

Exotic Physics With ADMX



Gray Rybka

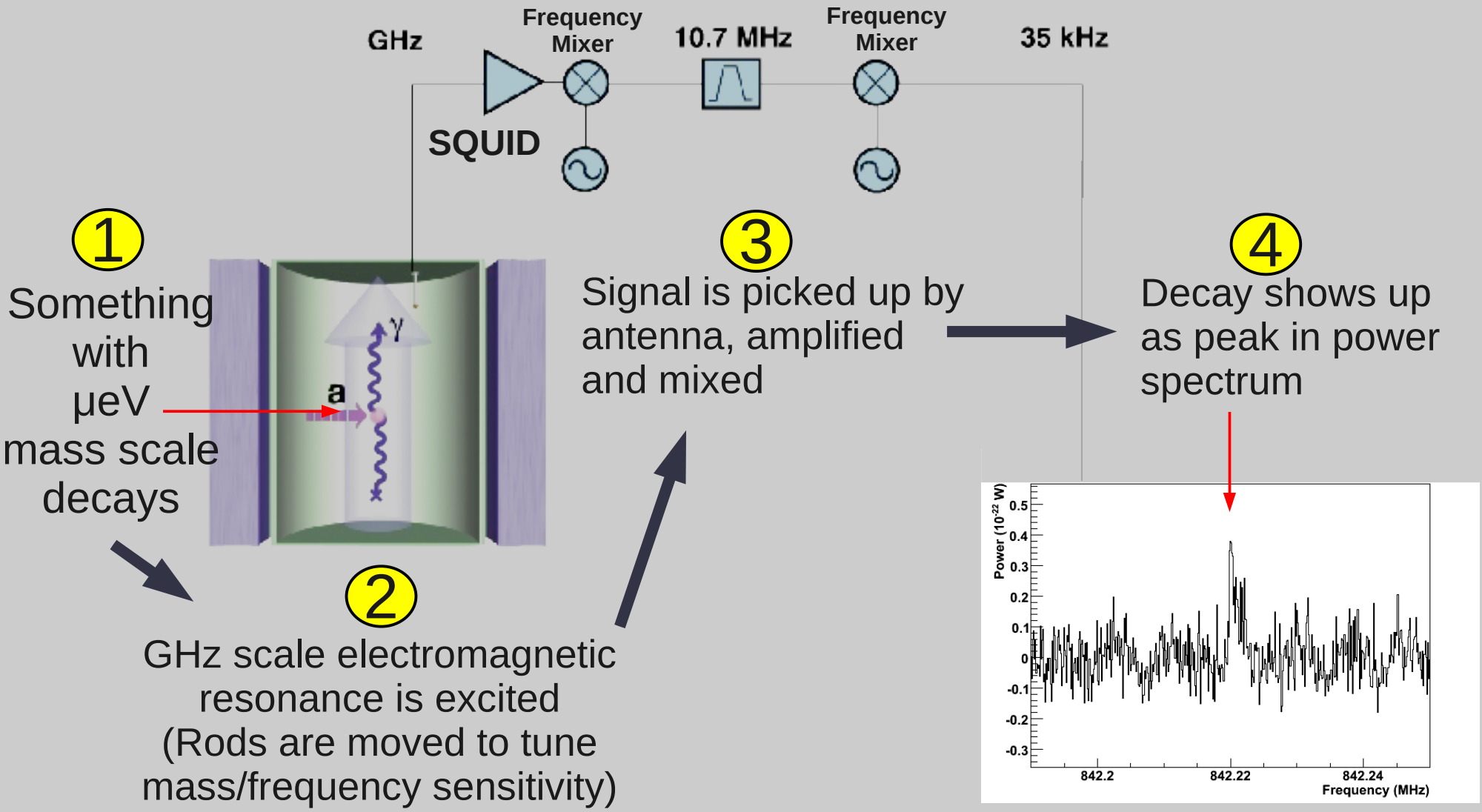
University of Washington



APS April Meeting

Feb. 2010

How ADMX Works



10^{-26} Watt Sensitivity

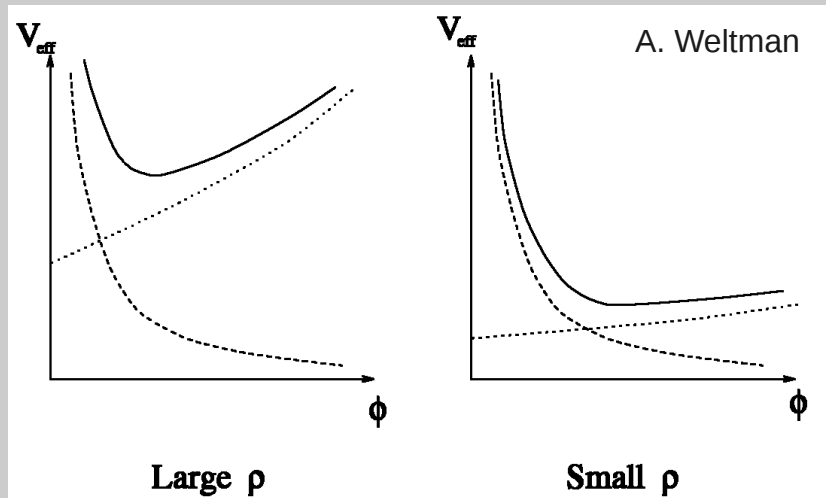


Chameleons

Scalar Chameleons

What they are

Exotic particle with nonlinear self coupling
Effective Mass depends on local energy density



For example:

$$V(\phi) = \Lambda^4 e^{\Lambda^{4+n}/\phi^4} + \frac{\beta}{M_{Pl}} \phi F^{\mu\nu} F_{\mu\nu}$$

Khoury and Weltman, PRL 93.171104 (2004)

Why you should care

Candidate for dark energy



Chameleon Phenomenology

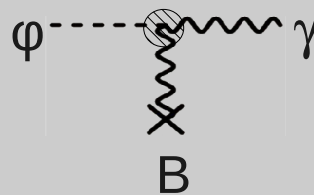
Chameleons

are reflected from dense matter

evade 5th Force Limits

evade Stellar Production Limits

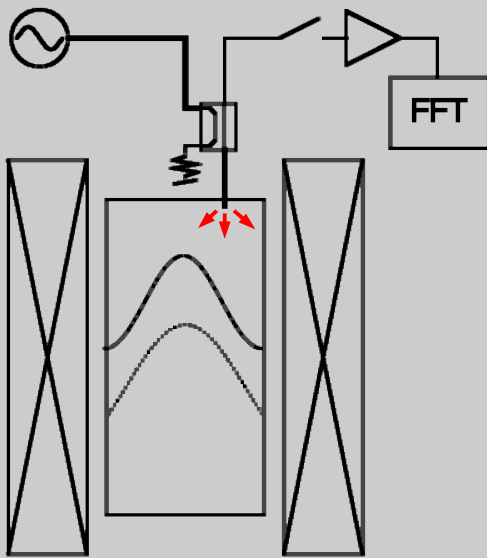
may have a coupling to photons



In a magnetic field, chameleons and photons can mix

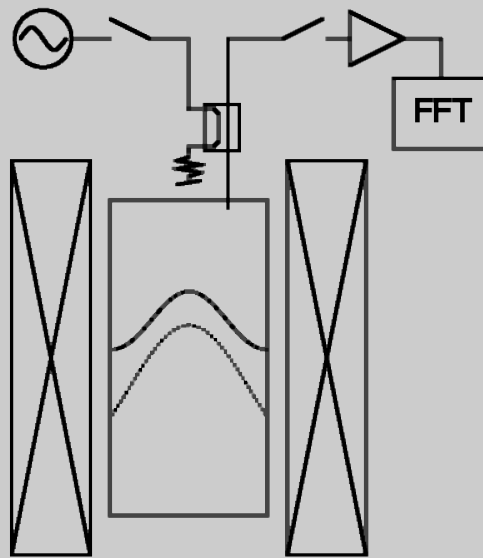


ADMX Chameleon Experiment



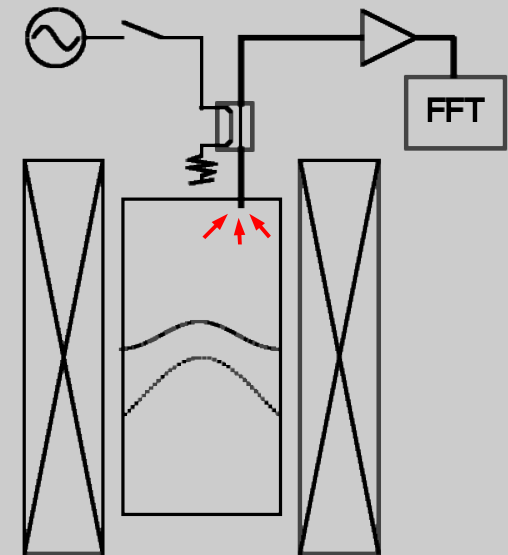
Step 1: Injected RF power excites E&M and chameleon modes

Timescale: 10 minutes
Power in ~ 25 dBm



Step 2: Power is turned off, E&M modes decay

Timescale: 100 milliseconds



Step 3: Chameleon modes slowly decay into E&M modes which are detected through antenna

Timescale: 10 minutes
Sensitivity $\sim 10^{-22}$ W
Bandwidth ~ 20 kHz

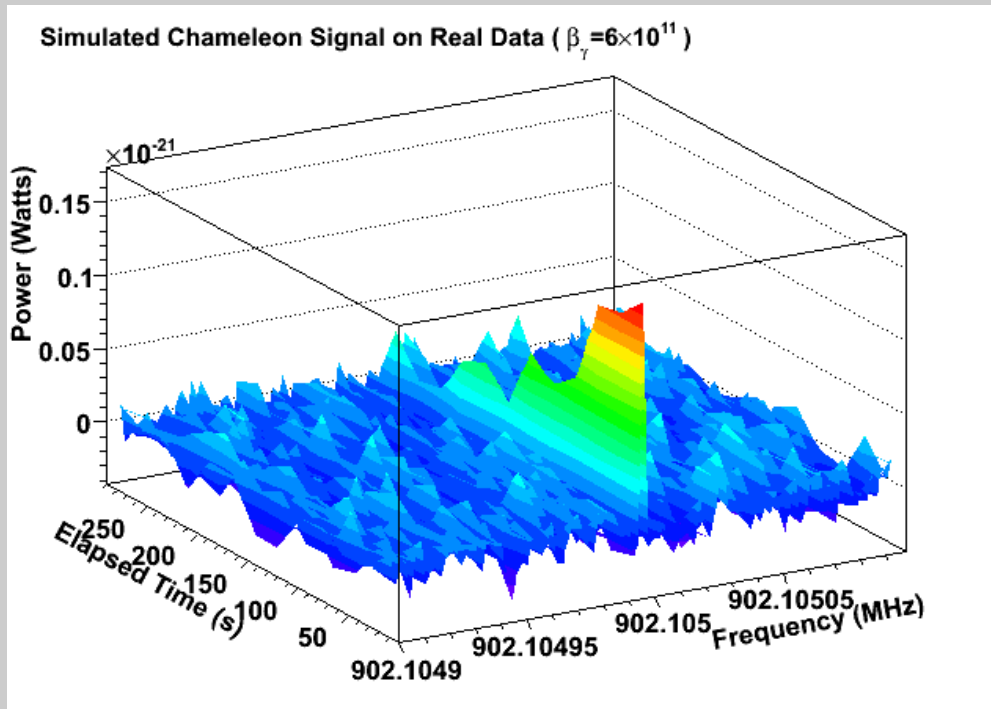
(Step 4: tune rods ~ 10 kHz and repeat)

Total Run Time: 1 Day

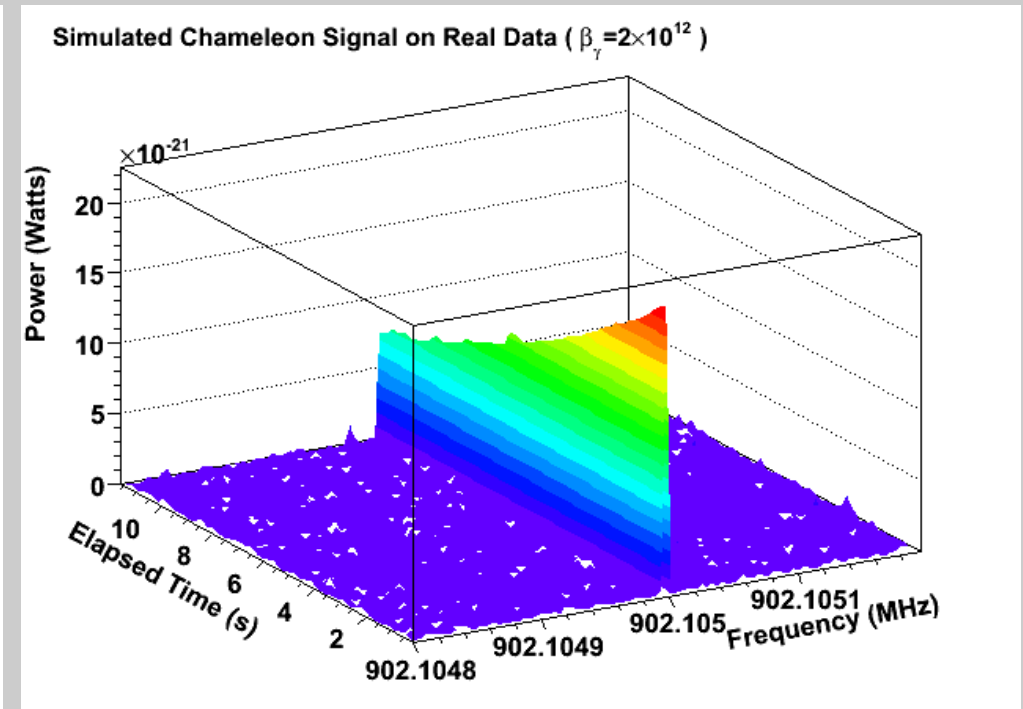


Simulated Chameleon Signals

Sequential power spectra may show chameleon resonance decay



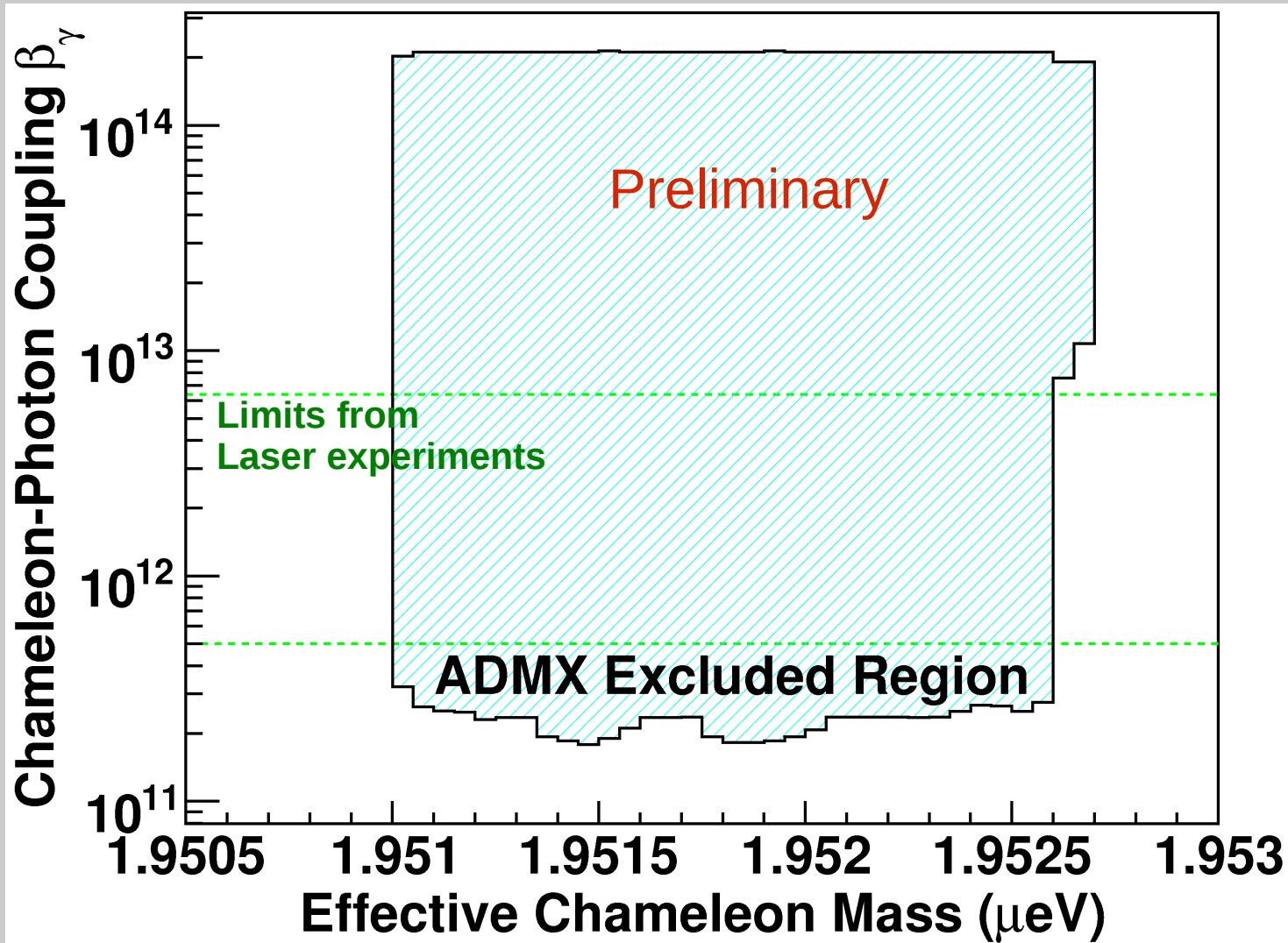
Weaker coupling leads to less signal,
longer decay



Stronger coupling leads to more signal,
but short decay time
(note time scale change)



ADMX Chameleon Results



Large coupling sensitivity: 3 orders of Magnitude

Narrow mass sensitivity: 1 neV



Hidden Sector Photons

Hidden Sector Photons

New U(1) symmetries that mix with photons are popular features in post-standard model physics

Motivated by string theory

“Hidden Sector Photon” or “paraphoton”



$$L = \frac{1}{4} F^{\mu\nu} F_{\mu\nu} - \frac{1}{4} B^{\mu\nu} B_{\mu\nu} - \frac{1}{2} \chi F^{\mu\nu} B_{\mu\nu} + \frac{1}{2} m_{\gamma'}^2 B_\mu B^\mu$$

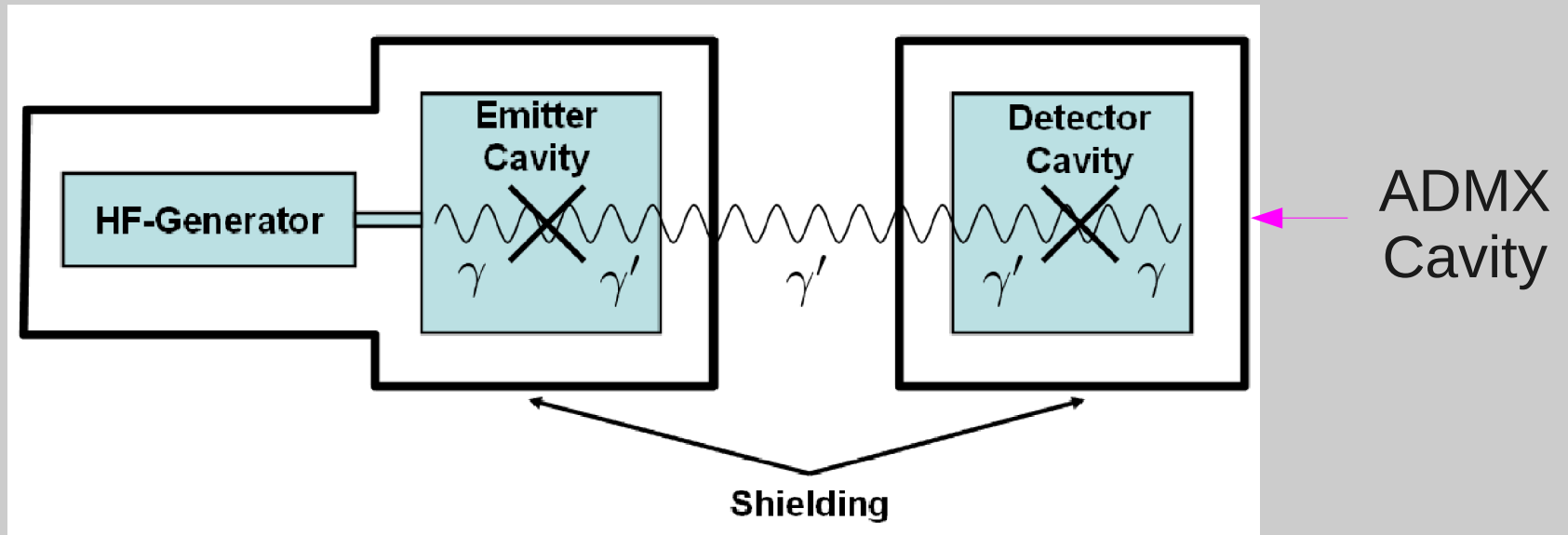
mixing parameter mass

Two Parameters in phenomenology



HSPs with ADMX

Paraphotons couple nearby electromagnetic resonant cavities

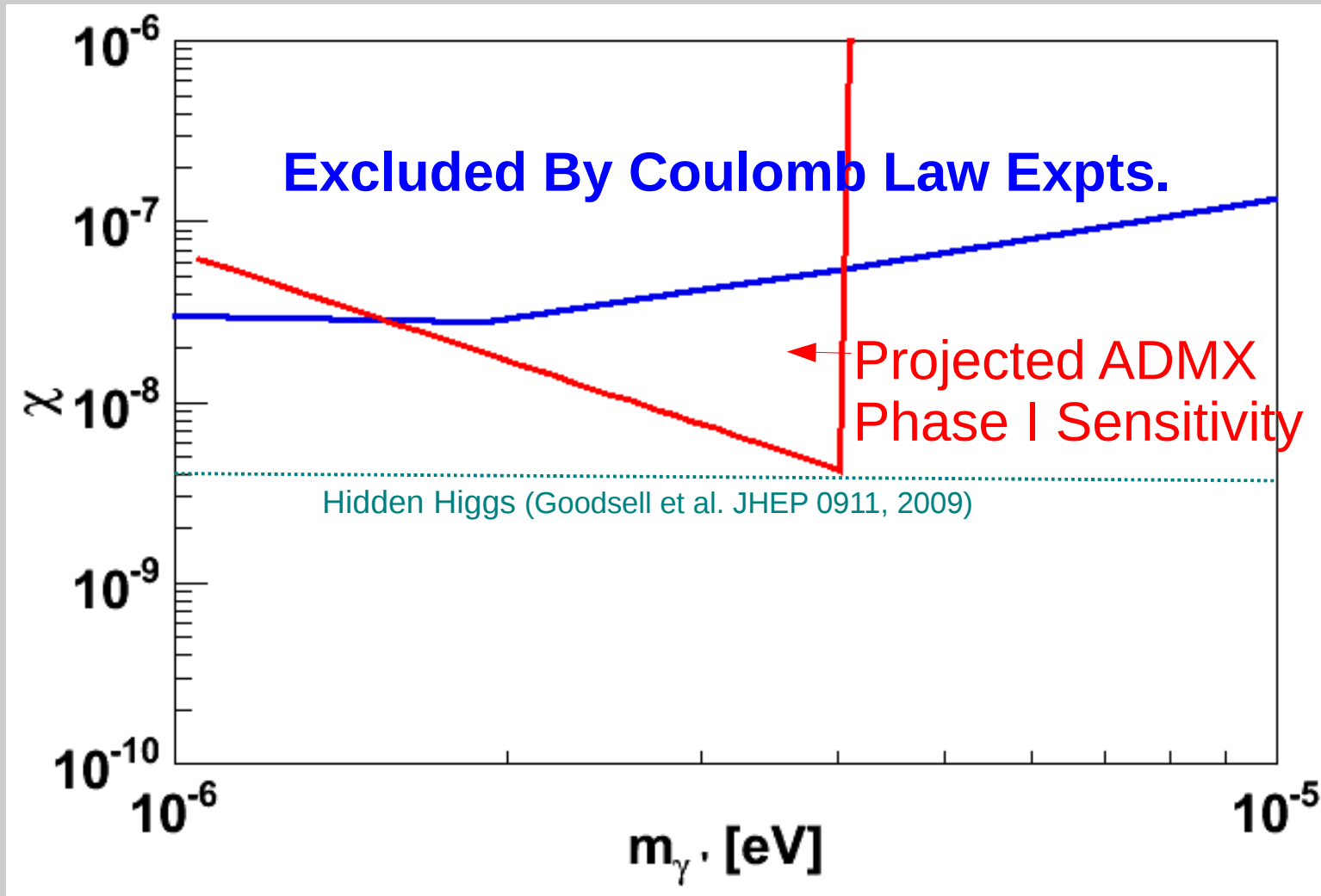


Jaeckel and Ringwald, Phys. Lett. B 659 (2008) 509

- We already have a sensitive detection cavity
- Generation cavity does not need to be cooled
- We can run HSP search at same time as Axion search



Projected ADMX HSP Sensitivity



An order of magnitude more sensitive to mixing parameter
Stay tuned: search planned for this spring



Summary

ADMX has set new limits on scalar chameleons,
a dark energy candidate

Potentially sensitive to 96% of the universe!

ADMX will be able to set new limits on hidden
sector photons

Entering theoretically interesting region!

ADMX is a laboratory for many new physics
theories



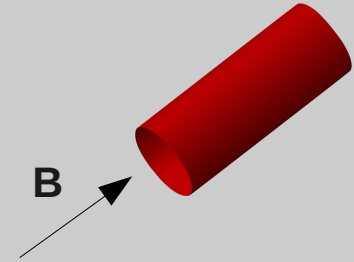
Slides I didn't have time for



Chameleons in Microwave Cavities

Back to ADMX...

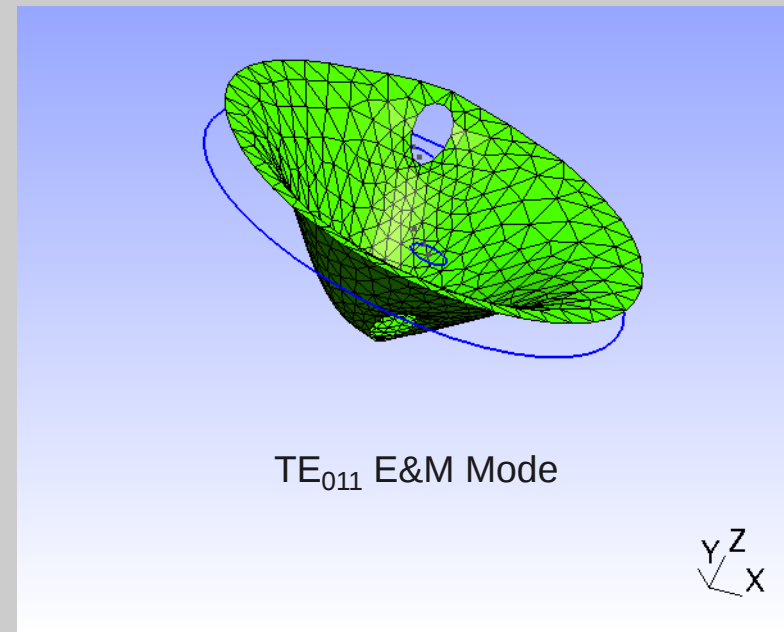
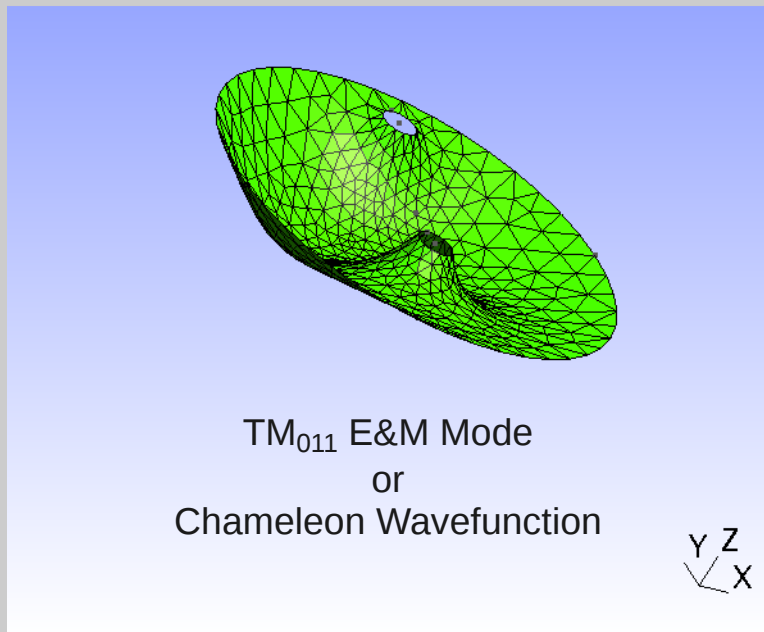
In a cylindrical cavity with a longitudinal B Field:



Pseudoscalar Coupling: $\mathbf{E} \cdot \mathbf{B}$ couple TM modes to chameleon modes

Scalar Coupling: $\mathbf{B} \cdot \mathbf{B}$ couple TE modes to chameleon modes

Vector Coupling: No \mathbf{B} Field Necessary



ADMX

Axion Dark Matter eXperiment

University of Washington

LLNL

University of Florida

UC Berkeley

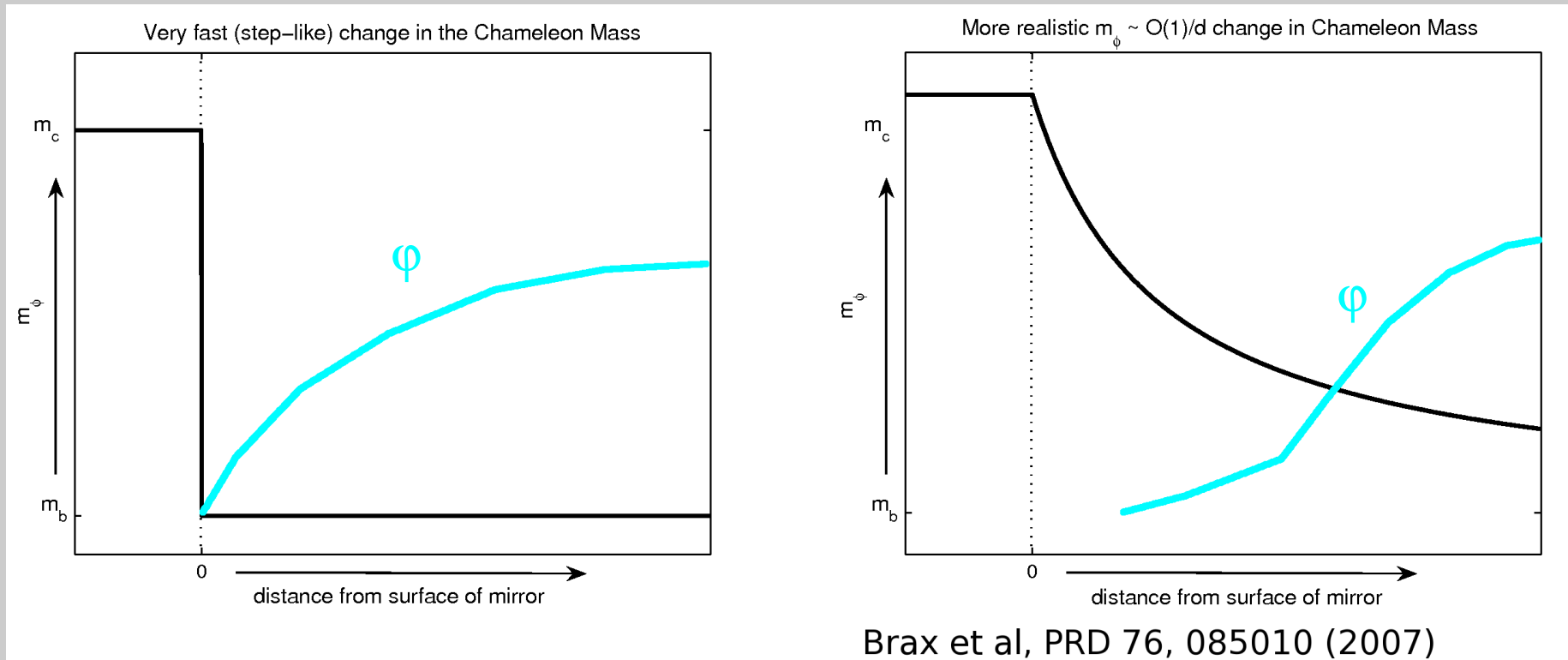
NRAO

Sheffield University

An ultra-sensitive microwave
photon detector



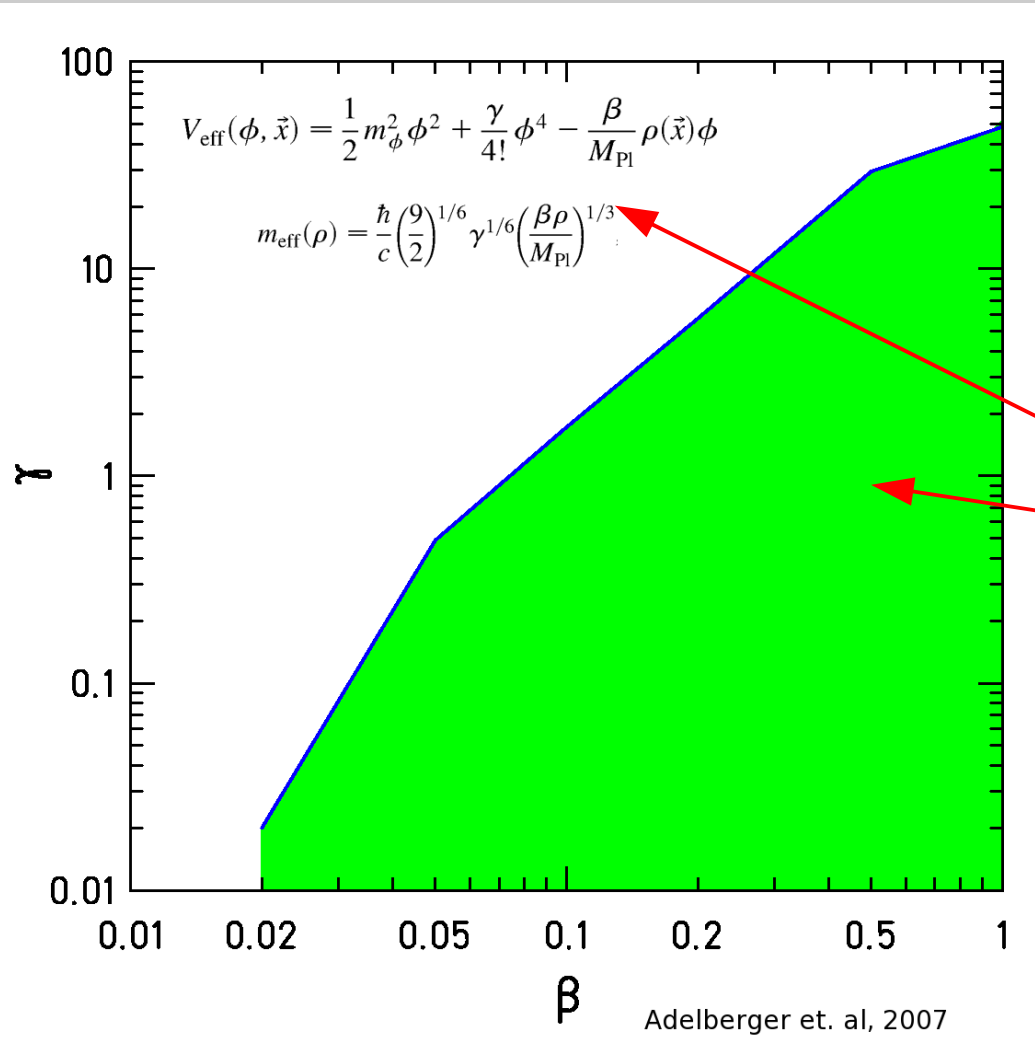
Subtleties of Chameleon Resonances



1. B^2 & residual gas energy density affects chameleon mass
2. Model dependent edge effects can modify wave function
 \Rightarrow Sensitivity can only be quoted in “effective mass”



Chameleons: Mass Coupling Limits



Fifth force and equivalence principle experiments still put the most stringent limits on chameleons

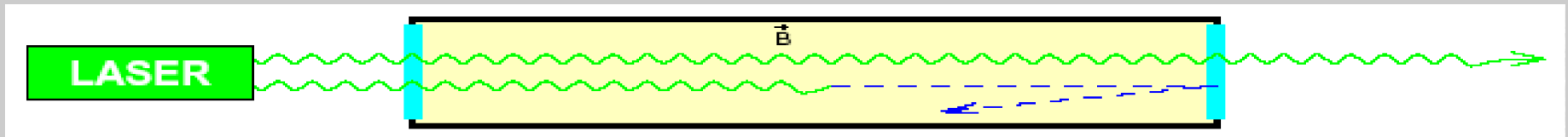
Pick a potential
Exclude Natural Parameters

More exotic potentials still allowed.

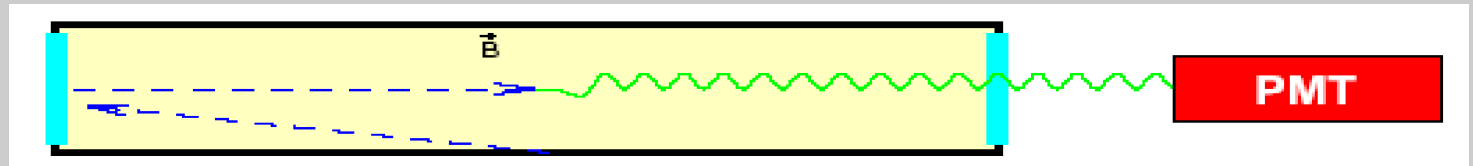


Chameleons: Photon Coupling Limits

The GammeV Experiment looked for chameleon-photon coupling
 (Fermilab) (Direct Questions to Aaron Chou and Will Wester)



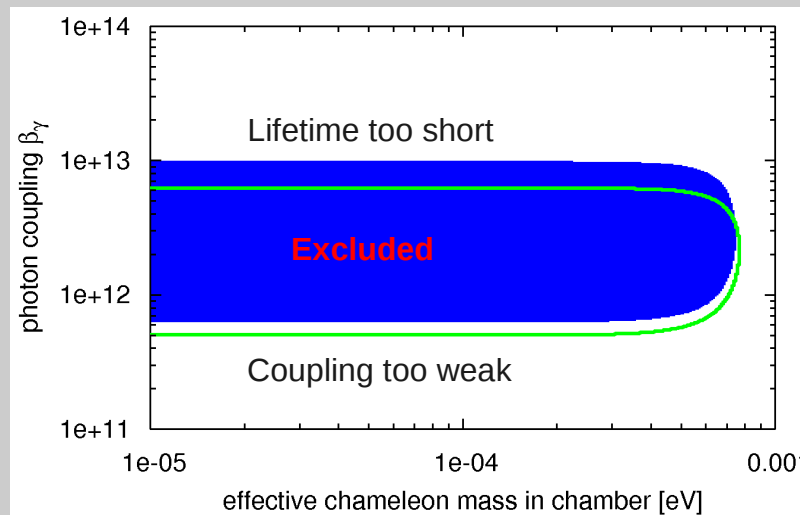
Step 1: Fill box with chameleons made from photons



Step 2: Look for photons from chameleon decay

Interaction

parameterized by: $L_{int} = e \frac{\beta_\gamma \phi}{M_{Pl}} \rho_\gamma$



pseudoscalar
 scalar

Chou et al. PRL 102 030402 (2009)



Potential Chameleon Improvements

Action	Sensitivity Increase
ADMX Phase II Cooling	3
Improved Cavity Q	2
More Power Injection	2

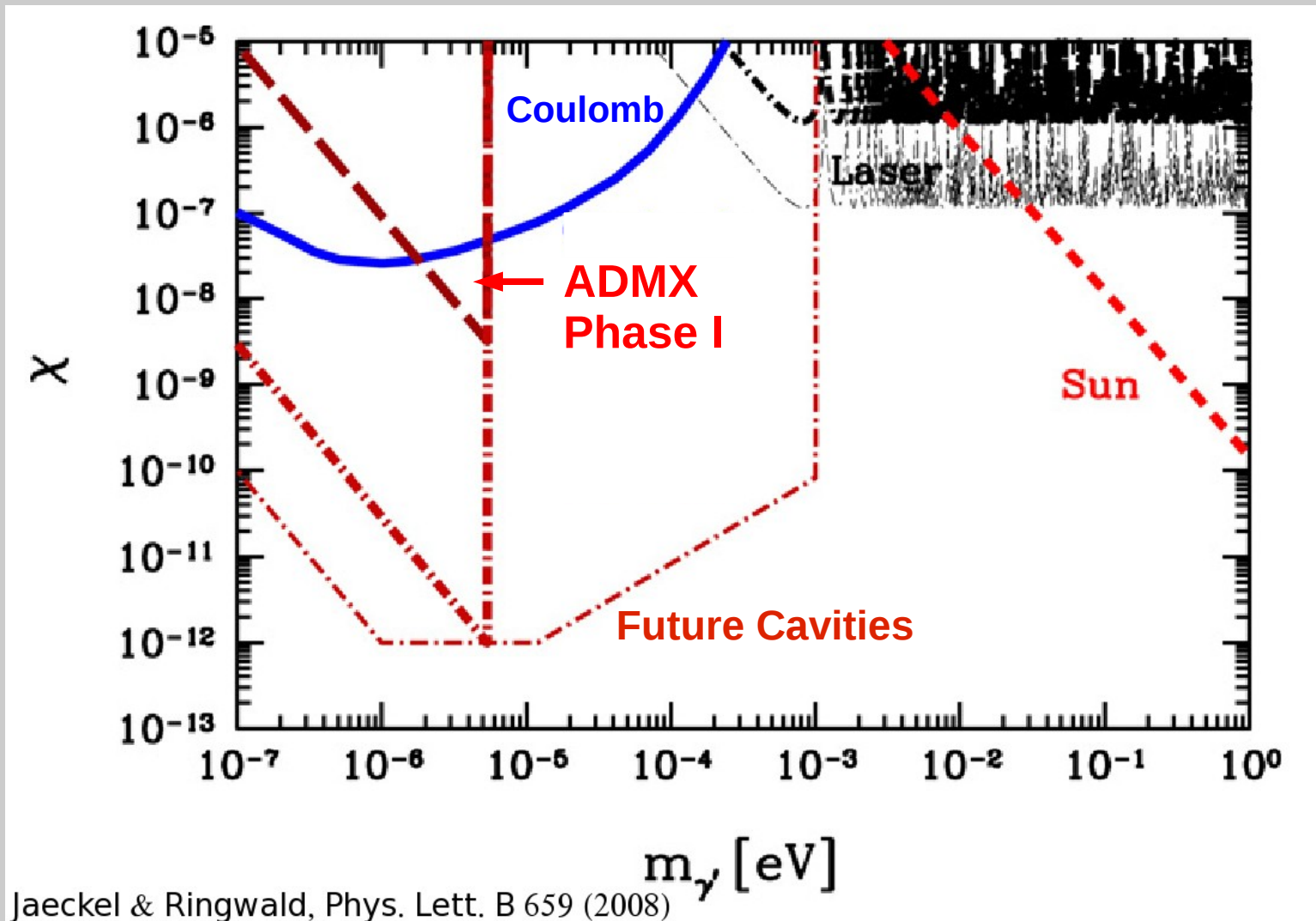
(Stronger couplings can be probed with weaker B field)

ADMX Phase II could improve sensitivity to β_γ by over a factor of 10

Sadly, mass scan rate will not improve unless only strong couplings are probed



Projected ADMX HSP Sensitivity



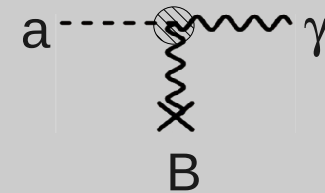
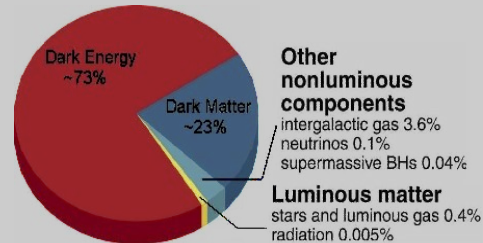
Stay tuned: search planned for this spring



What I mean by Exotic

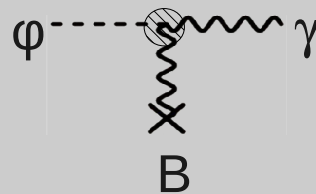
Exotic:

Axion Dark Matter

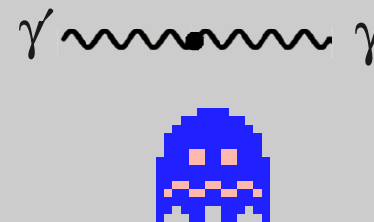


Really Exotic:

Chameleons



Hidden Sector Photons



Topic of this Talk

