A Testable Conventional Hypothesis for the DAMA-LIBRA Annual Modulation Signal

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LBNL

S is modulation signal amplitude:
S = 0.0178 ±0.0020 (2-5 keV)

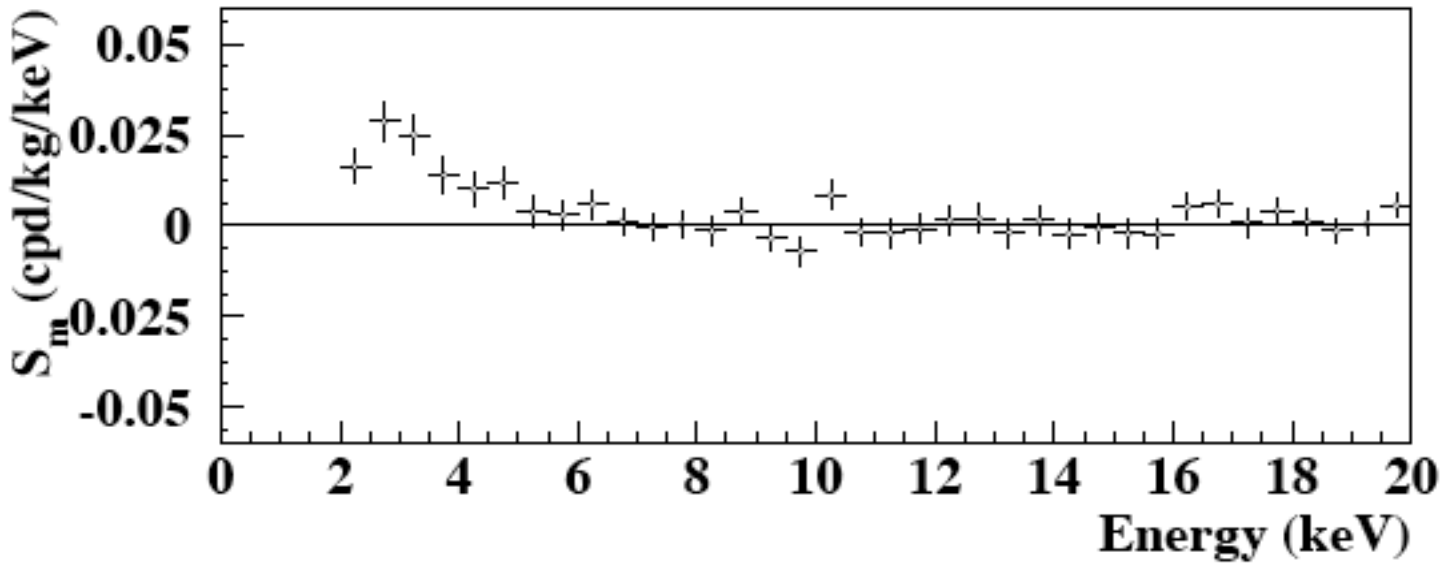


Figure 9: Energy distribution of the $S_{m,k}$ variable for the total exposure (0.82 ton×yr, DAMA/NaI & DAMA/LIBRA). See text. A clear modulation is present in the lowest energy region, while $S_{m,k}$ values compatible with zero are present just above. In fact, the $S_{m,k}$ values in the (6–20) keV energy interval have random fluctuations around zero with χ^2 equal to 24.4 for 28 degrees of freedom. See also Appendix A.

First results from DAMA/LIBRA and the combined results with DAMA/NaI

from: arXiv 0804.2471

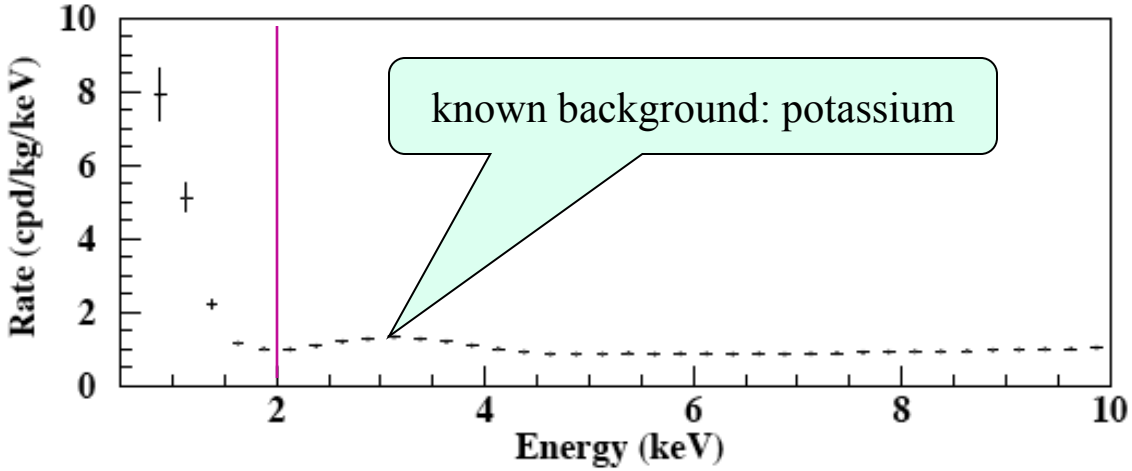


Figure 1: Cumulative low-energy distribution of the *single-hit* scintillation events (that is each detector has all the others as veto), as measured by the DAMA/LIBRA detectors in an exposure of 0.53 ton $\times$ yr. The energy threshold of the experiment is 2 keV and corrections for efficiencies are already applied.

Signal or Background: n, γ, μ, or ν?

- High energy neutrons calculated to be weak by two to three orders of magnitude;
  - Ralston argues that epithermal neutrons have been under-appreciated: arXiv:1006.5255v1
- Multi-hit events show no modulation in D-L
  - Why not? Icarus sees ~4% neutron modulation
  - Are multi-hit events all γ-rays?
- Can't be atmospheric neutrinos ($\sigma \sim 1$ mb)

Did the muons really do it?

- Muons in Gran Sasso display modulation
  - S_{muons} ~0.015 ±0.0006 according to LVD
  - Phase (LVD): 15 July ± 15 days
- Muons strike D-L about 5 - 6 times a day
  - about 2,000,000 keV are deposited/day
  - D-L modulation signal: 3,000 keV/day
- Muons deposit ~600 times more energy

The delayed pulse hypothesis

- From St. Gobain Technical note #527 on exposure of NaI(Tl) crystals to UV:

"*With mild exposure several pulses/second can be seen in the 6-10 keV region of a spectrum*. If the crystal is stored in a dark area, this mild UV exposure will eventually disappear, although it may take from several hours to several days for the effects to stop." (Emphasis added).

Here, the manufacturer of the D-L crystals suggests that a delayed phosphorescence phenomenon can produce pulses in the approximate energy range of interest for D-L!

Plausible or implausible?

- *6 - 10 keV is not exactly the right range...*
  - but, maybe, D-L is uniquely able to see pulses below 6 keV due to extreme radiopurity.
- *Does NaI(Tl) display phosphorescence?*
  - Yes, time constants of 0.15 s to hours, days
  - NaI displays strong temperature dependence indicating thermal activation energies exist, also with non-luminescent pathways

Plausible or implausible?

- *What does UV have to do with muons?*
  - Herbert N. Hersh, *Phys. Rev.* **148(2)** (1966) p928 argues that UV, x-rays, high-energy ionizing particles have very similar production of excitons within alkali halide crystal lattice.
  - These excitons can migrate through the lattice, sometimes leading to defects and color centers
  - Muons may evoke phosphorescence.

Plausible or implausible?

- *But, how does the NaI crystal turn stored energy into pulses of light?*
  - Not clear, but not implausible
  - Excitonic migration exists, then aggregation along muonic ionization path may occur
  - Smaller pulses seem more likely than large ones
  - Worthy of attention: "...the effects of UV light to NaI have never been closely studied..." - St. Gobain, #527

Amplitude OK?

- D-L:
  - modulation amplitude of 0.0178 ± 0.0020
- LVD:
  - modulation amplitude of 0.0150 ± 0.0006 (μ)
- Icarus:
  - modulation amplitude of 4% (neutrons)
- Water content of Gran Sasso varies
- Not clear how to interpret disparities

Phase OK?

- D-L: Phase is June 2 ±7 days
- LVD: Phase is July 15 ±15 days

D-L's assertion that the discrepancy is ~6σ ignores the error quoted by LVD!

Also, the 7 day phase error is obtained only if the period is fixed in the fit; including period in the fit increases phase error by ~ 3.

Phase discrepancy appears to be less than 2.5 σ

What to do?

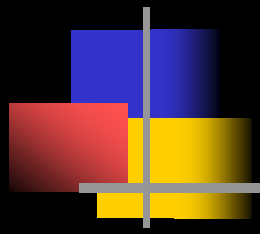
- D-L could search for space-time correlation in their data; which crystals were hit by muons, followed by a "signal event"
  - any level of correlation is a **red flag!**
- D-L could run with a substantially lower temperature, "freezing out" delayed phosphorescence effects discussed here.
  - easier than building new detector or moving

What to do?

- D-L could expose a crystal in their detector to a γ-ray source to evoke phosphorescence;
  - test could possibly disprove this hypothesis
- Others could also perform this test if their setup is sufficiently radio-pure to see 3 keV
  - underground muons at x10 level of D-L OK

Summary:

- An obligation endures to ensure that no conventional explanation can satisfy all the requirements of D-L for a WIMP signal
- The delayed pulse hypothesis may provide at least part of a conventional explanation.
- Easier to test than a completely new cycle of running or construction!



Thank you for your attention