

# The CHASE laboratory search for chameleon Dark Energy

**Jason H. Steffen**

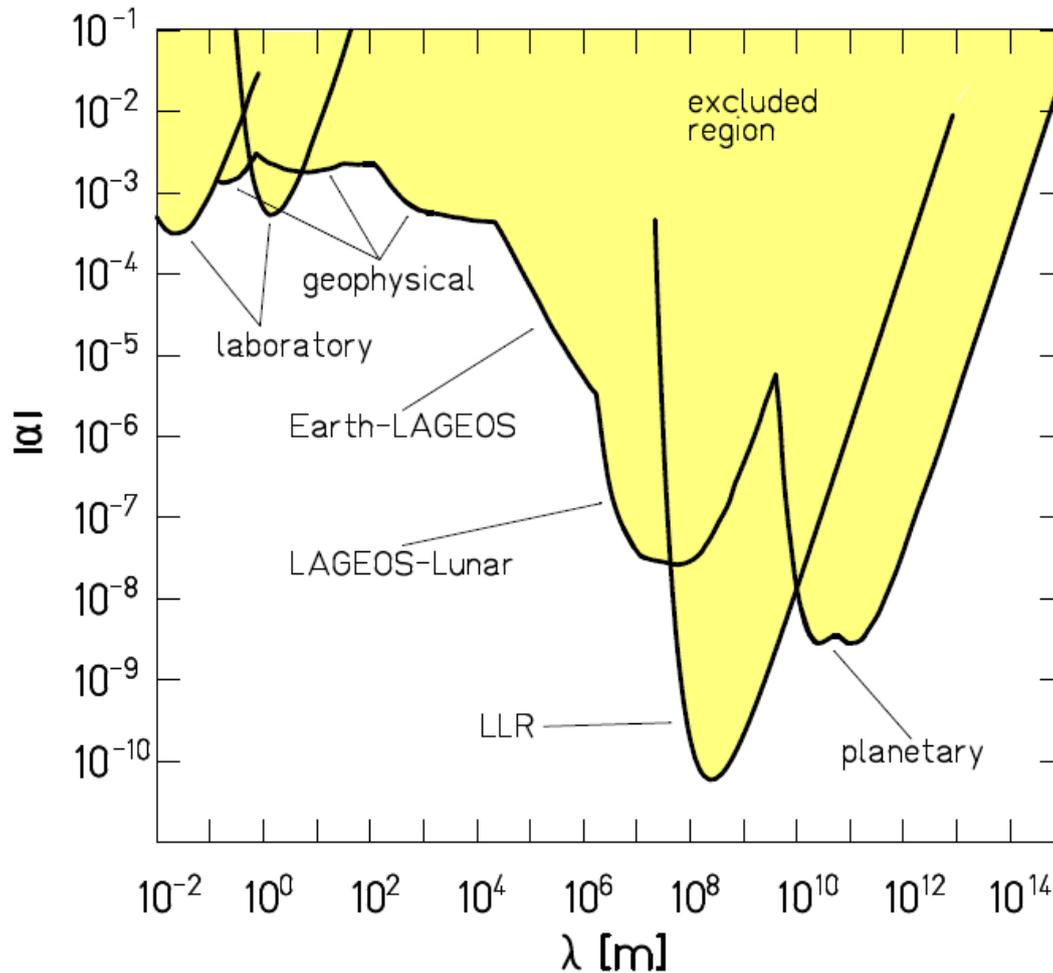
Fermilab Center for Particle Astrophysics

July 2010

Al Baumbaugh, Aaron Chou, Peter Mazur, Jason H. Steffen,  
Ray Tomlin, Amol Upadhye, Amanda Weltman, William Wester

# Experimental Constraints on Scalars

A scalar field is a common suspect for dark energy.



## Three possibilities

- Inherently weak couplings (quintessence)
- Weak couplings locally (DGP braneworld)
- Large masses locally (chameleon mechanism)

# Searching for Dark Energy

Most effort is devoted to measuring the equation of state parameter  $w$ .

If cosmological constant, then  $w = -1$ .

If not (e.g. some particle), then  $w$  can have a range of values.

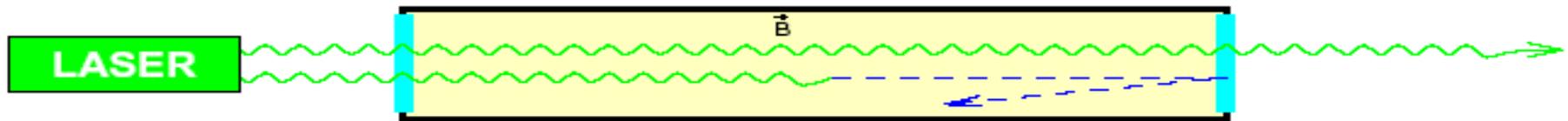


**Many models, including chameleon dark energy, are indistinguishable from a cosmological constant with astronomical surveys.**

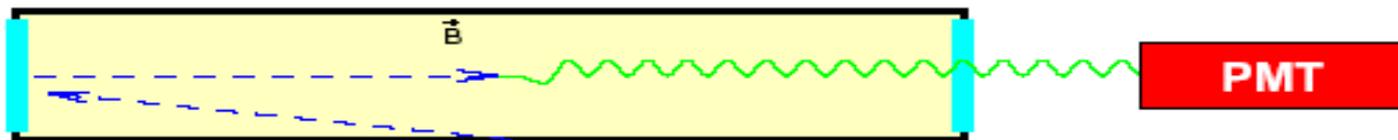
# CHASE Experimental Approach

First applied in the GammeV experiment.

Strong matter effects cause the magnet walls and vacuum windows to act like fully reflective mirrors.



The laser shining into the cavity will fill the “jar” with chameleons.

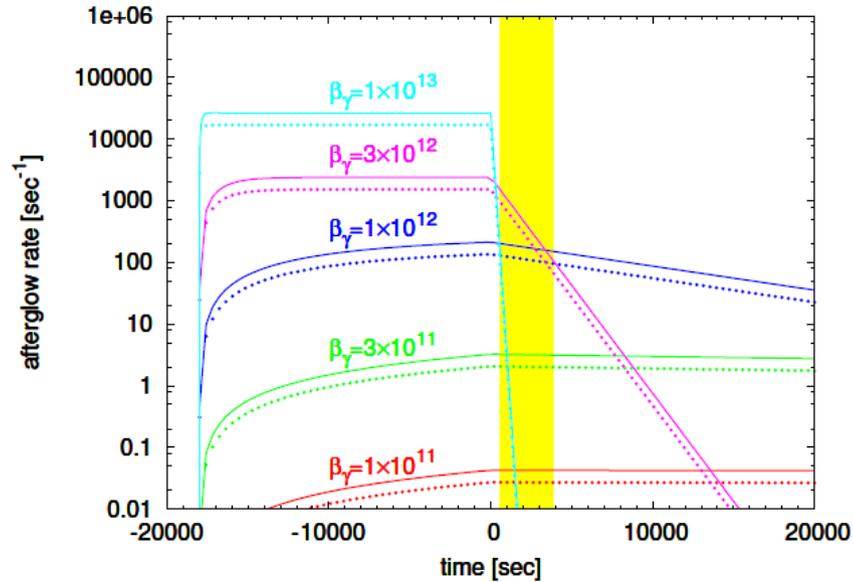


After the jar is filled and the laser is turned off, you should see an afterglow as the chameleons reconvert to photons and escape.

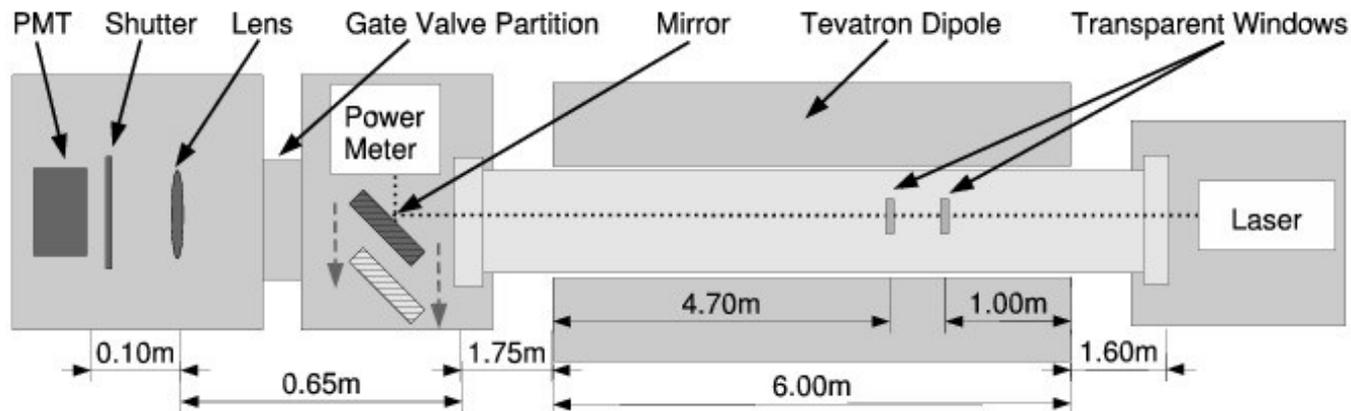
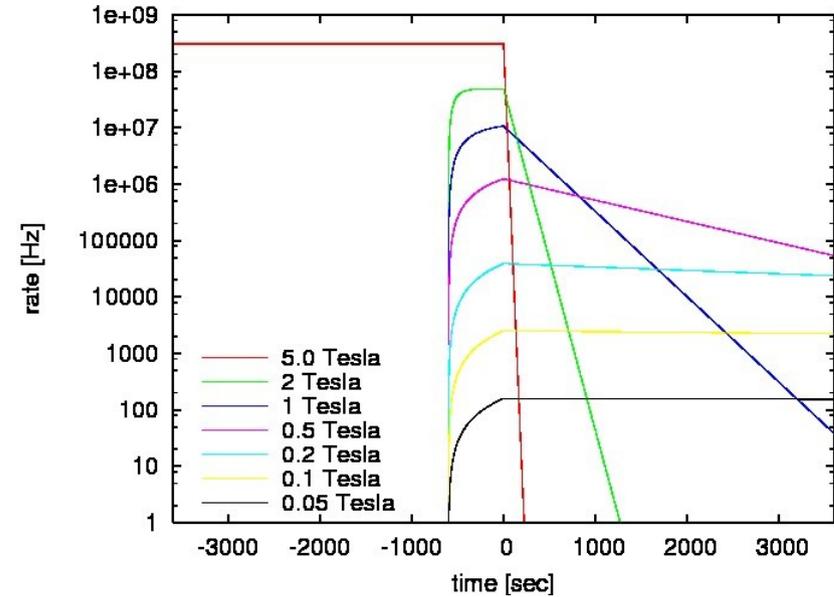
Note: This requires a photon coupling in addition to a matter coupling. However, matter couplings give effective photon couplings so this is generally satisfied.

# CHASE Experimental Approach

## Fixed magnetic field

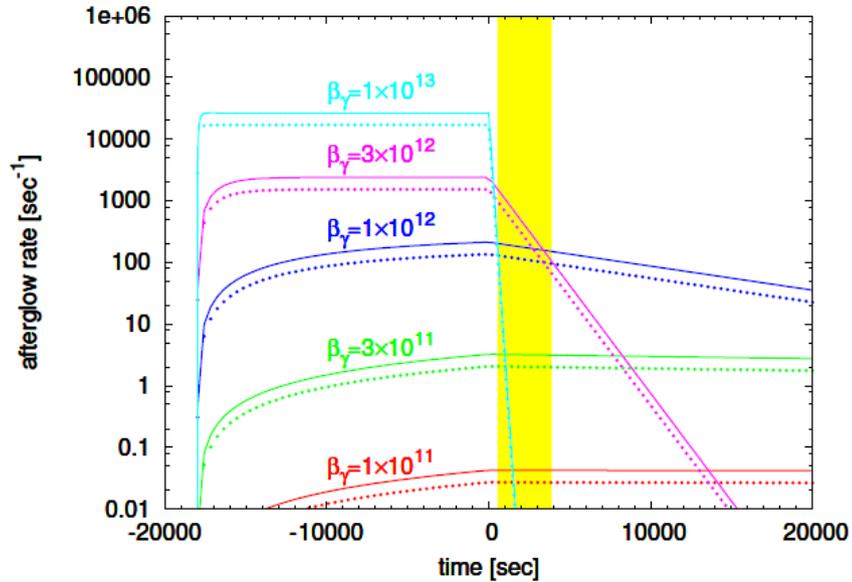


## Fixed chameleon couplings

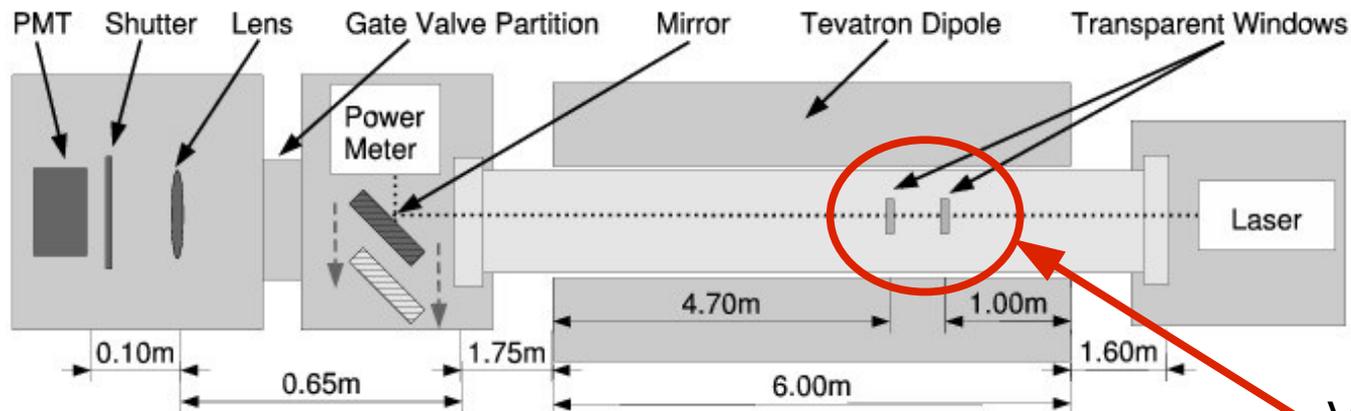
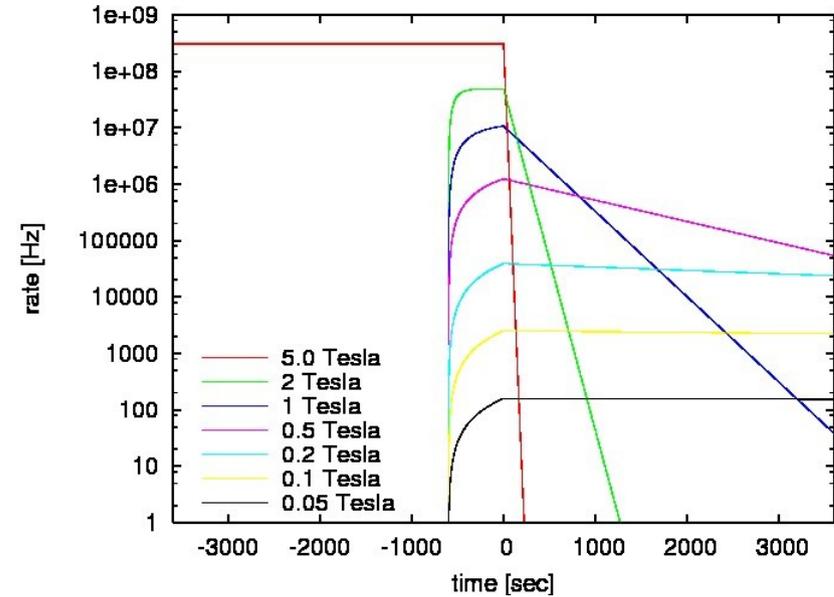


# CHASE Experimental Approach

## Fixed magnetic field

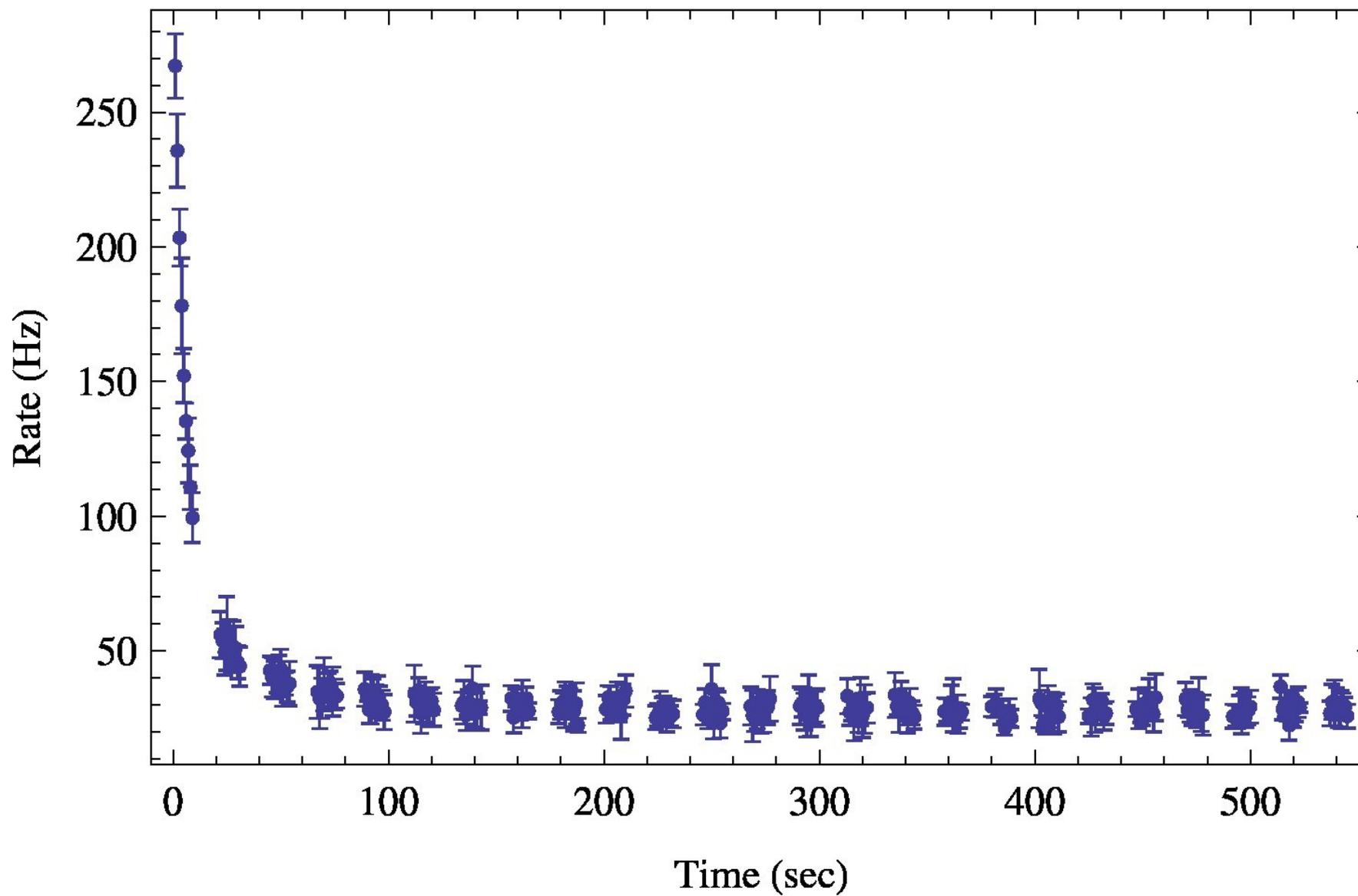


## Fixed chameleon couplings



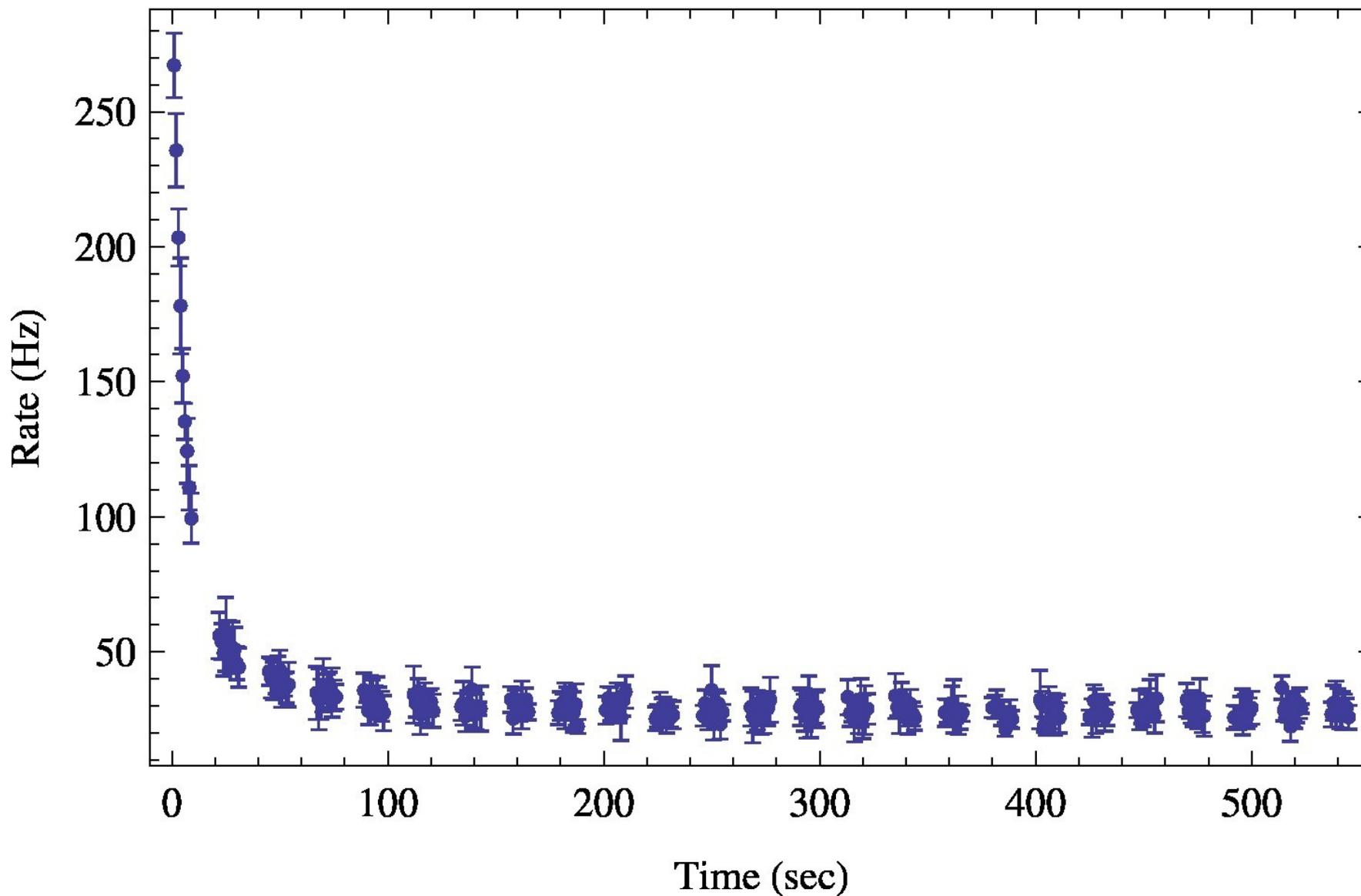
Variety of lengths  
(i.e. masses).

# First Discovery



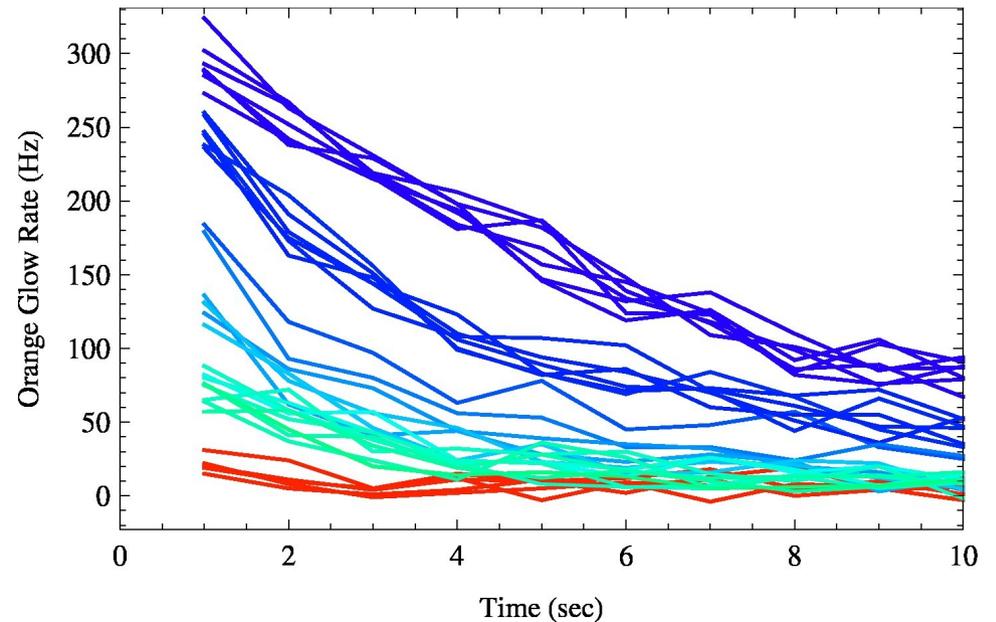
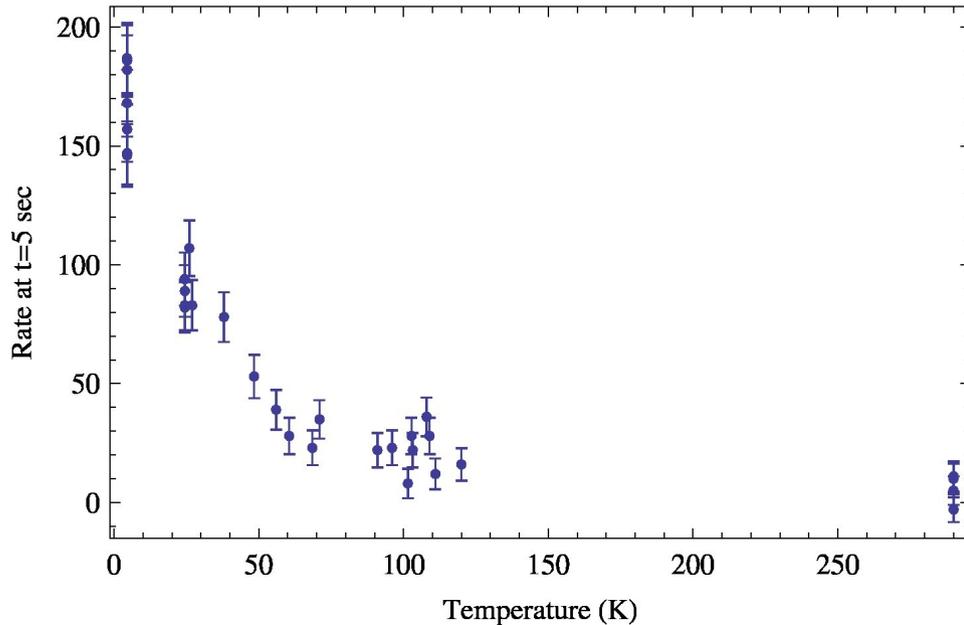
~~First Discovery~~

*Systematic*



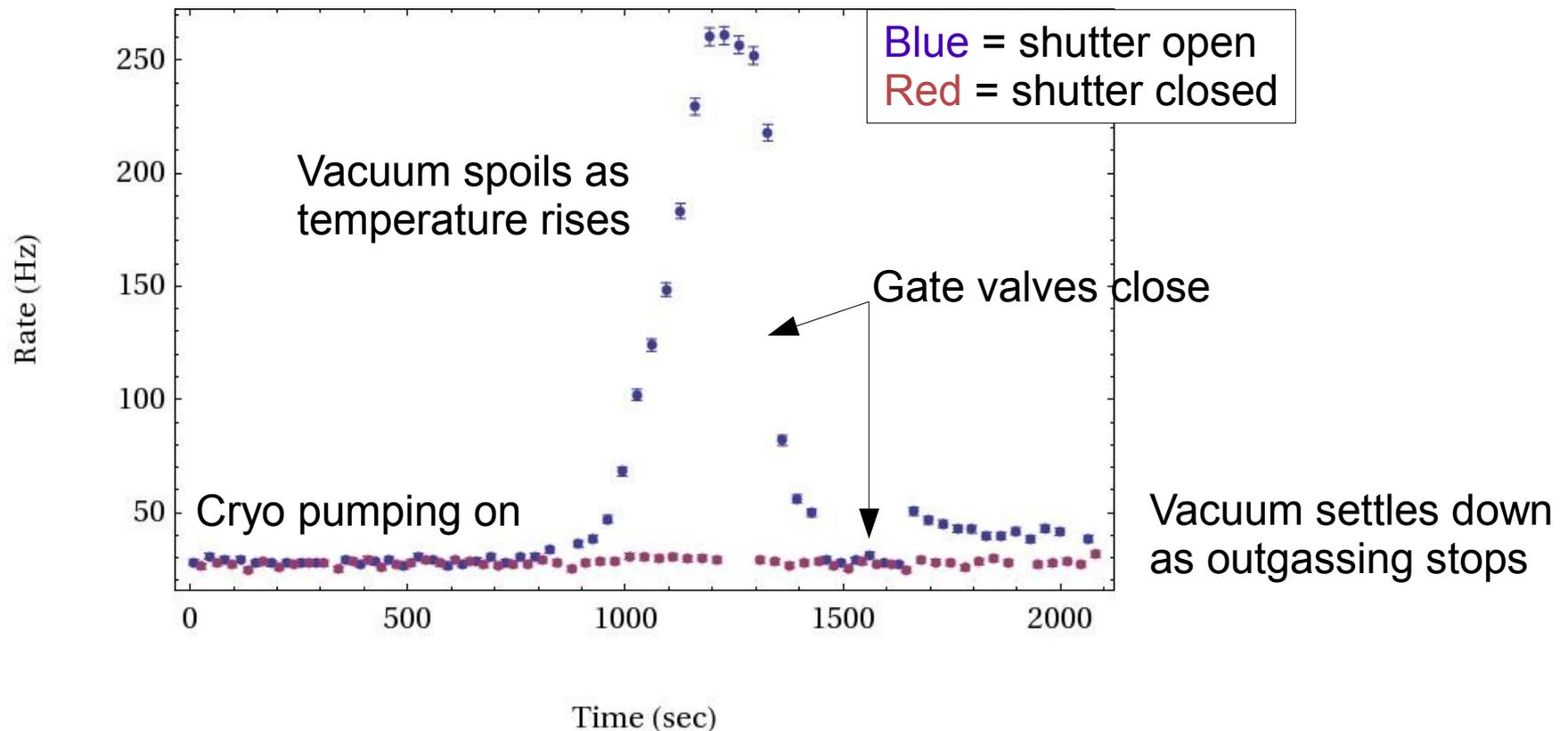
# First Systematic: Orange Glow

- Orange glow only appears in the red and orange part of the spectrum not in the green where a chameleon signal is expected.
- Orange glow is independent of the magnetic field and laser polarization unlike a chameleon signal.
- The afterglow has a strong temperature dependence, also unlike a chameleon signal.



# Second Systematic: Pump Glow

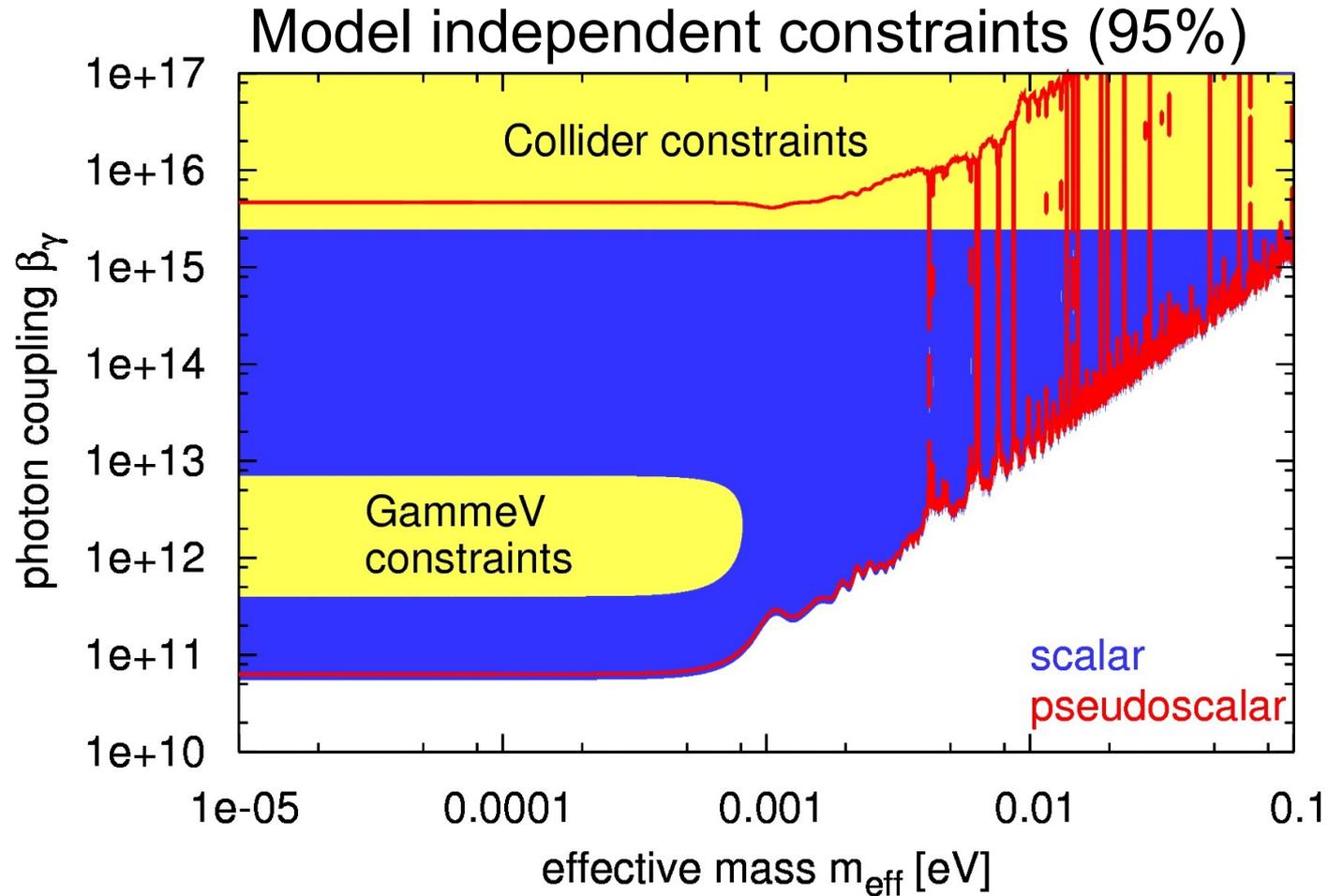
- We expected to see some discharge from both ion gauges and ion pumps.
- Ion gauges are very bright so we turn them off during our observations.
- Ion pumps remain on, excess discharge ( $\sim 1$  Hz) is measured and monitored with frequent calibration measurements.
- The pump glow has a strong vacuum dependence.



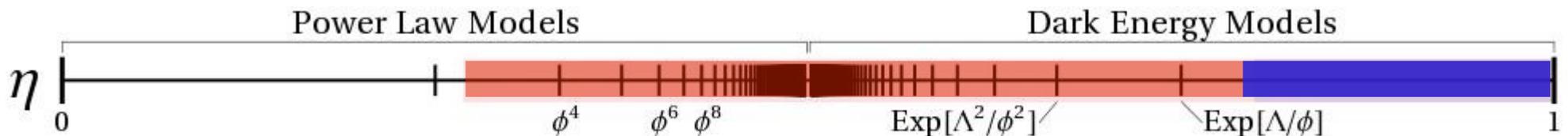
# CHASE science data

- Take data with two different laser polarizations to search for scalar and pseudoscalar chameleons
- Take data with seven different magnetic field strengths to probe a variety of photon couplings
- Three different partitions allow us to probe a larger range of chameleon masses
- Calibration data taken before and after (or between) each chameleon science run
- Characterized orange glow independently and removed it

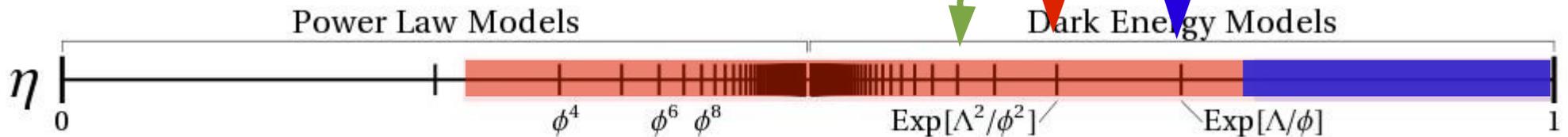
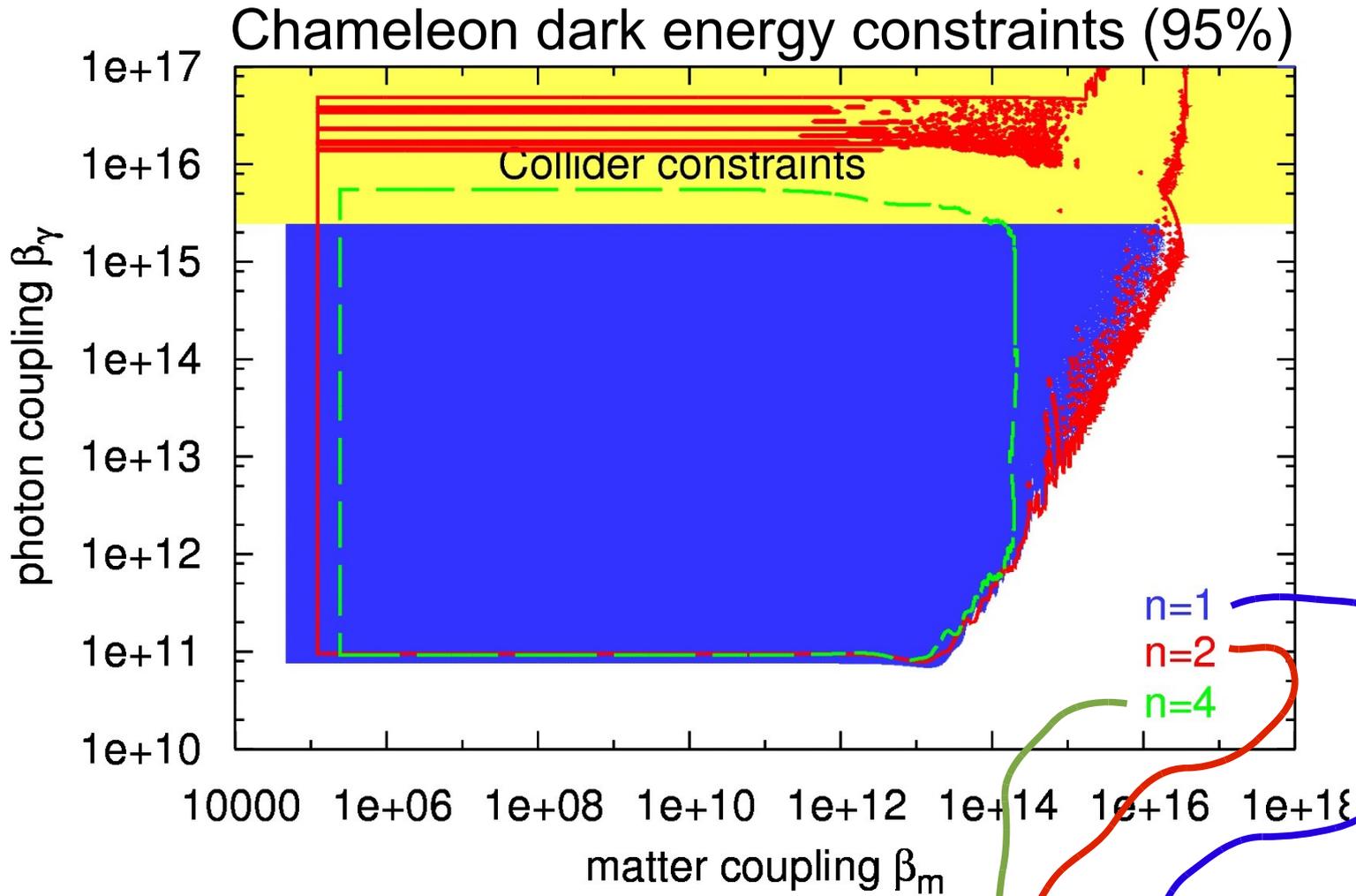
# CHASE preliminary results



Range of models probed by GammeV (blue) and CHASE (red).



# CHASE preliminary results



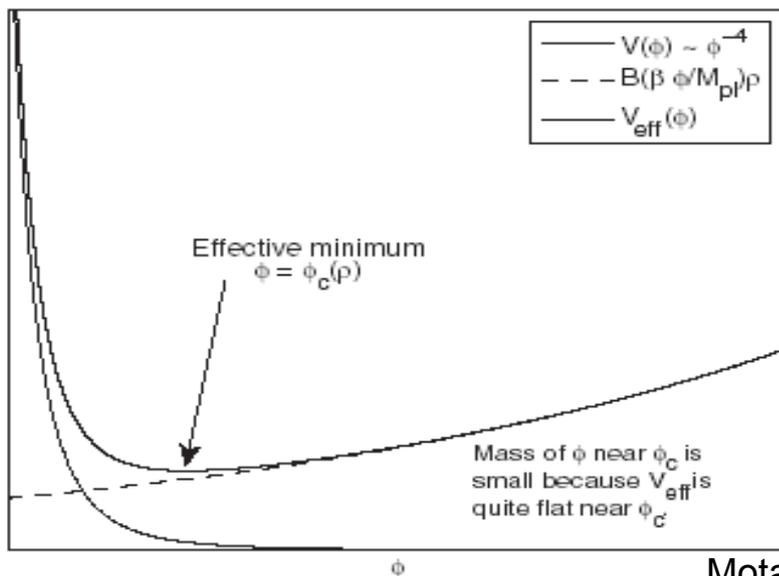
# Conclusions

- Laboratory test of dark energy models is important to our understanding of its properties
  - Many models are indistinguishable from cosmological constant and can not be understood from surveys
- CHASE is an important laboratory probe of a class of viable dark energy models
- CHASE data have been taken and analysis is near completion
  - Expect to announce first results soon (August 2010)
- Preliminary results exclude chameleon dark energy models over a wide range of photon and matter couplings.

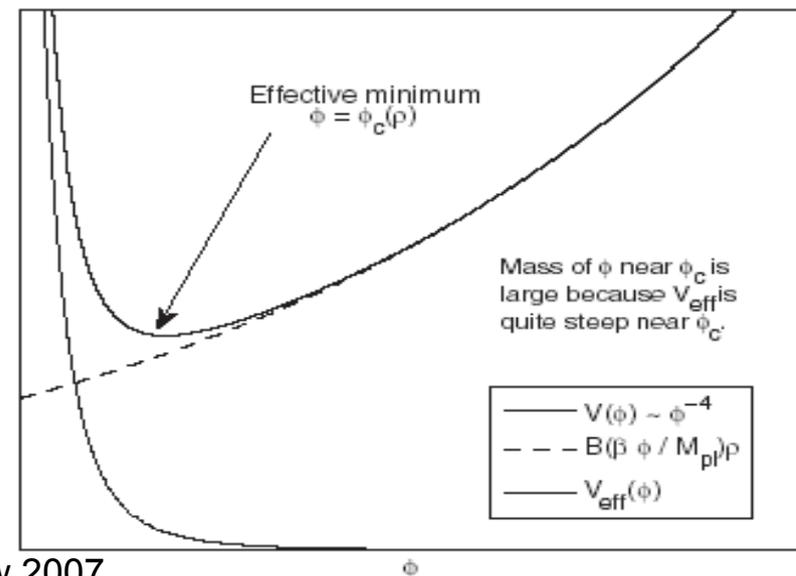
# Chameleon Mechanism

- New scalar field with nontrivial potential and coupling to the energy–momentum tensor
- Mass is a strong function of the local energy density
- Hides the axions of string theory (Khoury/Weltman)

Sketch of chameleon mechanism: Low Density Background



Sketch of chameleon mechanism: High Density Background



Mota & Shaw 2007

Note: The simplest models predict  $m_{\text{eff}} \sim \rho^\eta$ .