ANOMALIES IN THE DECAY OF PARTICULAR NUCLEAR ISOTOPES

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Final Report

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Anomalous in the Decay of Particular Nuclear Isotopes

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It is extremely challenging to measure the half-life of long-lived isotopes. A USAFA-Purdue-Stanford-CCHEN collaboration has documented experiments in which small, unexplained fluctuations were found in the half-lives of select radioisotopes. Since the fluctuation was small in each case (on the order of 0.5%), the effect usually had only a relatively minor impact on the determination of the half-life. A comparison of the periodic behavior of the data from several of the experiments indicated that the periods of the primary mode of oscillation are remarkably similar. While the systematic effects are certainly possible, the group notes the anomalies are similar in nature to some experimental Dark Matter searches that may indicate new physics.

The group has gained access to daily calibration data for the IAEA’s International Monitoring System. In a surprising turn of events, the group showed many of the IMS detectors are measuring small annual oscillations in many of the same isotopes as the aforementioned.

Nuclear Decay, Periodic Variations

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Nuclear Decay, Periodic Variations

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Precision Nuclear Decay Monitoring Experiment

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Nuclear decay rates are constant?

- Many ways to perturb decay rates
  - Chemical comp, pressure, E & B field...
- Literature shows many discrepancies
  - Dark Matter Searches
  - Unexplained Periodicities (Neutrino Interactions?)

\[
\frac{dN}{dt} = -\lambda N
\]

Vaninbrouckx
Lagoutine
Schrader
Unterreger
Martin

Days

1000 2000 3000 4000 5000

Time (day)

2-6 keV

DAMA/NaI ≈ 100 kg
(0.29 ton×yr)

DAMA/LIBRA ≈ 250 kg
(0.87 ton×yr)

Measured Half-lives for \(^{134}\text{Cs}\) and \(^{109}\text{Cd}\)
CCHEN Decay Experiment: Unraveling Reports of Anomalous Decay

- Periodic Variations Reported in 25 Long-term Nuclear Decay Experiments
  - Select β & E.C. Decay Affected
  - Wide variety of detectors types
  - Few experiments run for many years; independent confirmation difficult

- Periodic Variations found in IAEA’s International Monitoring System (IMS) of precision radiodistotope detectors
  - System monitors nuclear prolif
  - Anomalies confirmed in calibration sources across network
  - Matches some anomaly reports

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Effect Observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^3$H</td>
<td>Periodicity: 1 yr$^{-1}$</td>
</tr>
<tr>
<td>$^3$H</td>
<td>Periodicity: 1/d, 12.1 yr$^{-1}$, 1 yr$^{-1}$</td>
</tr>
<tr>
<td>$^3$He</td>
<td>Periodicity: ~12.5 yr$^{-1}$</td>
</tr>
<tr>
<td>$^3$He</td>
<td>Periodicity: ~2 yr$^{-1}$</td>
</tr>
<tr>
<td>$^{22}$Na/$^{44}$Ti[a]</td>
<td>Periodicity: 1 yr$^{-1}$</td>
</tr>
<tr>
<td>$^{36}$Cl</td>
<td>Periodicity: 1 yr$^{-1}$, 11.7 yr$^{-1}$, 2.1 yr$^{-1}$</td>
</tr>
<tr>
<td>$^{36}$Cl</td>
<td>Periodicity: 1 yr$^{-1}$</td>
</tr>
<tr>
<td>$^{54}$Mn</td>
<td>Periodicity: 1 yr$^{-1}$</td>
</tr>
<tr>
<td>$^{56}$Mn</td>
<td>Periodicity: 1 yr$^{-1}$</td>
</tr>
<tr>
<td>$^{60}$Co</td>
<td>Periodicity: 1 yr$^{-1}$</td>
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<tr>
<td>$^{60}$Co</td>
<td>Periodicity: 1/d, 12.1 yr$^{-1}$</td>
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<tr>
<td>$^{85}$Kr</td>
<td>Periodicity: 1 yr$^{-1}$</td>
</tr>
<tr>
<td>$^{90}$Sr/$^{90}$Y</td>
<td>Periodicity: 1 yr$^{-1}$, 11.7 yr$^{-1}$</td>
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<tr>
<td>$^{108}$mAg</td>
<td>Periodicity: 1 yr$^{-1}$</td>
</tr>
<tr>
<td>$^{133}$Ba</td>
<td>Periodicity: 1 yr$^{-1}$</td>
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<tr>
<td>$^{137}$Cs</td>
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<td>$^{152}$Eu</td>
<td>Periodicity: 1 yr$^{-1}$</td>
</tr>
<tr>
<td>$^{154}$Eu</td>
<td>Periodicity: 1 yr$^{-1}$</td>
</tr>
<tr>
<td>$^{222}$Rn[c]</td>
<td>Periodicity: 1 yr$^{-1}$, 11.7 yr$^{-1}$, 2.1 yr$^{-1}$</td>
</tr>
<tr>
<td>$^{226}$Ra[c]</td>
<td>Periodicity: 1 yr$^{-1}$, 11.7 yr$^{-1}$, 2.1 yr$^{-1}$</td>
</tr>
<tr>
<td>$^{239}$Pu</td>
<td>Periodicity: 1/d, 13.5 yr$^{-1}$, 1 yr$^{-1}$</td>
</tr>
</tbody>
</table>

Prominent 1yr & 28da Periodicities

Studying this phenomena is of practical as well as scientific value...
CCHEN Decay Experiment: Present Status

Mimic IMS Calibration Measurements but at Higher Data Rates & Longer Integration Times

Variety of Detectors & Sources
- $^{54}\text{Mn}$, $^{36}\text{Cl}$, $^{90}\text{Sr}$, $^{32}\text{Si}$
- Empty Detectors as Control
- Monitor Environmental Variables (TPH)

Coordinated w/ 4 Additional Sites
- CCHEN (Santiago, Chile)
- US Air Force Academy
- Purdue University
- Brigham Young University

Now Completing Final Report

Six Detector Array: 4 Isotopes + 2 Empty

First 12 Months of Data Show Oscillations in Several Detectors
Analysis Methodology

1) Determination of Residuals from Fit

2) Spectral Analysis (modified Lomb-Scargle)

3) Significance Estimates (Shuffle Test)
Recent Results

Analysis is well underway with focus on cross-comparisons between locations and autocorrelation with environmental factors (phase is complicated!)

Preliminary Results Indicate Phase Shifts Between Locations...
Recent Results

- Oscillations have different phase than TPH measurements
  - Possibly a lag in NaI(d) response
- Empty detector shows null response
- No corresponding oscillations in GM Detectors

Preliminary Results Indicate Several Non-Random Secondary Peaks...
## Transition Approach

### Direct Beneficiaries

**Time-Series Analysis of Nuclear Decay Residuals Boosts Measurement Capabilities and Diagnostic Power**

- Comprehensive Test Ban Treaty Org. (CTBTO)
- AFTAC
- DTRA
- MDA
- Laboratori Nazionali del Gran Sasso
- Other Gov’t Agencies

### Papers / Presentations

- **10 Peer-Reviewed Papers (2012-14)**
  - *Power-Spectrum Analysis of Reconstructed DAMA Data*. In Review. 2014

- + 5 Recent Conference Presentations
- + Invited Book Chapter

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*Adoption of Methodology and Approach Is Growing Rapidly!*