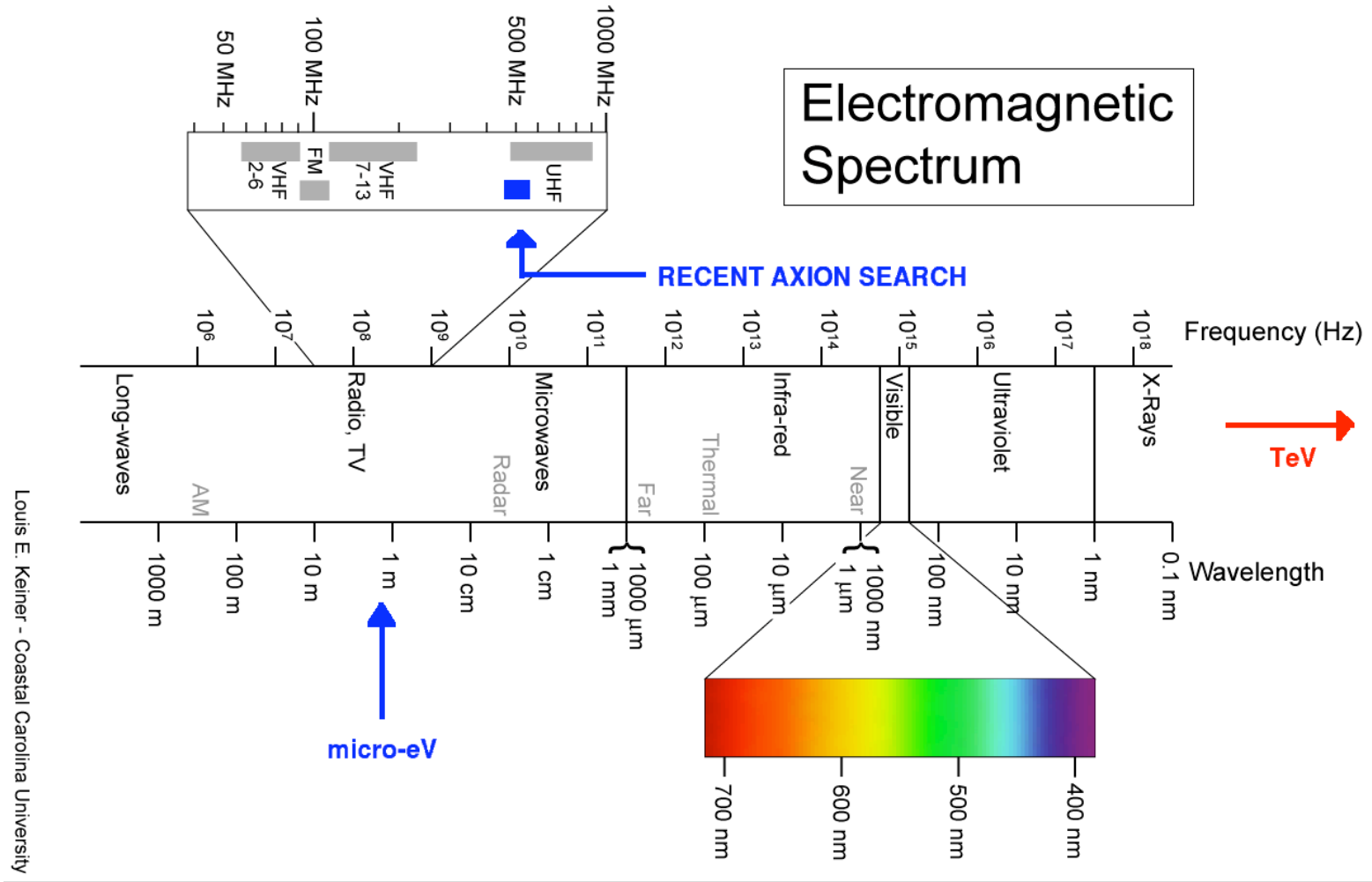
Search procedure:

(1) Scan entire range of interest for candidate signals above a certain threshold.

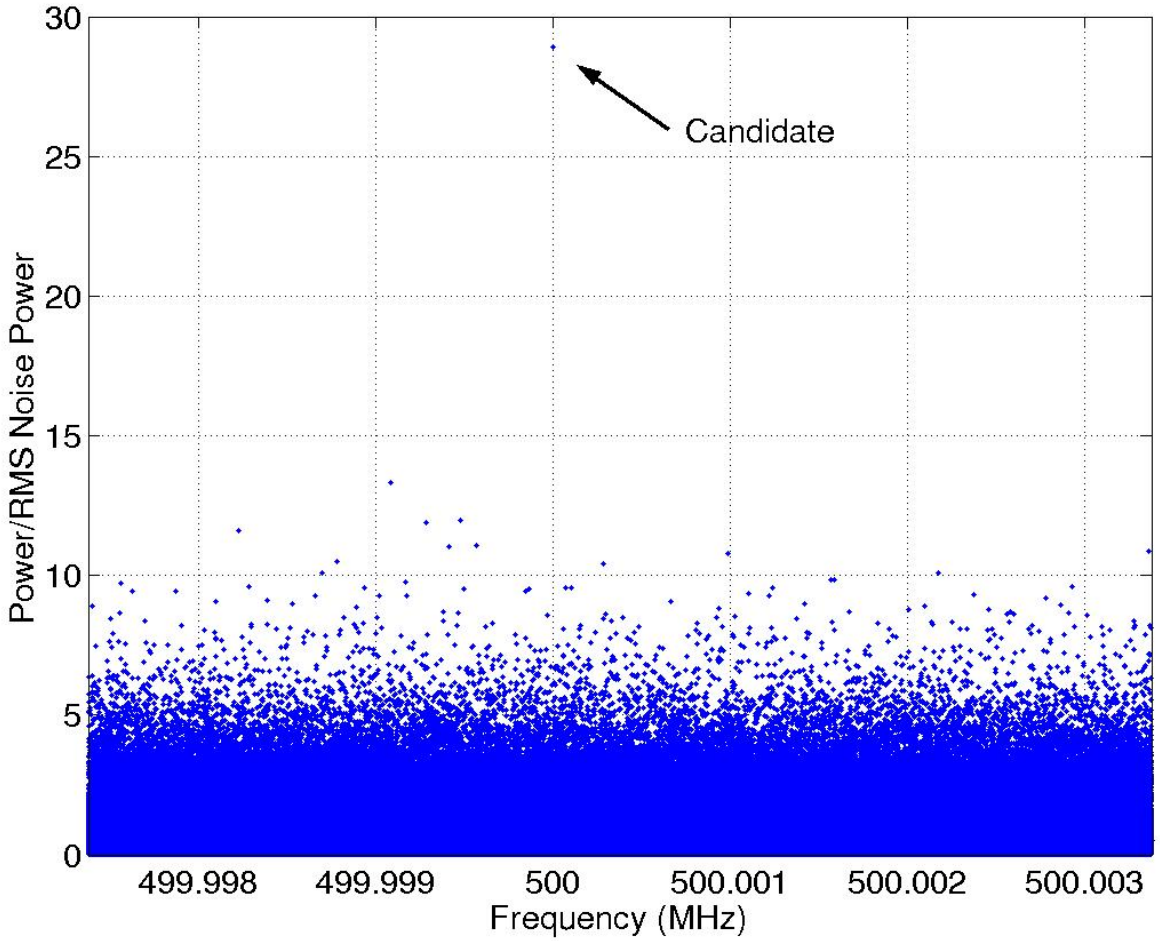
(2) Reexamine candidates from (1), to see if they persist.

(3) Identify the source of any persistent candidates remaining from (2).

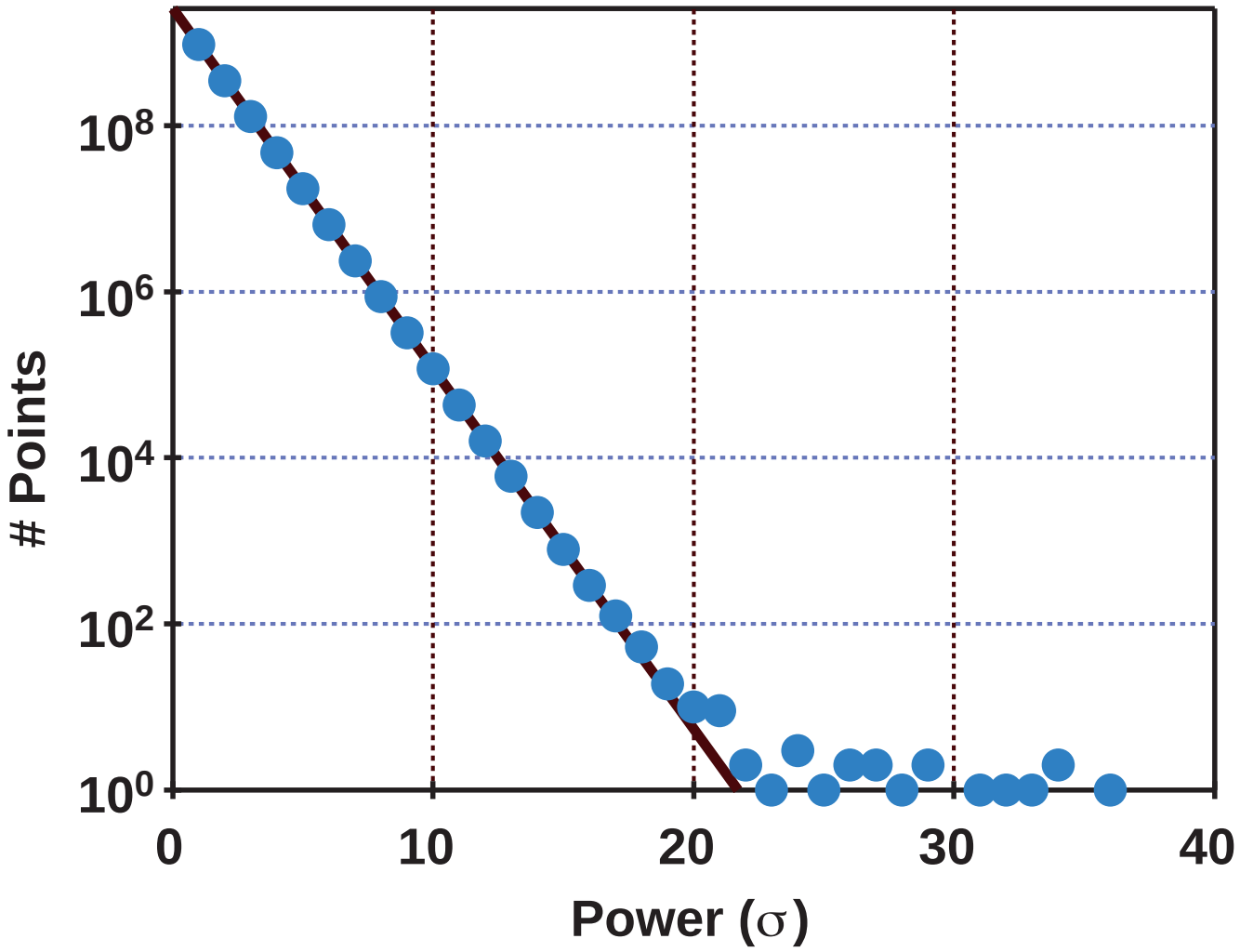
Recent Search Spectrum



Data Sample


Candidate
Power/RMS Noise Power
Frequency (MHz)
0
5
10
15
20
25
30
499.998
499.999
500
500.001
500.002
500.003

Noise Statistics



Signal Modulation

Daily: Frequency shift $\sim$ 1 Hz

HR Resolution: 0.02 Hz

Scan time: 50 s $\longrightarrow \delta f \sim$ 0.002 Hz

Annual: Frequency shift $\sim$ 100Hz

HR Bandwidth: 6kHz

Data Interpretation

- Signal width:

$$\delta f = f v \delta v \tag{3}$$

f = frequency

v = velocity

δv = velocity dispersion

- Combined bin searches are performed to allow for different signal widths.

- Power due to resonant axion–photon conversion:

$$P \propto g_\gamma^2 \rho_a m_a \tag{4}$$

g_γ = model–dependent constant

ρ_a = local density of axions

m_a = axion mass

Models:

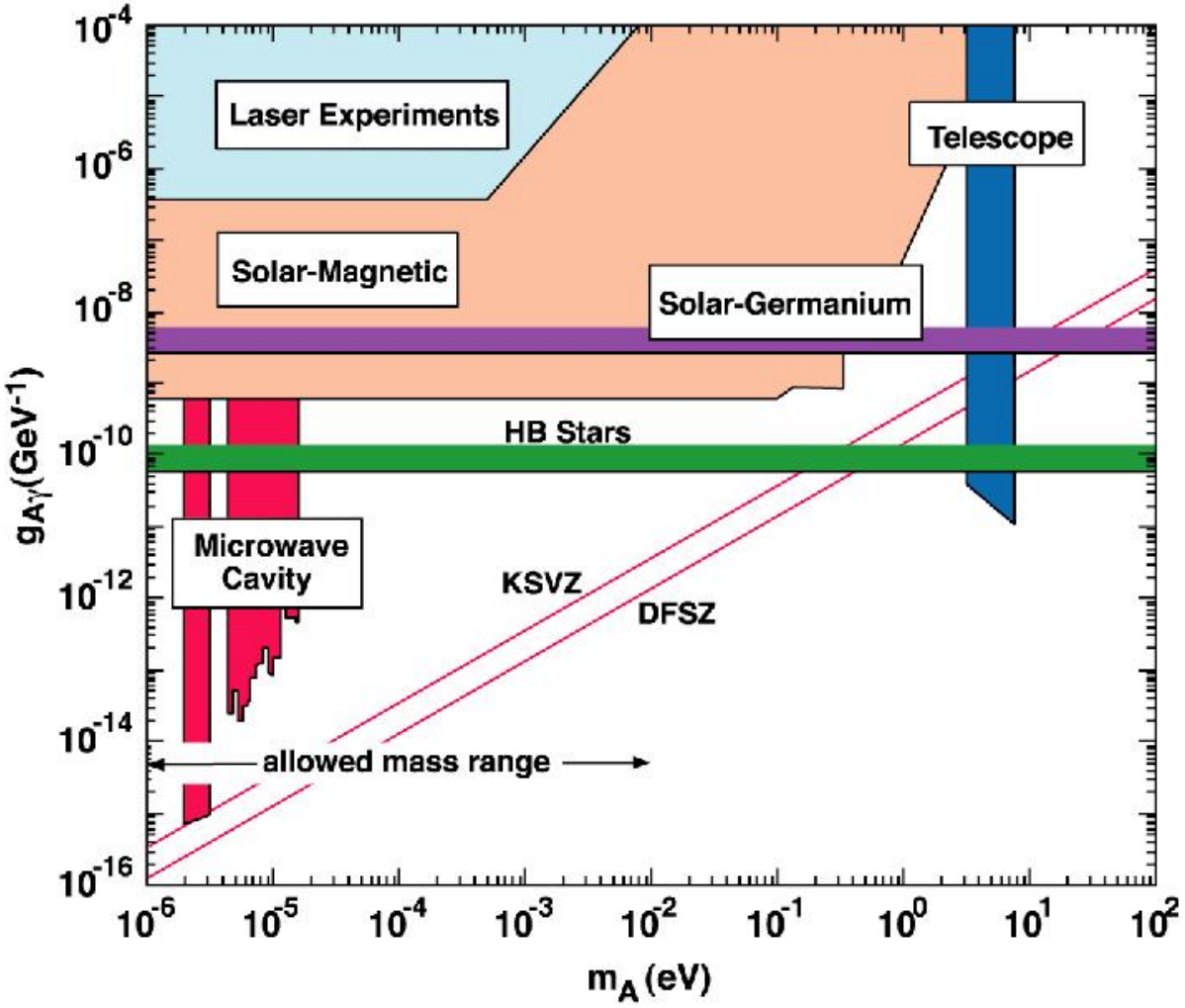
- KSVZ: $g_\gamma = 0.97$

(Kim, 1979; Shifman, Vainshtein and Zakharov, 1980)

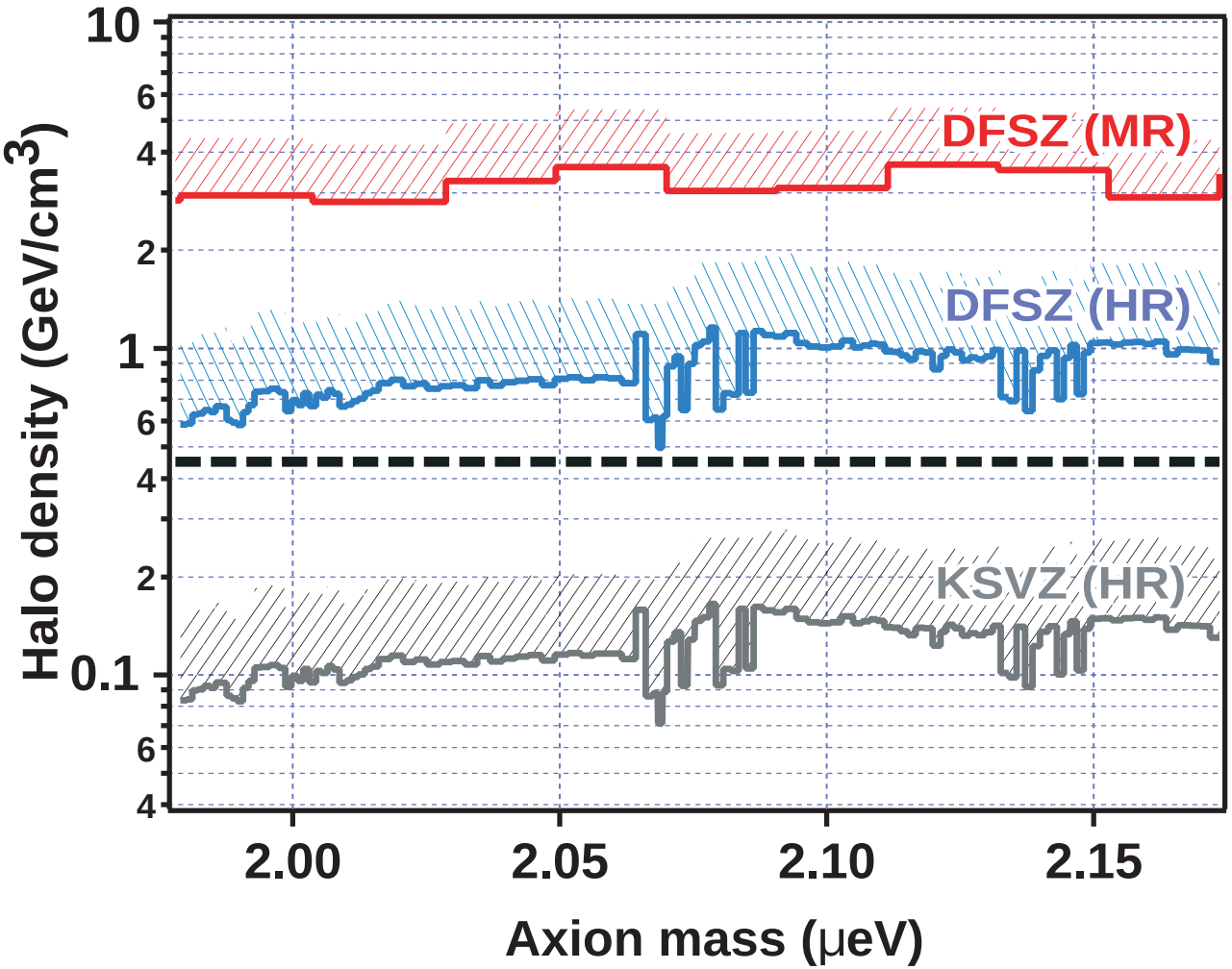
- DFSZ: $g_\gamma = -0.36$

(Dine, Fischler and Srednicki, 1981; Zhitnitsky, 1980)

Axion Limits



New High Resolution Result LD et al, 2005



Summary and Outlook

- Axions are a good candidate for the dark matter of the universe.
- The microwave cavity search is probing the allowed parameter space.
- The new high resolution channel has increased sensitivity and improves the potential of finding the axion.
- If the dark matter consists of axions, it will be found!