Dark-Sector Photo-Magnetic Luminescence: The Case for a Room Temperature Chameleon Search

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We report the results of studies showing that temperature dependent photoluminescence is the likely source of unexpected large background rates in afterglow searches for dark sector phenomena, commonly called "chameleons". Using this information, we examine the possibility of a room temperature chameleon afterglow search that automatically eliminates this background. Then, without this background, we discuss a modest search effort exploring the afterglow halflife range 0.1 sec $\leq T_{1/2} \leq$ 120 sec equivalent to photon coupling constant range $8 \times 10^{12} \leq \beta_\gamma \leq 3 \times 10^{14}$.

Considered by some to be quintessential components of Dark Energy (DE), chameleon particles should be formed by a DE scalar field oscillating into photons in the presence of a magnetic field. If formed inside a vacuum chamber, their effective mass characteristics would confine them to the vacuum chamber until they reconvert back to photons (see Ref. [1,2,3]). Chameleon production and subsequent decay forms the basis of the afterglow experimental technique from Ref. [4] . Conversion probabilities between photons and chameleons can be found in Ref. [1,2,3] and the afterglow flux from decay chameleon can be found in Ref. [4].

The generic layout of afterglow experiments is shown schematically in Figure 1. Note that in this work, laser induced delayed photon emission from standard matter is considered to be "luminescence" and laser induced delayed photon emission from chameleons is "afterglow".

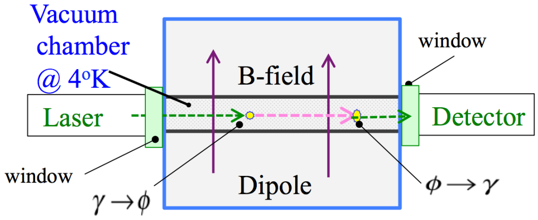

Figure 1: The generic layout of afterglow experiments.

The afterglow experiment, depicted in Figure 1, consists of a photon source laser shining through a viewport window into a vacuum chamber immersed in a dipole magnetic field where a chameleon "gas" is generated by the interaction of scalar field, photons, and magnetic field. Chameleons, by their very nature, cannot escape the vacuum chamber but can convert back to photons when they pass through the magnetic field. When the source laser is turned off the chameleon gas decays away and the resulting photons are either absorbed by the vacuum chamber walls or escape through viewports and captured by detectors.

Figure 2 shows the predicted afterglow rates. Note the build-up of chameleons while the source laser is on and the decay after the laser is turned off at t=0. All three groups, CHASE (Fermilab), GammeV-CHASE (Fermilab), and OSQAR-CHASE (CERN) reported an unexpected large backgrounds at the 4 K operating temperature of the dipole - so large, in fact, that all data within the first two minutes after laser turn-off, could not be used. The observed increase in count rates at low T could not be attributed to chameleon afterglow since the rate increase was independent of the dipole field.

The temperature dependence of the background luminescence is explained by a Jablonski diagram (see Ref. [10]) which depicts the sequence of events when a molecule absorbs a photon and then sheds the energy as it returns to the ground state. At room temperature, there are many paths back to the ground state, e.g. rotation or vibration, which do not radiate. In Figure 3, we show the proposed room temperature setup along with real luminescence images taken with the setup.

In Figure 4 we show the updated afterglow predictions for $\beta_\gamma = 20^{14}$. These plots include a background of 300 Hz that are not included in the other afterglow calculations. Even with this large background, the calculated afterglow for t=0 and 1.7 Tesla, the signal to noise ratio is significant.

And in Figure 5, we show a photograph of the current LIPSS setup to clearly show that most of the equipment needed for this experiment is on hand.

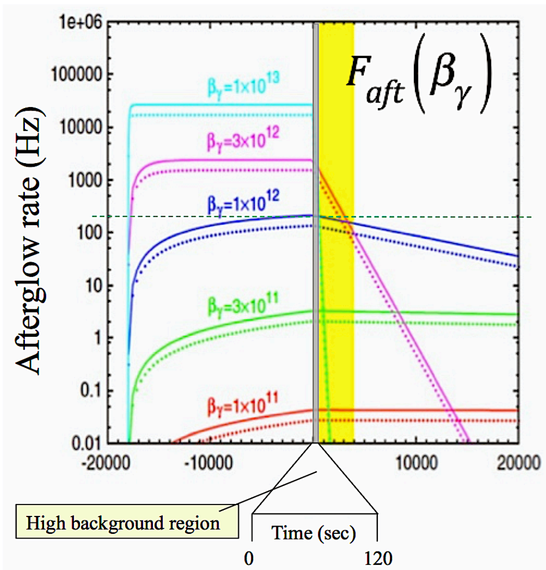

Figure 2: Predicted afterglow rates assuming several values of the coupling constant β_γ.

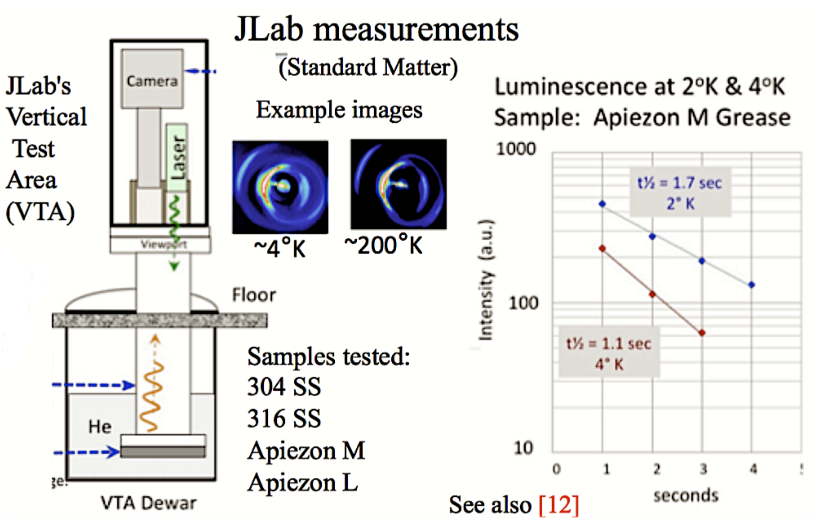

Figure 3: Temperature dependent luminescence.

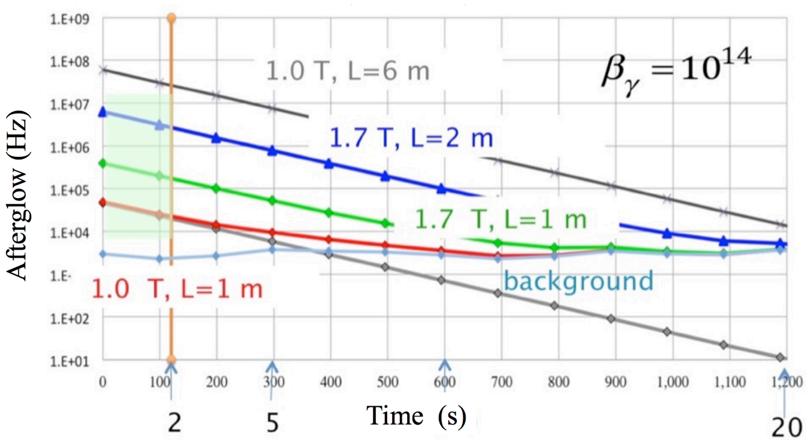

Figure 4: Afterglow in magnetic field.

In summary, we find that using 4K vacuum chambers standard matter luminescence photons contribute strongly to the background and would mask afterglow photons. Making the searches at room temperature automatically eliminates this background, permitting short decay time chameleon searches. Thus, we demonstrate how to make a room temperature chameleon search and test predictions of photon coupled chameleon scalar fields.

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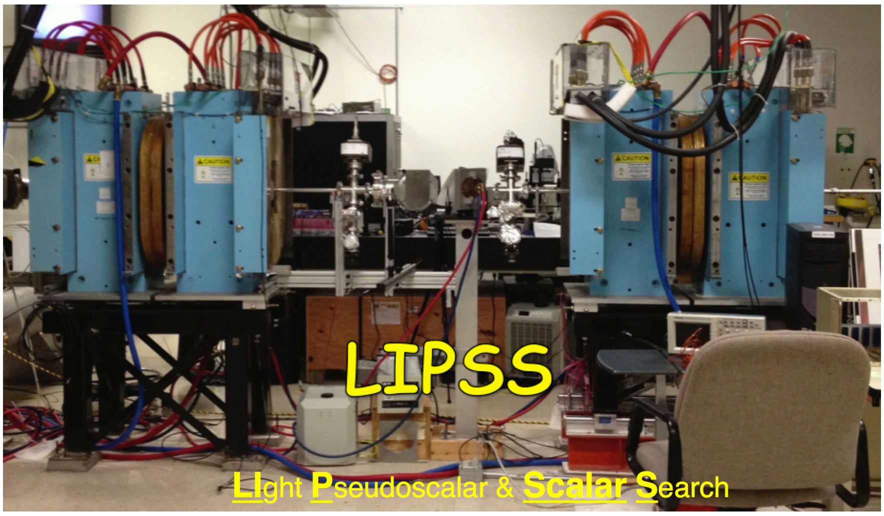

Figure 5: Image of the LIPSS experimental setup at Jefferson Lab. The dipoles are colored light blue and can be joined to form a 2 meter long, 1.7 Tesla B-Field.

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