Indications of an unexpected signal associated with the GW170817 binary neutron star inspiral

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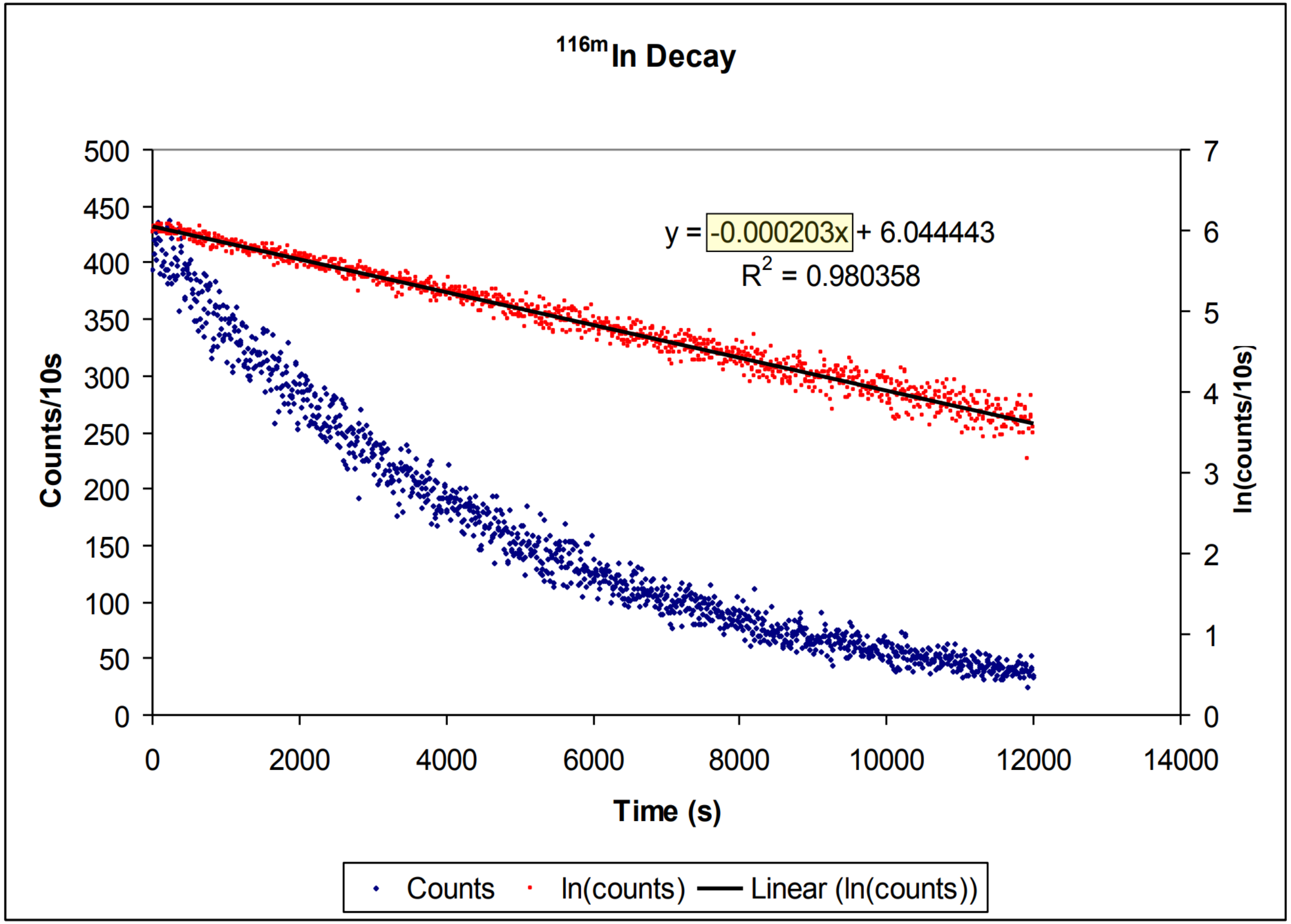
Ephraim Fischbach, Virtual Institute of Astroparticle physics (VIA) invited talk 9 February 2018

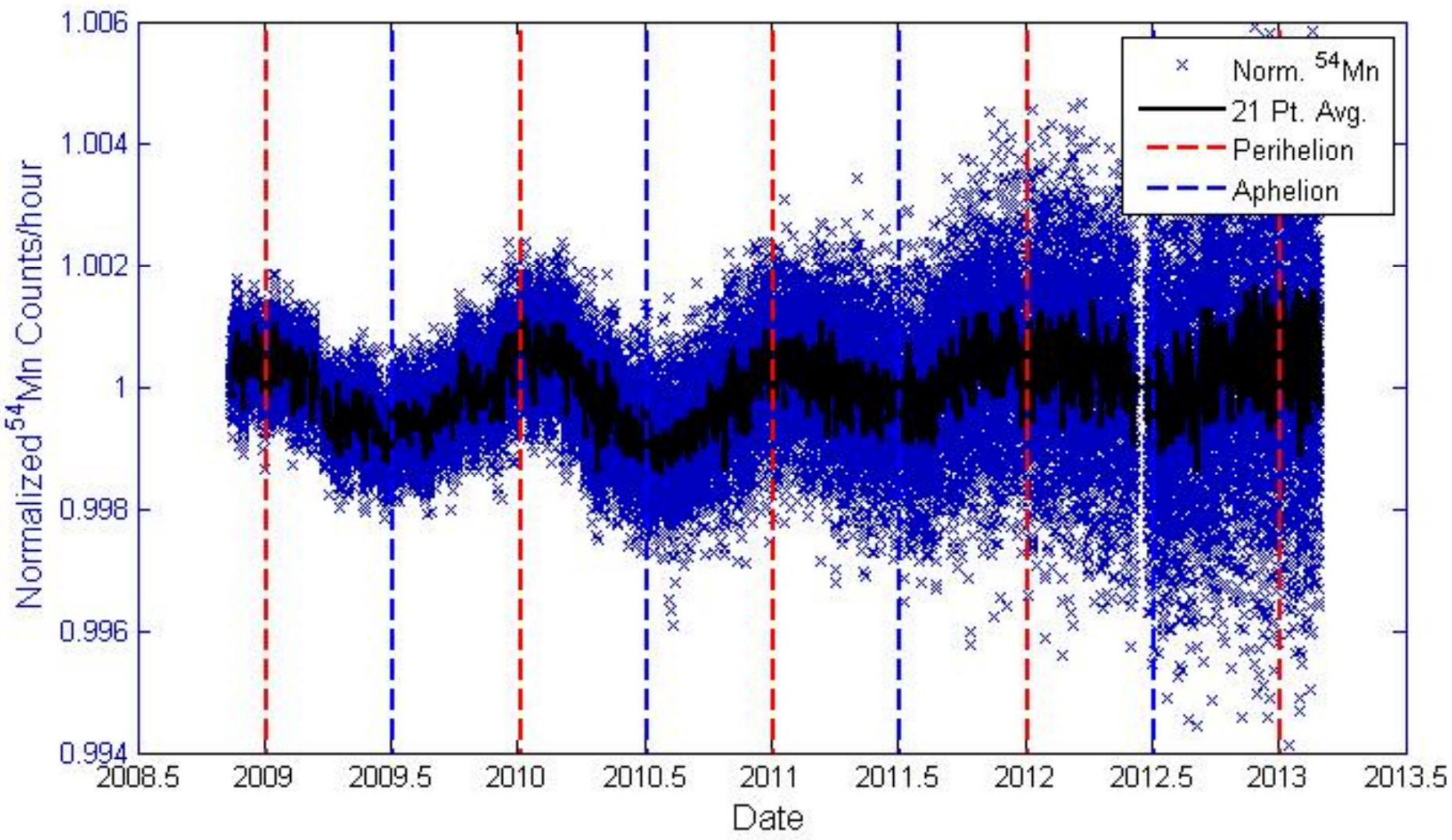
OUTLINE

- Historical Introduction
  - Time-varying nuclear decays
  - Correlation to solar storms
- Description of Si/Cl experiment
  - Apparatus
  - Experimental results
- Data From the Binary Neutron Star Inspiral
  - Raw data
  - Statistical tests
- Two Puzzles
  - Neutrino Fluence
  - Precursor Signal
- Conclusions

Decay Data over Short Time Intervals



^{54}Mn Decays 2008-2013



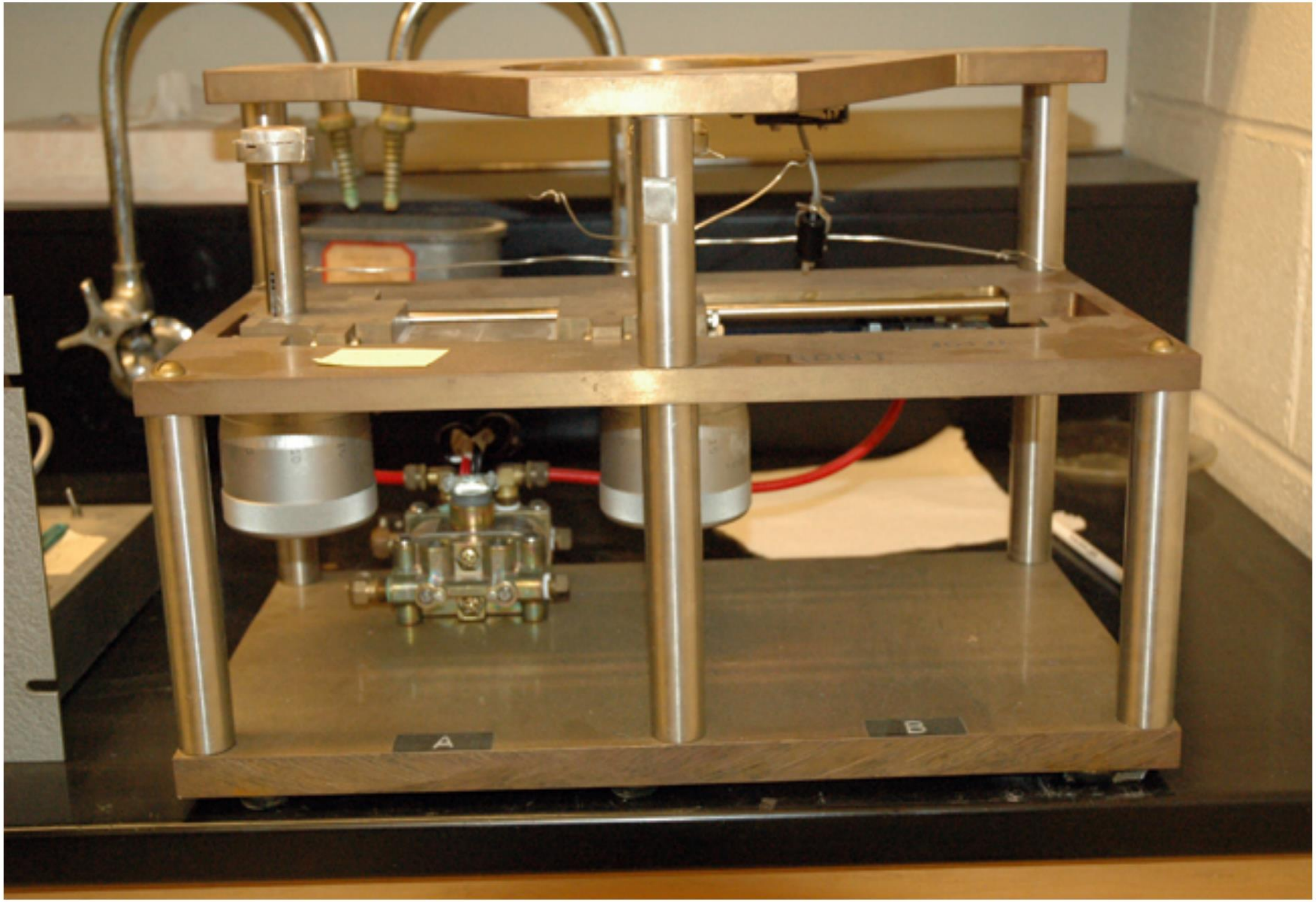
Brookhaven National Laboratory

Measurement of ^{32}Si Half-life

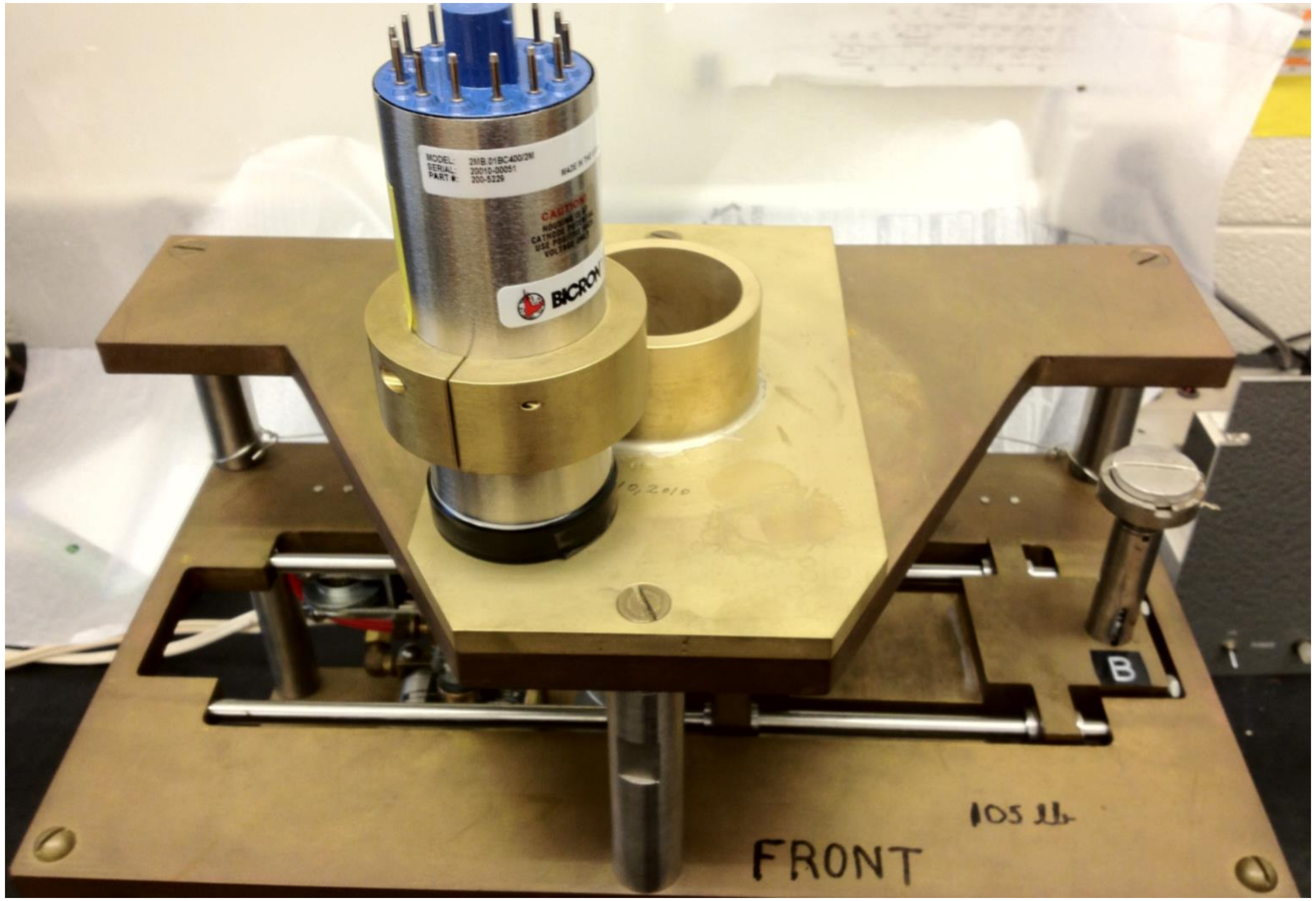
David Alburger

Garman Harbottle

Eleanor Norton


A
B

- The BNL apparatus for measuring the decay rates of Si-32 and Cl-36. Shown is pedestal B on which the Si-32 sample is placed, the Bicron plastic scintillation detector, and the collar to keep the detector rigidly in place. In the configuration shown, the Cl-36 sample (hidden) would be directly under the detector. The samples are driven along the track rails in the foreground by a pneumatic system which places each in turn under the detector. See text for further details



- Interior view of BNL apparatus

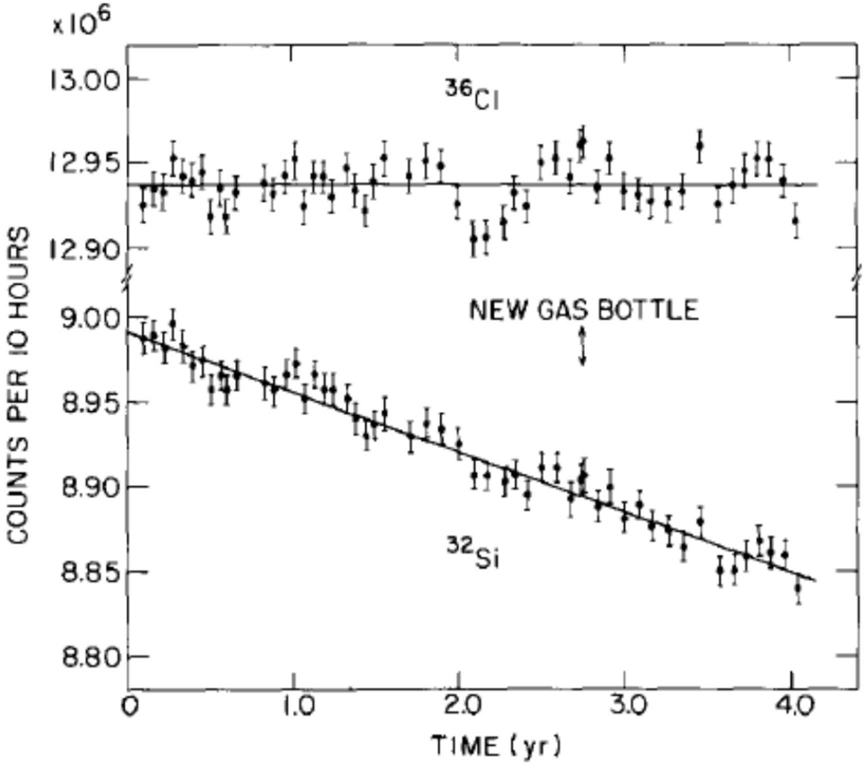


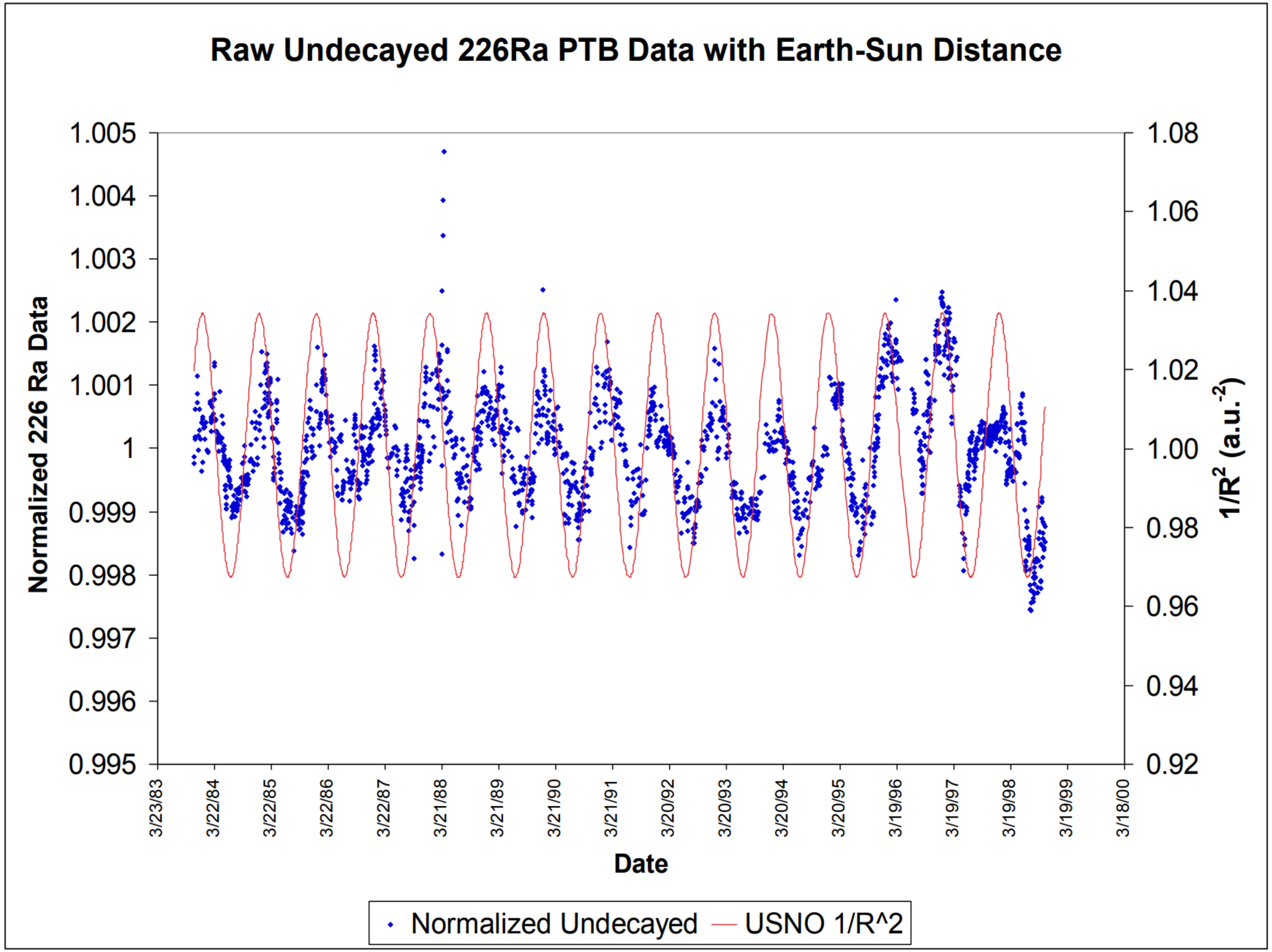
Fig. 3. Lower part, ^{32}Si singles counting rate measured over a period of 48 months; upper part, corresponding ^{36}Cl singles counting rate. Points are counts per 10 hr on each sample, averaged from 4 runs. Error bars are (arbitrarily) three times the statistical uncertainties. The solid curve shown for ^{32}Si is an exponential computer fit, although the ordinate is linear for convenience in plotting. The upper horizontal line is the average of all ^{36}Cl points. The results of the fit to the ^{32}Si data are $T_{1/2} = 173.8$ yr with an uncertainty of 4.8 yr and a standard deviation of 1.7 yr.

D.E. Alburger, G. Harbottle, E.F. Norton, Earth and Planetary Science Letters 78 (1986) 168.

Physikalisch-Technische Bundesanstalt (PTB)

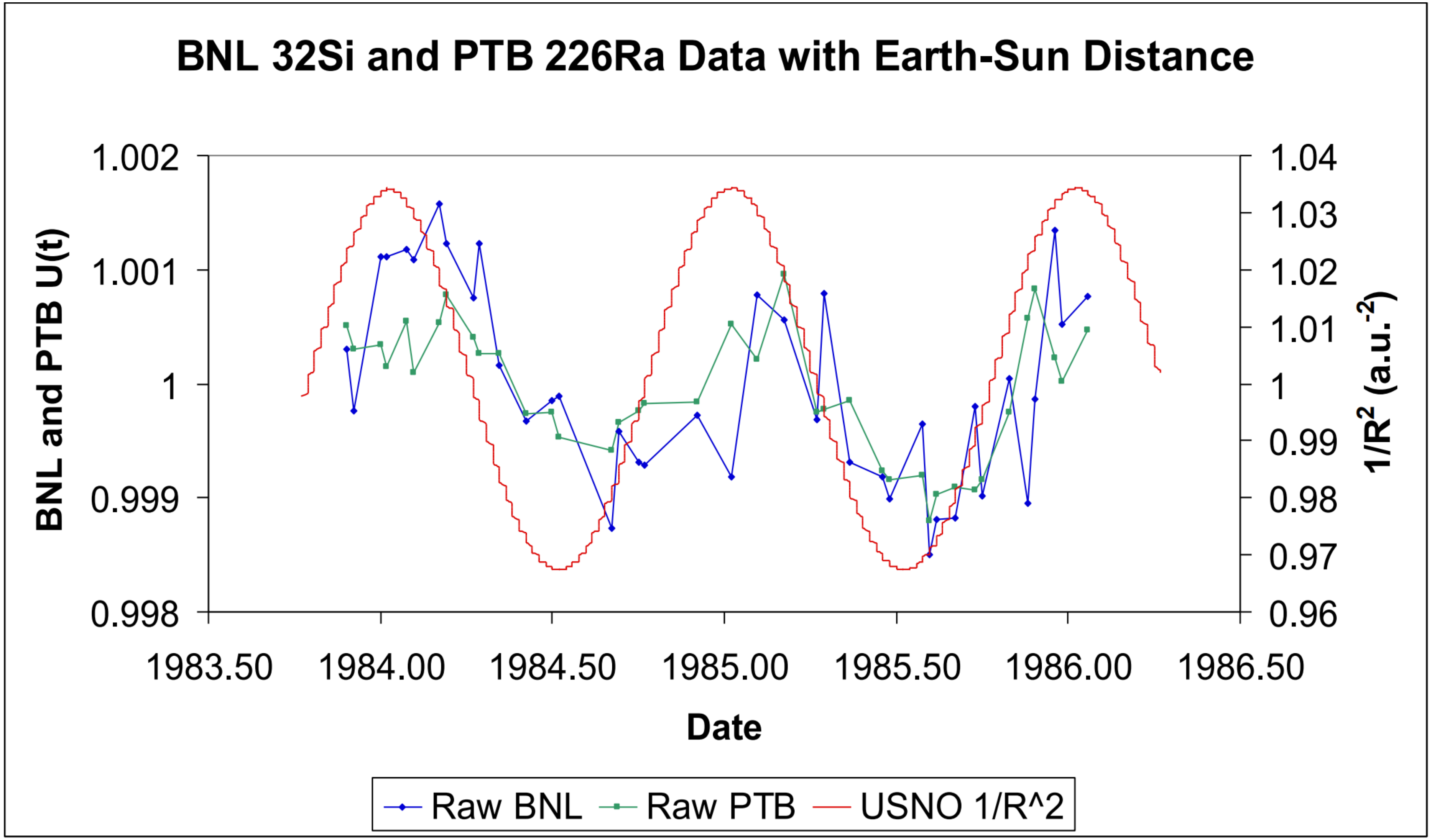
Europium Half-lives and Long Term Detector Stability

Helmut Siegert
Heinrich Schrader
Ulrich Schoetzig



Pearson Correlation Coefficient r=0.62, N=1974, Prob=5.13×10^{-210}

Data from Siegert, et al., Appl. Radiat. Isot. **49**, 1397 (1998) Fig. 1



Pearson Correlation Coefficient *r*=0.66, *N*=39, Prob=5.8x10^{-6}

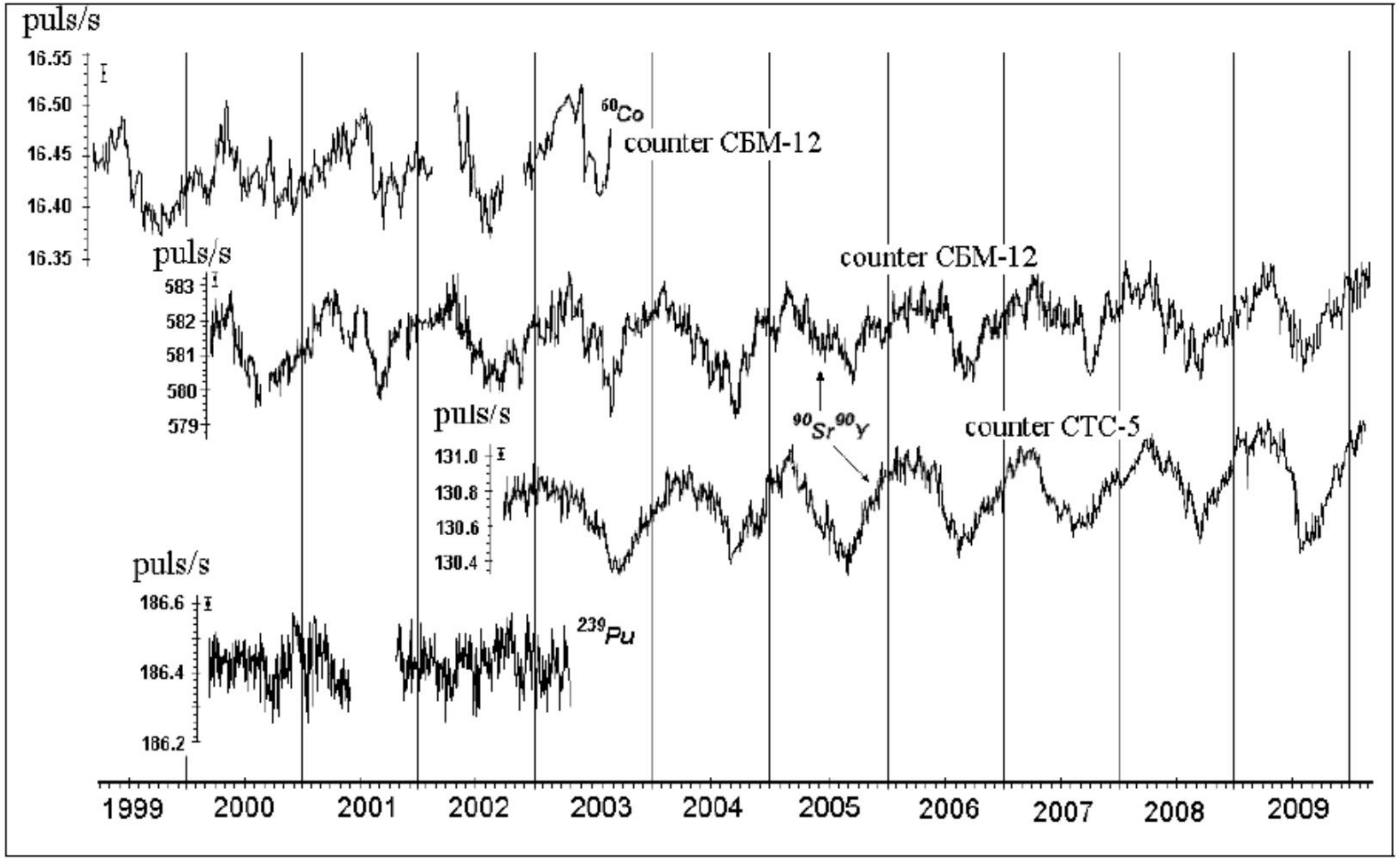
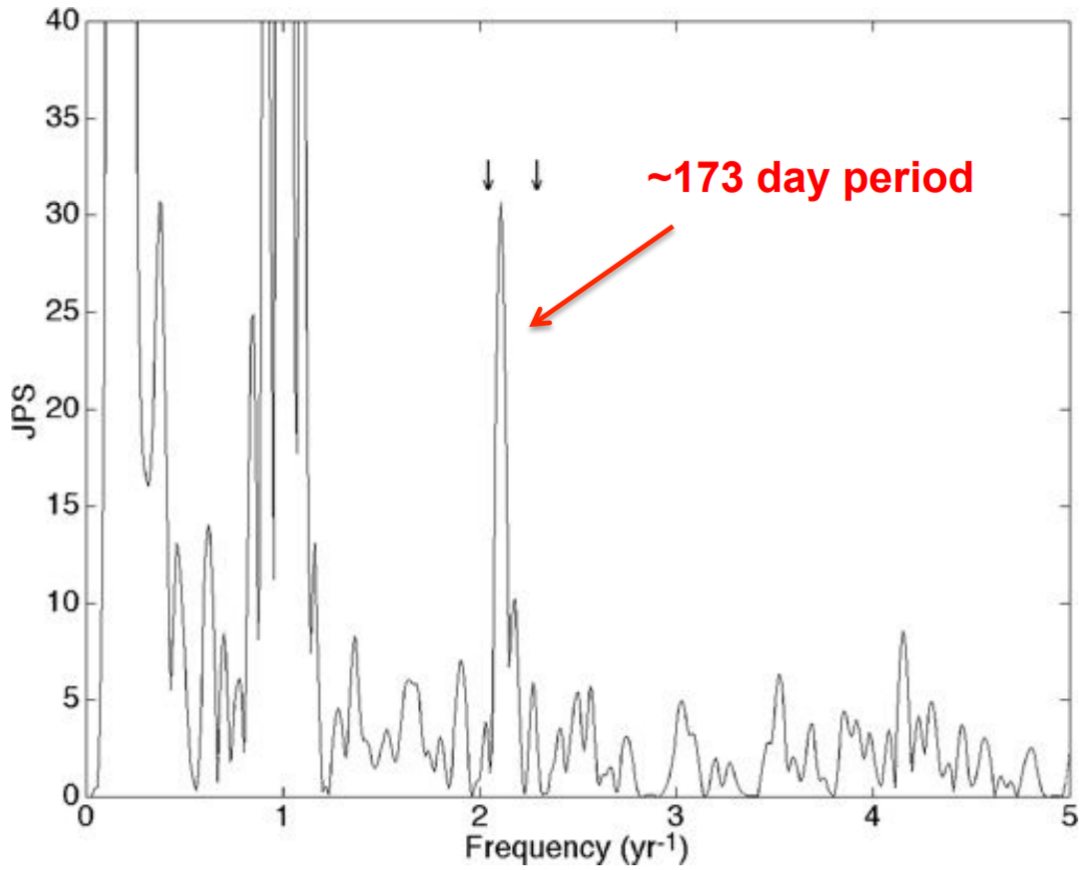


Fig. 1. Count rate of the ^{60}Co and ^{90}Sr-^{90}Y β sources, measured by G-M counters, adjusted for a drop of activity with half-lifes 5,27 and 28,6 years, and count rate of the ^{239}Pu α source, measured by the silicon detector [3, 5].

Parkhomov, A.G., Researches of alpha and beta radioactivity at long-term observations, arXiv:1004.1761v1 [physics.gen-ph], (2010)

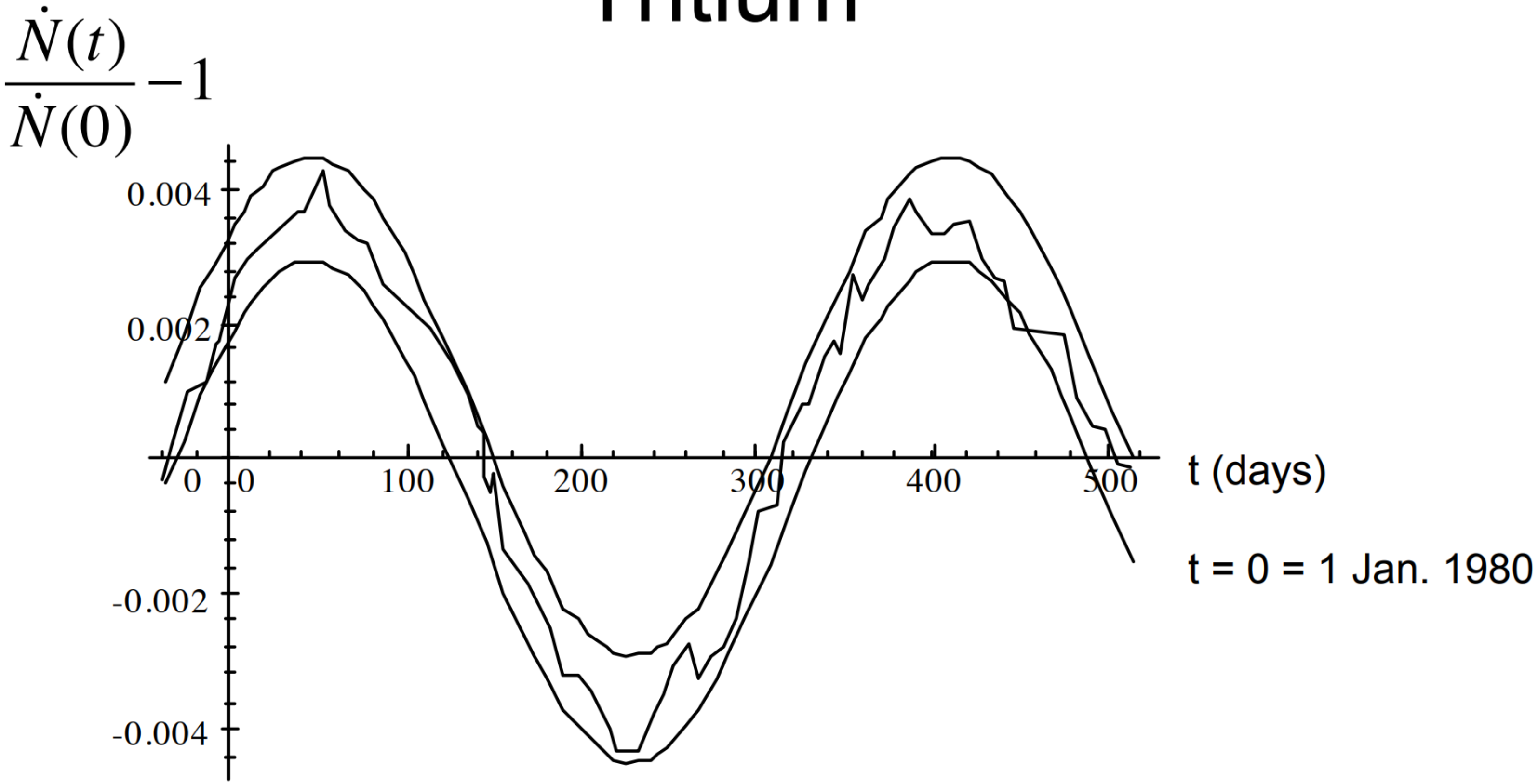
Evidence for a Rieger Periodicity: Joint Power Statistic from BNL/PTB Data

Figure 3 The joint power statistic formed from the BNL and PTB power spectra. The arrows indicate the search band 2.02 year^{-1} to 2.28 year^{-1}. The peak is found at $2.107 \pm 0.005\ \text{year}^{-1}$ with joint power statistic $J = 30.65$.



Reference: P. A. Sturrock, E. Fischbach, J. H. Jenkins, Solar Physics, **272**, 1 (2011)

Tritium



$$\text{Amplitude}(t) = (0.37\%)\cos\left(\frac{2\pi t}{1\ \text{year}} - \phi\right) \qquad \phi \sim \text{ Feb. 15}$$

Reference: E. D. Falkenberg, Apeiron **8** (2), 32 (2001)

Experiments Exhibiting Time-Dependent Decay Parameters

Astrophys Space Sci (2013) 344:297–303 301

Table 2 Some experiments where time-dependent decay rates have been observed

Isotope	Decay type	Detector type	Radiation measured	Reference
^{3}H	β^-	Photodiodes	β^-	Falkenberg (2001)
^{3}H	β^-	Liq. Scint.	β^-	Shnoll et al. (1998a, 1998b)
^{3}H	β^-	Liq. Scint.	β^-	Veprev and Muromtsev (2012)
^{3}H	β^-	Sol. St. (Si)	β^-	Lobashev et al. (1999)
^{22}Na/^{44}Ti[a]	β^+, κ	Solid State (Ge)	γ	Norman et al. (2009) and this article
^{36}Cl	β^-	Proportional	β^-	Jenkins et al. (2009); Sturrock et al. (2010a, 2011a)
^{36}Cl	β^-	Geiger-Müller	β^-	Jenkins et al. (2012a)
^{54}Mn	κ	Scint.	γ	Jenkins and Fischbach (2009)
^{54}Mn	κ	Scint.	γ	Jenkins et al. (2011)
^{56}Mn	β^-	Scint.	γ	Ellis (1990)
^{60}Co	β^-	Geiger-Müller	β^-,γ	Parkhomov (2010b, 2010a)
^{60}Co	β^-	Scint.	γ	Baurov et al. (2007)
^{85}Kr	β^-	Ion Chamber	γ	Schrader (2010)
^{90}Sr/^{90}Y	β^-	Geiger-Müller	β^-	Parkhomov (2010b, 2010a; Sturrock et al. (2012b)
^{108m}Ag	κ	Ion Chamber	γ	Schrader (2010)
^{133}Ba	β^-	Ion Chamber	γ	Jenkins et al. (2012b)
^{137}Cs	β^-	Scint.	γ	Baurov et al. (2007)
^{152}Eu	β^-, κ	Sol. St. (Ge)	γ[b]	Siegert et al. (1998)
^{152}Eu	β^-, κ	Ion Chamber	γ	Schrader (2010)
^{154}Eu	β^-, κ	Ion Chamber	γ	Schrader (2010)
^{222}Rn[c]	α, β^-	Scint.	γ	Steinitz et al. (2011); Sturrock et al. (2012a)
^{226}Ra[c]	α, β^-	Ion Chamber	γ	Jenkins et al. (2009); Sturrock et al. (2010b, 2011a)
^{239}Pu	β^-	Sol. St.	α	Shnoll et al. (1998a, 1998b)

Solar Flare Forces Shuttle Astronauts to Seek Shelter From Radiation

Wednesday, December 13, 2006

FOX NEWS

Astronauts scampered to shielded areas of the international space station and space shuttle Discovery Tuesday night to protect themselves from possibly being exposed to high levels of radiation from an unusually large solar flare, NASA said.

Activity aboard Discovery and the space station was interrupted when the solar flare erupted late Tuesday, as two astronauts were finishing the first spacewalk of the current shuttle mission.

Space.com categorized it as an X-3 flare, in the most dangerous category. Such storms are fairly common when the Sun is at its most active, but they are rare during the current low point in the 11-year cycle of solar activity.

• Click here to visit FOXNews.com's Space Center.

NASA spokesman Bill Jeffs told FOXNews.com that crew members slept overnight in "heavily shielded areas" of their respective craft — such as airlocks and the Destiny science lab aboard the space station — as a precautionary measure.

"That move was made to avoid having to wake the crew during their sleep period," NASA spokesman John Ira Petty told Space.com. "It was never a danger to the crew."

Astronauts Rewire the Space Station

Thursday, December 14, 2006

By MIKE SCHNEIDER, Associated Press Writer

CAPE CANAVERAL, Fla. — Two spacewalking astronauts

Severe Geomagnetic Storm Expected From Tuesday's Solar Flare

Thursday , December 14, 2006

By Robert Roy Britt

SPACE.com

Space weather forecasters revised their predictions for storminess Wednesday after a major flare erupted on the Sun overnight, threatening damage to communication systems and power grids while offering up the wonder of the Northern Lights.

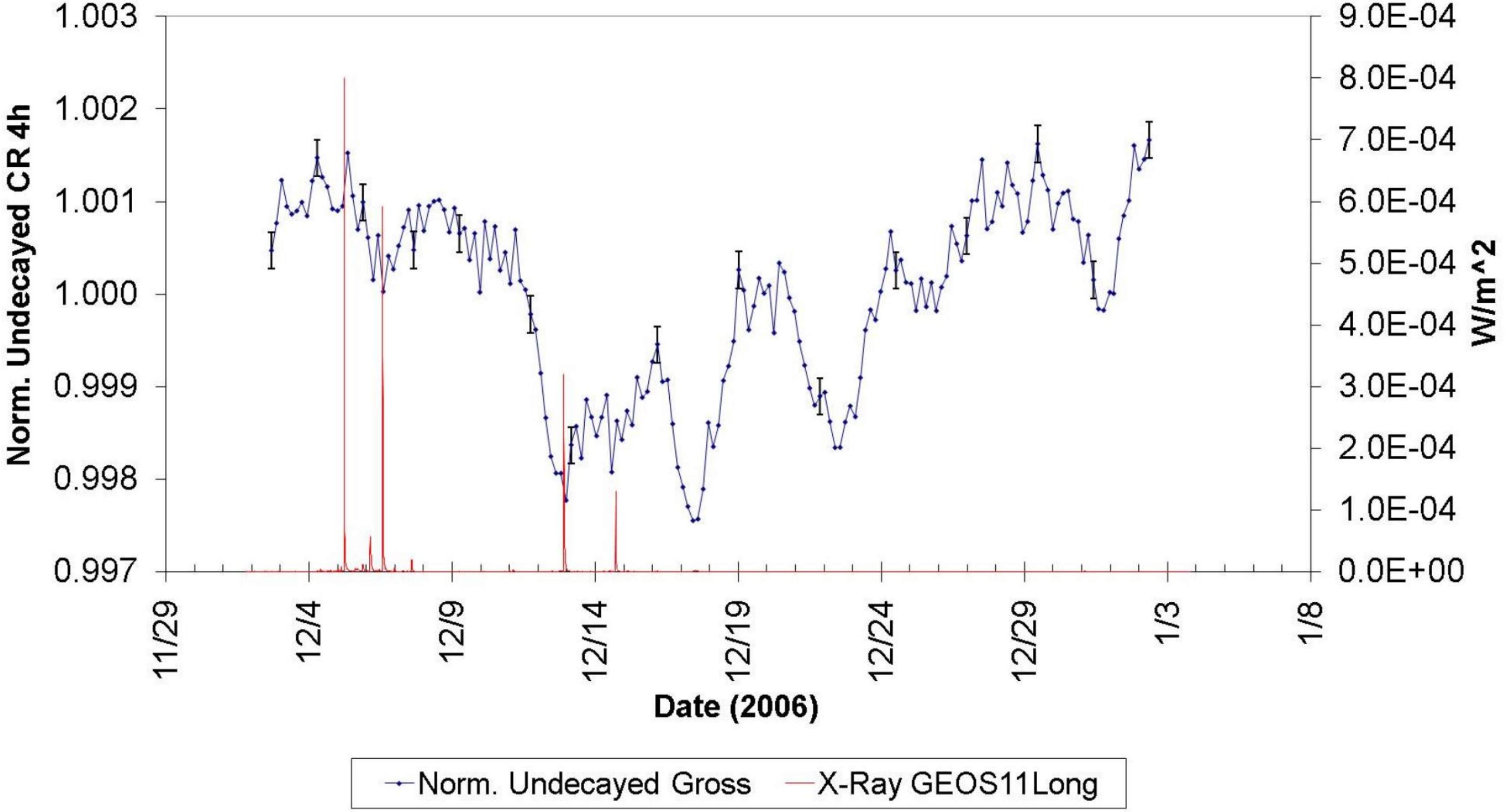
"We're looking for very strong, severe geomagnetic storming" to begin probably around mid-day Thursday, Joe Kunches, lead forecaster at the NOAA Space Environment Center, told SPACE.com.

The storm is expected to generate aurora or Northern Lights as far south as the northern United States Thursday night.

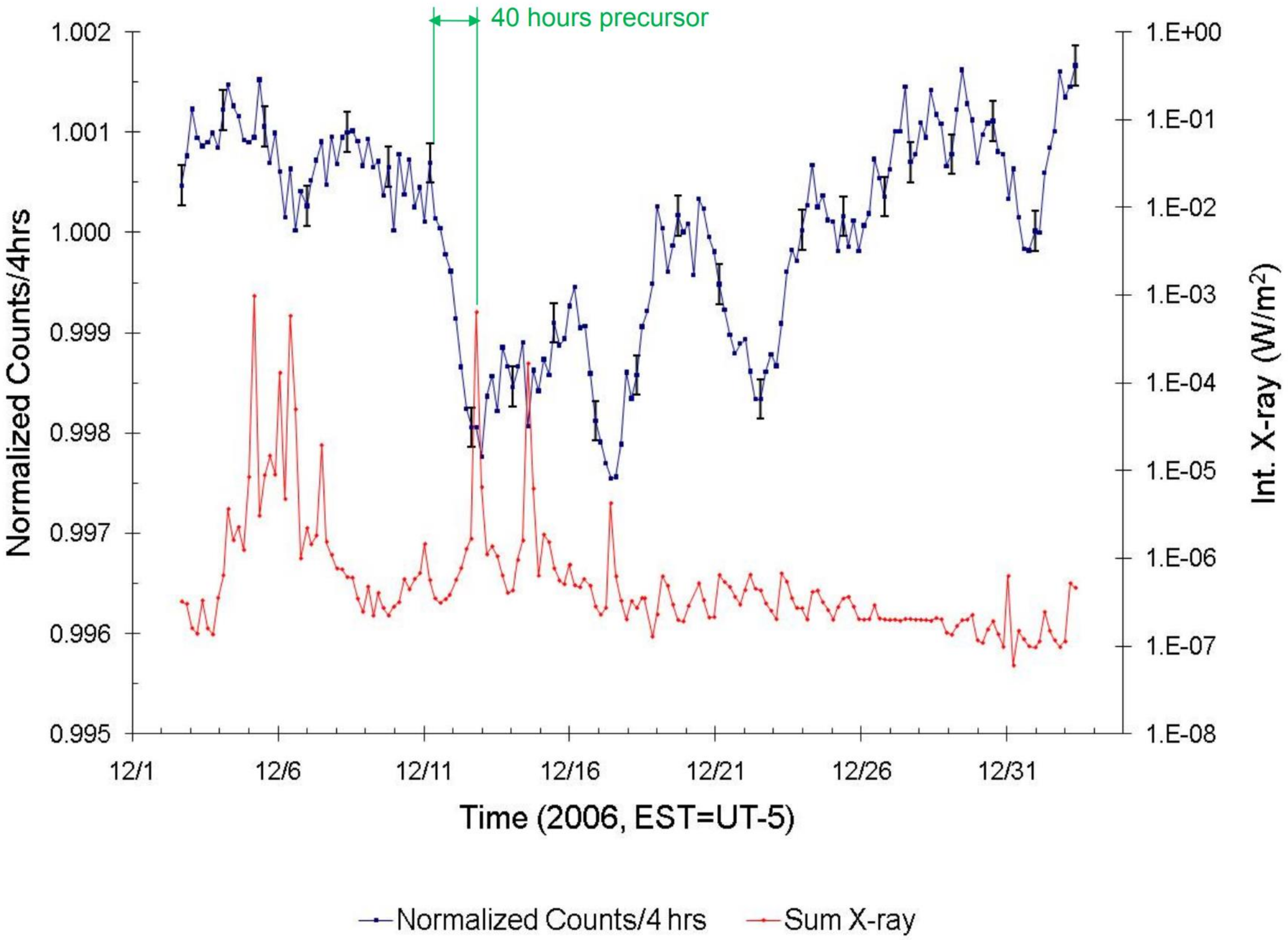
• Click here to visit FOXNews.com's Space Center.

Astronauts aboard the International Space Station are not expected to be put at additional risk, Kunches said.

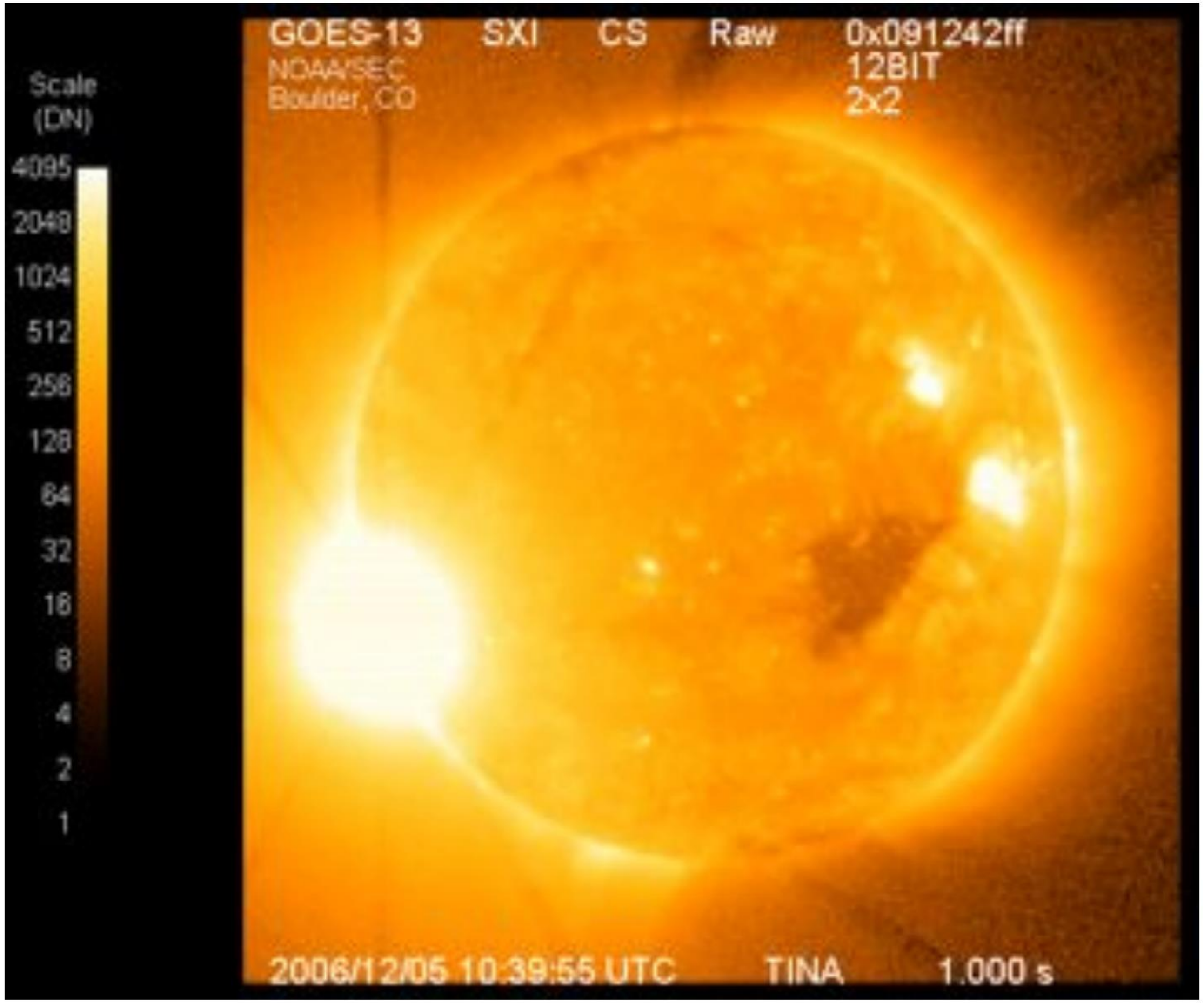
Physics 167 Mn-54 Consecutive 4 hr Counts Normalized with Linear GEOS11 x-ray Data



December ^{54}Mn Decay Data with Integral GOES-11 X-rays



5 Dec 2006: X-9 class flare



Evidence for correlations between fluctuations in ^{54}Mn decay rates and solar storms

Astroparticle Physics 75 (2016) 29–37

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Astroparticle Physics

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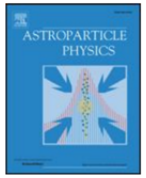

Evidence for correlations between fluctuations in ^{54}Mn decay rates and solar storms

CrossMark

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ARTICLE INFO

Article history:
Received 20 January 2015
Accepted 16 October 2015
Available online 6 November 2015

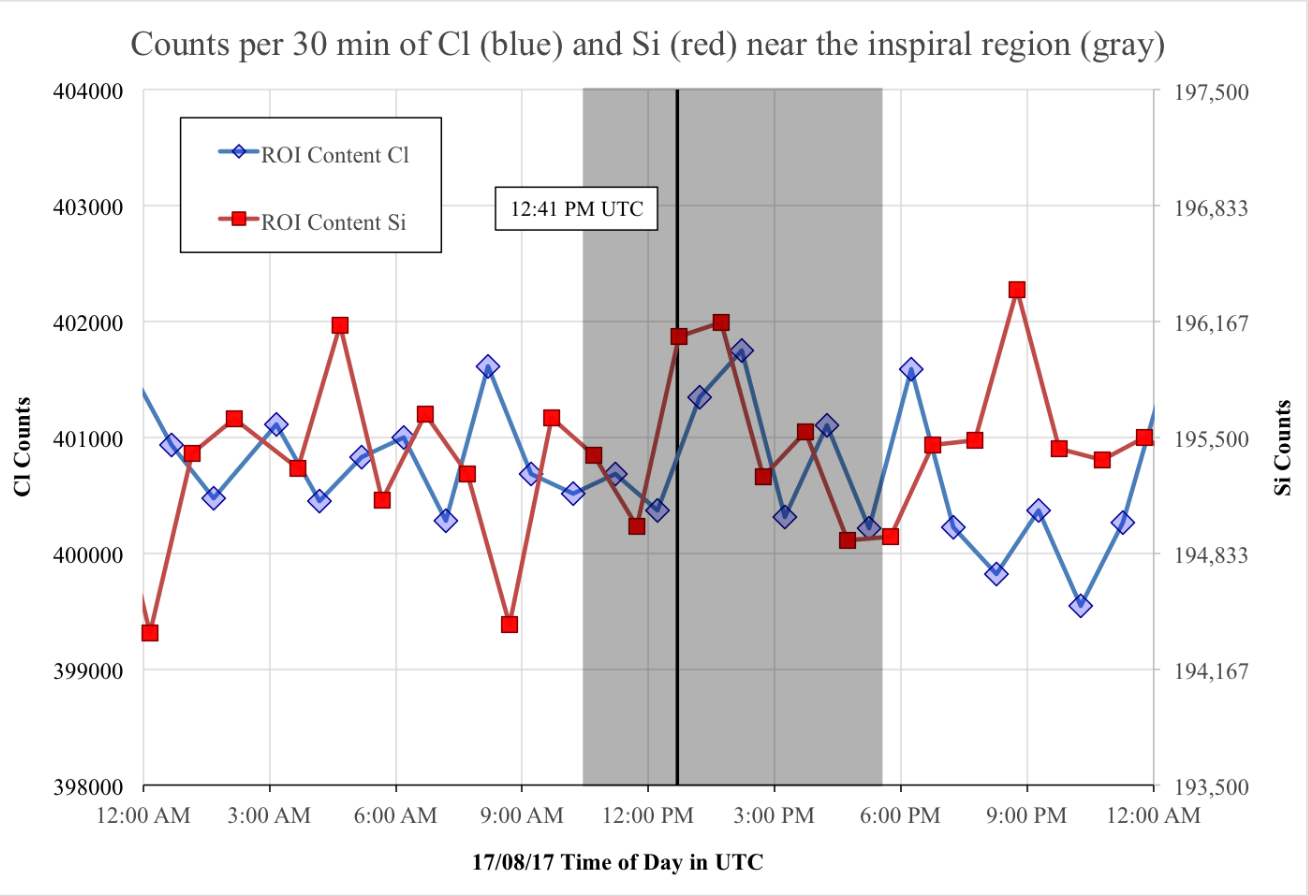
Keywords:
Beta decay
Decay rate fluctuations
Solar flares

ABSTRACT

Following recent indications that several radioactive isotopes show fluctuating decay rates which may be influenced by solar activity, we present findings from a 2 year period of data collection on ^{54}Mn. Measurements were recorded hourly from a 1 μCi sample of ^{54}Mn monitored from January 2010–December 2011. A series of signal-detection algorithms determine regions of statistically significant fluctuations in decay behaviour from the expected exponential form. The 239 decay flags identified during this interval were compared to daily distributions of multiple solar indices, generated by NOAA, which are associated with heightened solar activity. The indices were filtered to provide a list of the 413 strongest events during a coincident period. We find that 49% of the strongest solar events are preceded by at least 1 decay flag within a 48 h interval, and 37% of decay flags are followed by a reported solar event within 48 h. These results are significant at the 0.9σ and 2.8σ levels respectively, based on a comparison to results obtained from a shuffle test, in which the decay measurements were randomly shuffled in time 10,000 times. We also present results from a simulation combining constructed data reflecting 10 sites which compared and filtered decay flags generated from all sites. The results indicate a potential 35% reduction in the false positive rate in going from 1 to 10 sites. By implication, the improved statistics attest to the benefit of analysing data from a larger number of geographically distributed sites in parallel.

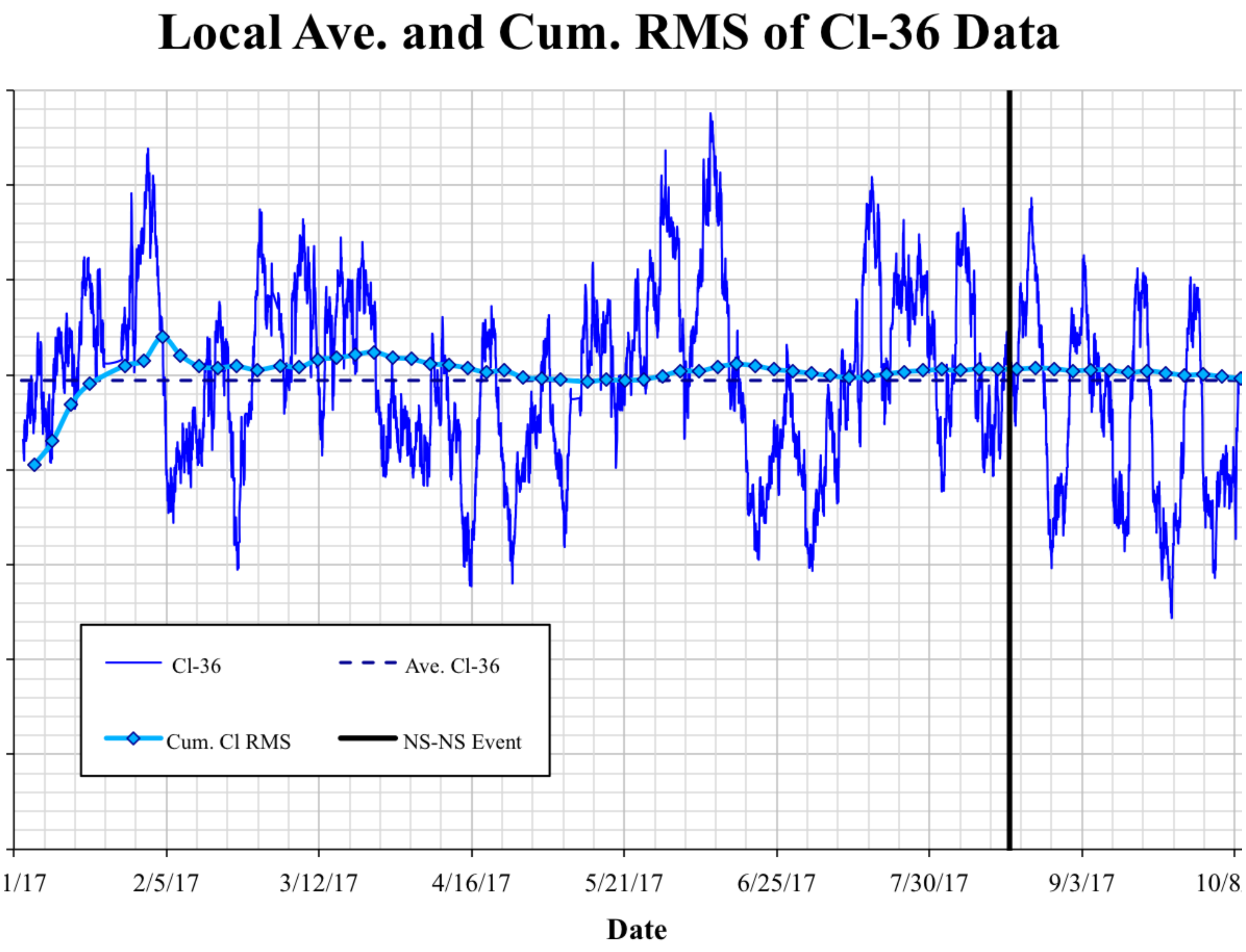
Mini-Review

1. Evidence for a solar influence on nuclear decays comes from the following observations:
   a. Solar flare data of 13 December 2006 and 16 December 2008
   b. Annual variation in nuclear decay rates of a variety of different isotopes measured by a variety of different techniques
   c. Evidence of ~30-day periodicity attributable to solar rotation
   d. Evidence of a ~173-day Rieger periodicity attributable to solar rotation
2. Known seasonally environmental influences do not appear to be capable of explaining these data
3. There is as yet no known theoretical mechanism to explain these data although indications point toward neutrinos with a modified dispersion relation possibly due to a medium.



- Si-32 and Cl-36 count rates during August 2017. The scales on the respective vertical axes are arbitrary, and do not affect the determination of correlations between the decay rates. The shaded gray region encompasses 7 pairs of Si-32/Cl-36 counts which our analysis suggests are highly correlated, and the dark vertical line at 12:41 UTC on 17 August 2017 denotes the GW170817 gravity wave's time of arrival.

- The local average and cumulative root-mean-square (RMS) fluctuations of the 2017 Cl-36 decay data for the period 1 January through 11 October. Each of the 6,438 points represented in the figure is the 101 point rolling RMS average deviation from the mean, including that point and the 50 earlier and later points. The horizontal dashed line denotes the average number of counts for the entire data set, where $\overline{N} = 400,864$ and $\sqrt{\overline{N}} = 632$. Also shown are both the individual RMS values, whose average is 649, and the cumulative RMS values as a function of time. See text for further details.



- Pearson correlation coefficients r relating the Si-32 and Cl-36 data sets for time intervals during the period 1 January - 11 October 2017. The 5-hour region is the period to the right of the vertical black line in the shaded area of Figure 2 denoting the arrival of the NS-NS inspiral gravity wave. The designation (right-shifted) refers to the Si-32 data which have been shifted to the right (later) by 30 minutes, so as to align with the Cl-36 data. The 7-hour region encompasses the entire shaded area in Fig. 2. See text for further details.

Intervals of 5 Cl-Si Pair Measurements (right-shifted)	
Region of Interest	Pearson Coefficient r
NS-NS Inspiral	0.94993
2017 Calendar to 11 Oct	0.02526
2017 w/o Inspiral	0.02516

Intervals of 5 Cl-Si Pair Measurements (left-shifted)	
Region of Interest	Pearson Coefficient r
NS-NS Inspiral	0.28341
2017 Calendar to 11 Oct	0.03733
2017 w/o Inspiral	0.03729

Intervals of 7 Cl-Si Pair Measurements (right-shifted)	
Region of Interest	Pearson Coefficient r
NS-NS Inspiral	0.95383
2017 Calendar to 11 Oct	0.02526
2017 w/o Inspiral	0.02502

Intervals of 7 Cl-Si Pair Measurements (left-shifted)	
Region of Interest	Pearson Coefficient r
NS-NS Inspiral	0.05919
2017 Calendar to 11 Oct	0.03733
2017 w/o Inspiral	0.03729

If we were to further assume that E_x, the energy of the emitted neutrinos, or neutrino-like particles "neutrellos" [21], is $E_x \simeq 10$ MeV, we then find from Eq. (2),

$$m_x < 16 \text{ eV}. \tag{3}$$

We note from Eq. (1) that the ~ 5 hour spread in the arrival times of whatever particles might be responsible for the observed features may be attributable in part to a spread in the energies E_x in Eq. (1). This energy spread could arise in part from the scattering of the emitted particles leaving the binary. Furthermore, if these particles are in fact neutrinos, or neutrino-like "neutrellos" [21], then the expected flavor oscillations could also somewhat broaden the spread of arrival times compared to that of the gravity signal.

The result for m_x in Eq. (3) is larger than the limits inferred in several scenarios for the presumed neutrino mass eigenstates m_1, m_2, and m_3. These are derived from neutrino oscillation data combined with limits on the mass of $\bar{\nu}_e$ from tritium β-decay, $m(\bar{\nu}_e) \lesssim 2$ eV [22]:

$$\text{Normal Hierarchy: } m_1 \ll m_2 < m_3 : m_2 \simeq 0.0087 \text{ eV}; m_3 \simeq 0.05 \text{ eV}, \tag{4}$$

$$\text{Inverted Hierarchy: } m_3 \ll m_1 < m_2 : m_{1,2} \simeq 0.049 \text{ eV}, \tag{5}$$

$$\text{Quasi-degenerate: } m_1 \simeq m_2 \simeq m_3 \geq 0.1 \text{ eV}. \tag{6}$$

Even the largest result Eq. (6), which is compatible with the limit $m_\nu \geq 0.4$ eV derived from the stability of neutron stars and white dwarfs [23], would lead to a neutrino mass limit smaller than that obtained for m_x in Eq. (3). However, if we were to assume that $E_x \simeq 1$ MeV in Eq. (2), which is the characteristic neutrino energy in neutron β-decay, we would find $m_x \simeq (1.6 \pm 0.3)$ eV, which could be compatible with existing neutrino data in models involving sterile neutrinos. Additionally, taking into account the earliest part of the signal further reduces the mass estimate.

Robert Ehrlich[1]
[1] *George Mason University, Fairfax, VA 22030**
(Dated: January 9, 2018)

According to conventional wisdom the 5-hour early Mont Blanc burst probably was not associated with SN 1987A, but if it was genuine, some exotic physics explanation had to be responsible. Here we consider one truly exotic explanation, namely faster-than-light neutrinos having $m_\nu^2 = -0.38$ keV^2. It is shown that the Mont Blanc burst is consistent with the distinctive signature of that explanation i.e., an 8 MeV antineutrino line from SN 1987A. It is further shown that a model of core collapse supernovae involving dark matter particles of mass 8 MeV would in fact yield just such an 8 MeV neutrino line. Moreover, the dark matter model fits the observed spectrum of MeV gamma rays from the galactic center, a place where one would expect large amounts of dark matter to collect. Thus, a fit to those data yields the model's dark matter mass, as well as the calculated source temperature and angular size, thereby supporting the existence of an 8 MeV antineutrino line from SN 1987A. Further support comes from the spectrum of $N \sim 1000$ events recorded by the Kamiokande-II detector on the day of SN 1987A, which appear to show an 8 MeV line atop the detector background. This $\bar{\nu}$ line, if genuine, has been well-hidden for 30 years because it occurs very close to the peak of the background. While this fact might ordinarily justify extreme skepticism, this disbelief should be tempered by (a) the very high statistical significance of the result (30σ), (b) the use of a detector background independent of the SN 1987A data, and (c) the prediction of the 8 MeV $\bar{\nu}$ line (based on the Mont Blanc data and the dark matter model) being made *before* its observation in the K-II data. Lastly, it is noted that the tachyonic interpretation of the Mont Blanc burst fits the author's earlier unconventional $3+3$ model of the neutrino mass states, and that results from the KATRIN experiment should prove or reject that model in a short data-taking period.

keywords: neutrino mass, SN 1987A, supernova, dark matter, galactic center, tachyon, KATRIN

PACS numbers:

- Graph of our Cl-36 decay data overlapped with solar activity indicated by the number of sunspots