The Case for a Solar Influence on Certain Nuclear Decay Rates

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in collaboration with Ephraim Fischbach (Purdue U.),
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S1207A01

Experiments Exhibiting Variable Decay Rates

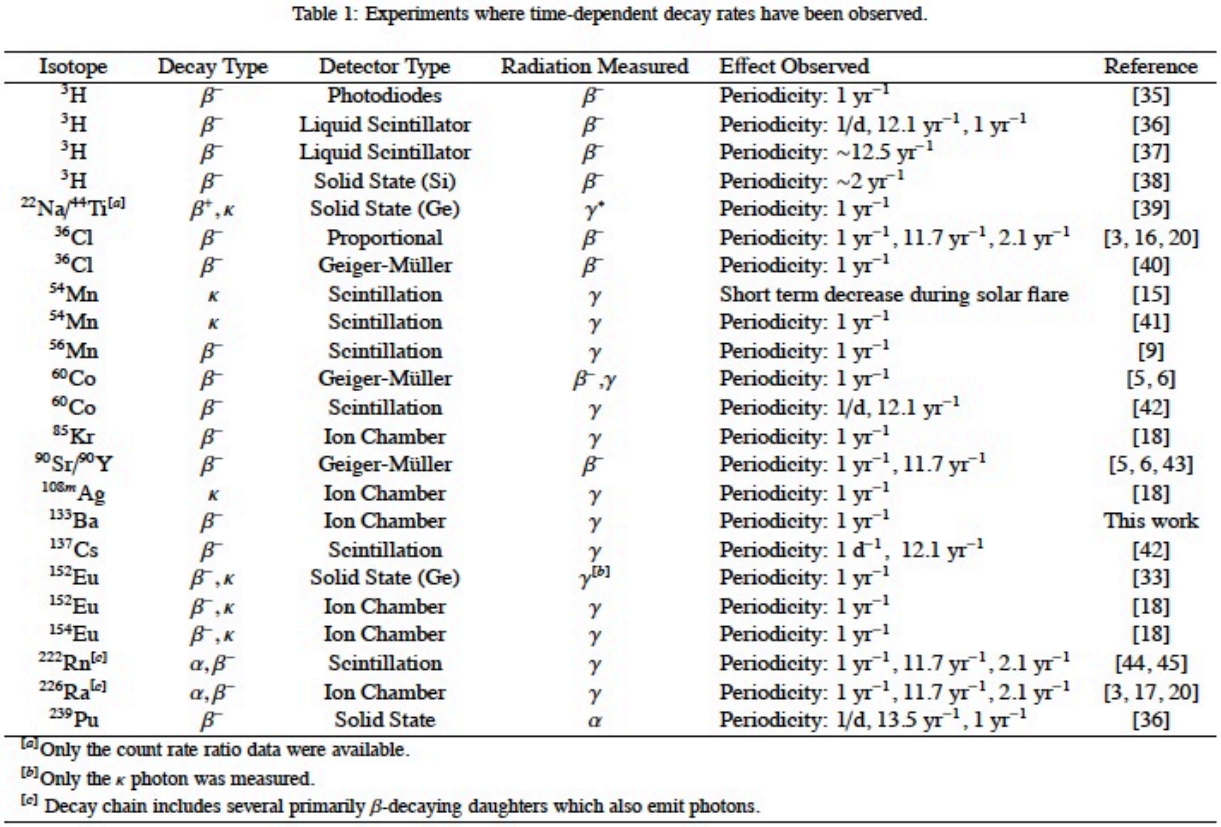


Table 1: Experiments where time-dependent decay rates have been observed.

Isotope	Decay Type	Detector Type	Radiation Measured	Effect Observed	Reference
^{3}H	β^-	Photodiodes	β^-	Periodicity: 1 yr^{-1}	[35]
^{3}H	β^-	Liquid Scintillator	β^-	Periodicity: 1/d, 12.1 yr^{-1}, 1 yr^{-1}	[36]
^{3}H	β^-	Liquid Scintillator	β^-	Periodicity: ~12.5 yr^{-1}	[37]
^{3}H	β^-	Solid State (Si)	β^-	Periodicity: ~2 yr^{-1}	[38]
^{22}Na/^{44}Ti[a]	β^+, κ	Solid State (Ge)	γ^*	Periodicity: 1 yr^{-1}	[39]
^{36}Cl	β^-	Proportional	β^-	Periodicity: 1 yr^{-1}, 11.7 yr^{-1}, 2.1 yr^{-1}	[3, 16, 20]
^{36}Cl	β^-	Geiger-Müller	β^-	Periodicity: 1 yr^{-1}	[40]
^{54}Mn	κ	Scintillation	γ	Short term decrease during solar flare	[15]
^{54}Mn	κ	Scintillation	γ	Periodicity: 1 yr^{-1}	[41]
^{56}Mn	β^-	Scintillation	γ	Periodicity: 1 yr^{-1}	[9]
^{60}Co	β^-	Geiger-Müller	β^-, γ	Periodicity: 1 yr^{-1}	[5, 6]
^{60}Co	β^-	Scintillation	γ	Periodicity: 1/d, 12.1 yr^{-1}	[42]
^{85}Kr	β^-	Ion Chamber	γ	Periodicity: 1 yr^{-1}	[18]
^{90}Sr/^{90}Y	β^-	Geiger-Müller	β^-	Periodicity: 1 yr^{-1}, 11.7 yr^{-1}	[5, 6, 43]
^{108m}Ag	κ	Ion Chamber	γ	Periodicity: 1 yr^{-1}	[18]
^{133}Ba	β^-	Ion Chamber	γ	Periodicity: 1 yr^{-1}	This work
^{137}Cs	β^-	Scintillation	γ	Periodicity: 1 d^{-1}, 12.1 yr^{-1}	[42]
^{152}Eu	β^-, κ	Solid State (Ge)	γ[b]	Periodicity: 1 yr^{-1}	[33]
^{152}Eu	β^-, κ	Ion Chamber	γ	Periodicity: 1 yr^{-1}	[18]
^{154}Eu	β^-, κ	Ion Chamber	γ	Periodicity: 1 yr^{-1}	[18]
^{222}Rn[c]	α, β^-	Scintillation	γ	Periodicity: 1 yr^{-1}, 11.7 yr^{-1}, 2.1 yr^{-1}	[44, 45]
^{226}Ra[c]	α, β^-	Ion Chamber	γ	Periodicity: 1 yr^{-1}, 11.7 yr^{-1}, 2.1 yr^{-1}	[3, 17, 20]
^{239}Pu	β^-	Solid State	α	Periodicity: 1/d, 13.5 yr^{-1}, 1 yr^{-1}	[36]

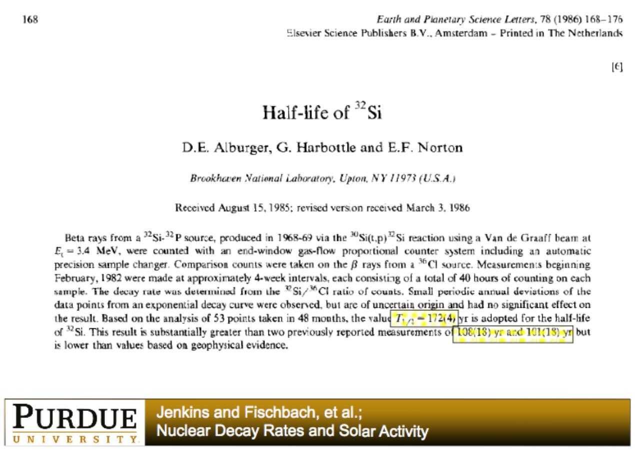
[a] Only the count rate ratio data were available.

[b] Only the κ photon was measured.

[c] Decay chain includes several primarily β-decaying daughters which also emit photons.

To date, 23 reports of experiments
involving 16 nuclides,
finding oscillations at 1 year^{-1},
about 2 year^{-1},
and in the range 12 – 13.5 year^{-1}.

BNL Decay Data (1998)



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Earth and Planetary Science Letters, 78 (1986) 168–176
Elsevier Science Publishers B.V., Amsterdam – Printed in The Netherlands

[6]

Half-life of ^{32}Si

D.E. Alburger, G. Harbottle and E.F. Norton

Brookhaven National Laboratory, Upton, NY 11973 (U.S.A.)

Received August 15, 1985; revised version received March 3, 1986

Beta rays from a ^{32}Si-^{32}P source, produced in 1968-69 via the ^{30}Si(t,p)^{32}Si reaction using a Van de Graaff beam at $E_t = 3.4$ MeV, were counted with an end-window gas-flow proportional counter system including an automatic precision sample changer. Comparison counts were taken on the β rays from a ^{36}Cl source. Measurements beginning February, 1982 were made at approximately 4-week intervals, each consisting of a total of 40 hours of counting on each sample. The decay rate was determined from the ^{32}Si/^{36}Cl ratio of counts. Small periodic annual deviations of the data points from an exponential decay curve were observed, but are of uncertain origin and had no significant effect on the result. Based on the analysis of 53 points taken in 48 months, the value $T_{1/2} = 172(4)$ yr is adopted for the half-life of ^{32}Si. This result is substantially greater than two previously reported measurements of 108(18) yr and 101(18) yr but is lower than values based on geophysical evidence.

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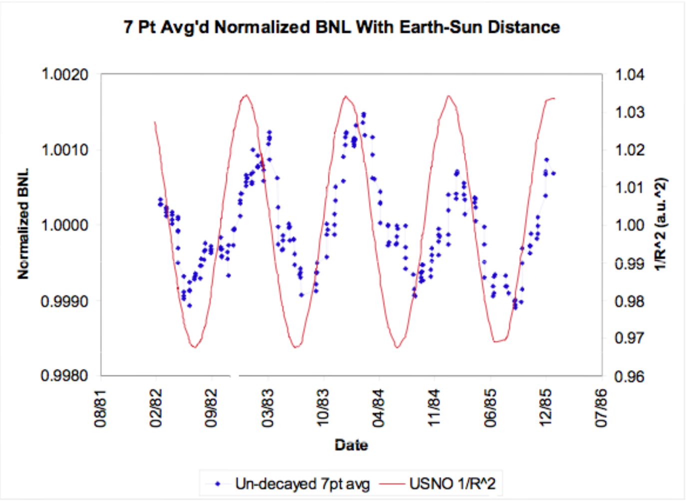
Jenkins and Fischbach, et al.;
Nuclear Decay Rates and Solar Activity



Pearson Correlation Coefficient *r*=0.66, *N*=233, Prob=1.0x10^{-31}

Data from: Alburger, et al., Earth and Planet. Sci. Lett., **78**, (1986) 168-176

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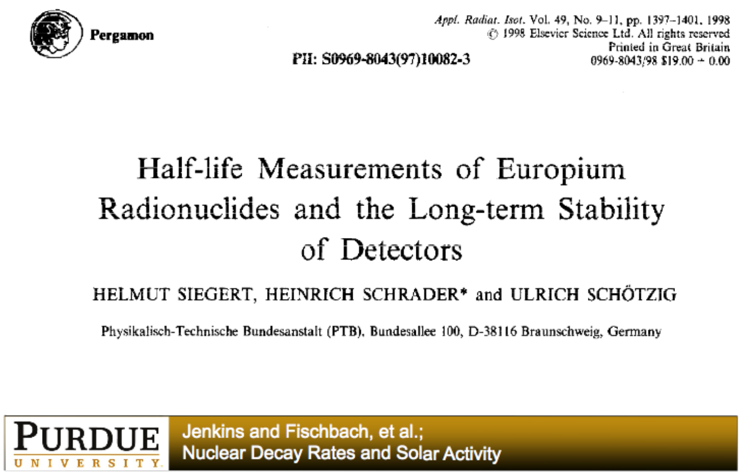
Jenkins and Fischbach, et al.;
Nuclear Decay Rates and Solar Activity

Amplitude of Oscillation approximately 0.1%

PTB Decay Data (1998)



Pergamon

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Half-life Measurements of Europium Radionuclides and the Long-term Stability of Detectors

HELMUT SIEGERT, HEINRICH SCHRADER* and ULRICH SCHÖTZIG

Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, D-38116 Braunschweig, Germany

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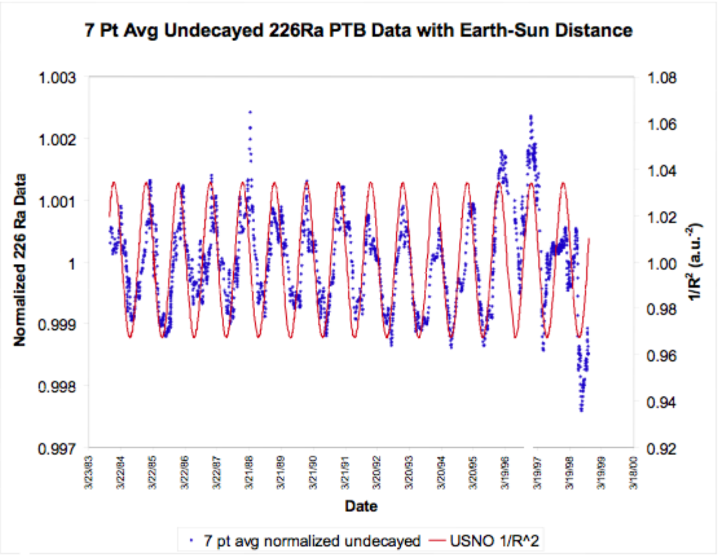
Jenkins and Fischbach, et al.;
Nuclear Decay Rates and Solar Activity



Pearson Correlation Coefficient *r*=0.65, *N*=1968, Prob=3.12×10^{-246}

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

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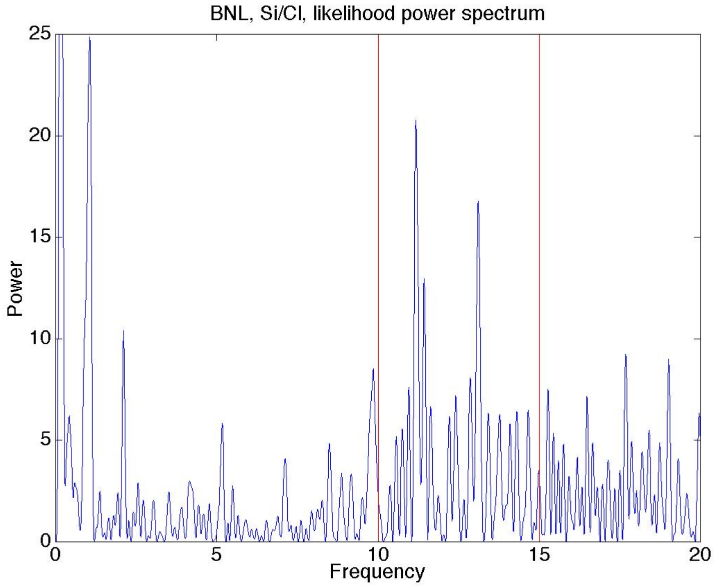
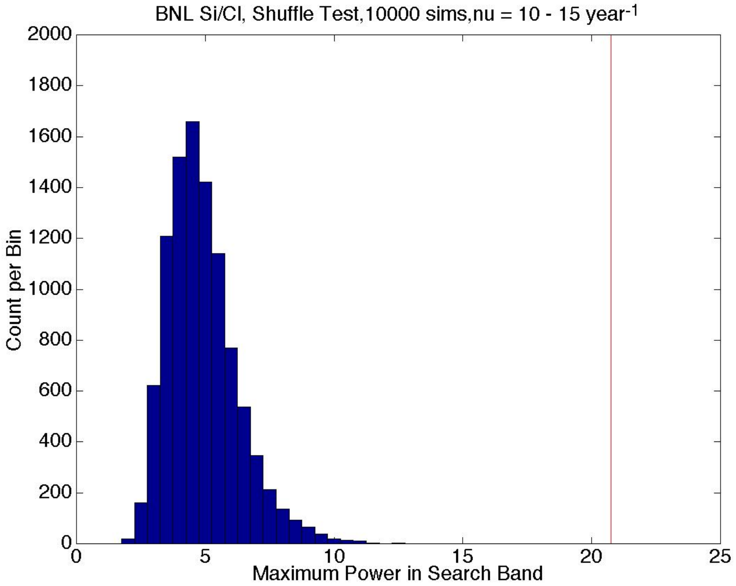
Nuclear Decay Rates and Solar Activity

Amplitude of Oscillation approximately 0.1%



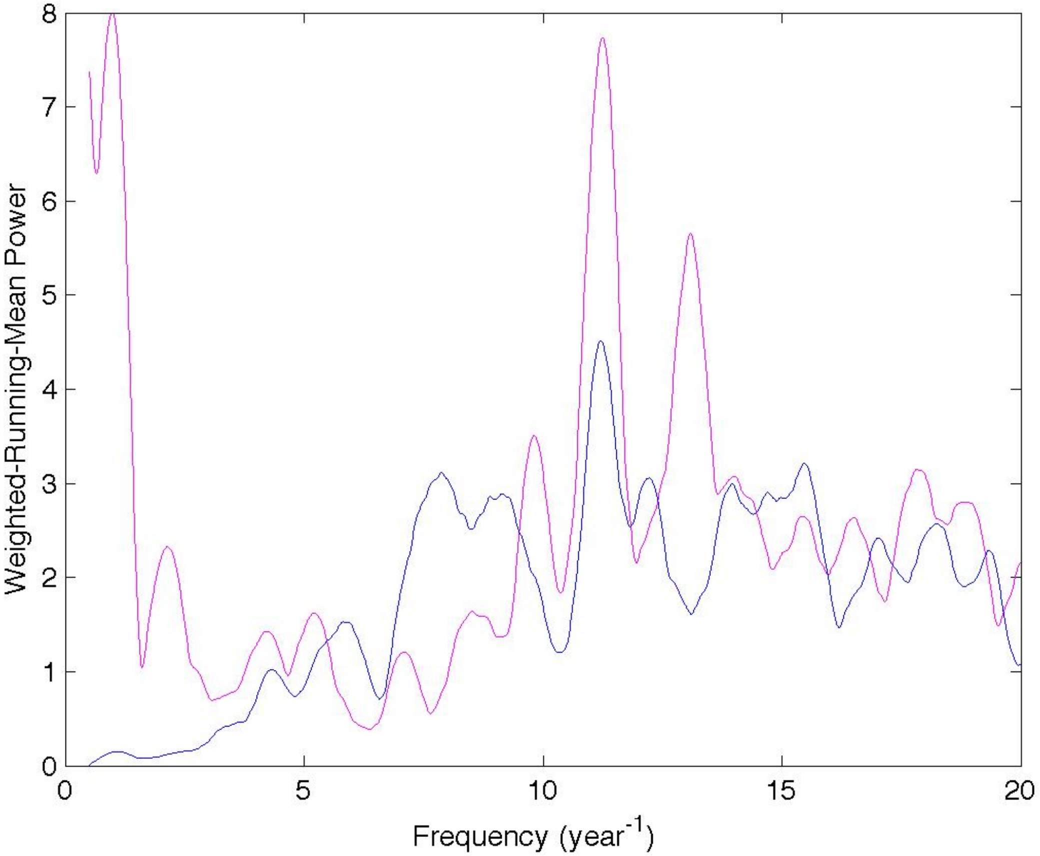


Power spectrum formed from the ratio of the Si and Cl count rates. There are strong peaks at 1.0, 11.2, and 13.1 year^{-1}.

Histogram of the results of 10,000 shuffles of the Si/Cl data, for frequencies in the range 10 - 15 year^{-1}.

None produces a power as large as the actual power (20.8).

A logarithmic display indicates that there is only one chance in 10^6 of finding that big a peak in that band by chance.



BNL (magenta) and PTB (blue) running-mean power spectra. Peaks at 11.24 and 11.27 yr^{-1}

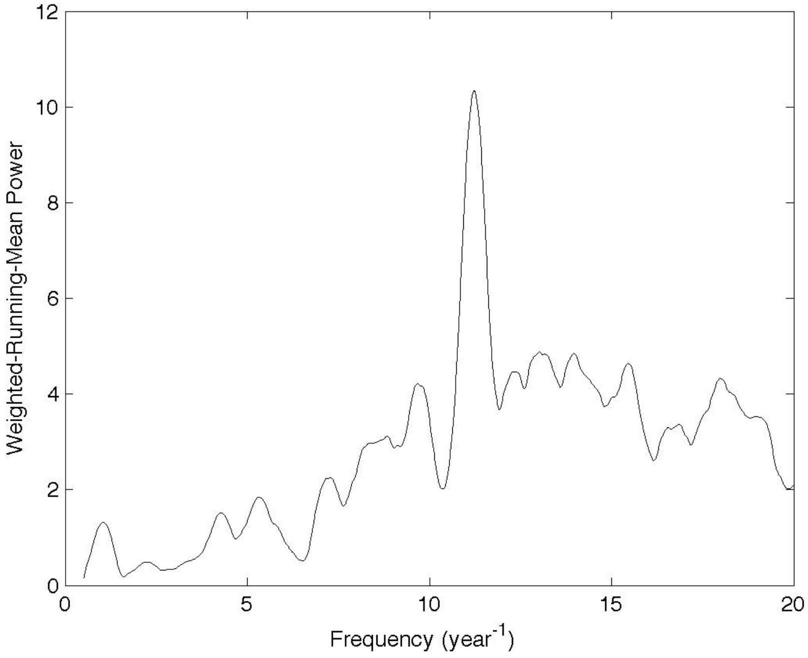
The Joint Power Statistic (JPS) is a function of the product of the powers. If each power has an exponential distribution, the JPS has an exponential distribution

For just two powers, as a function of

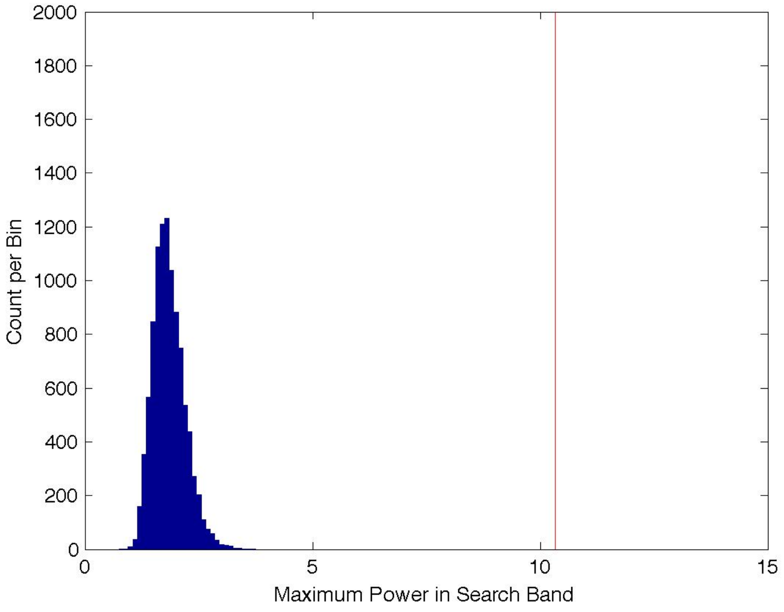
$$Y = (S_1 * S_2)^{1/2}$$

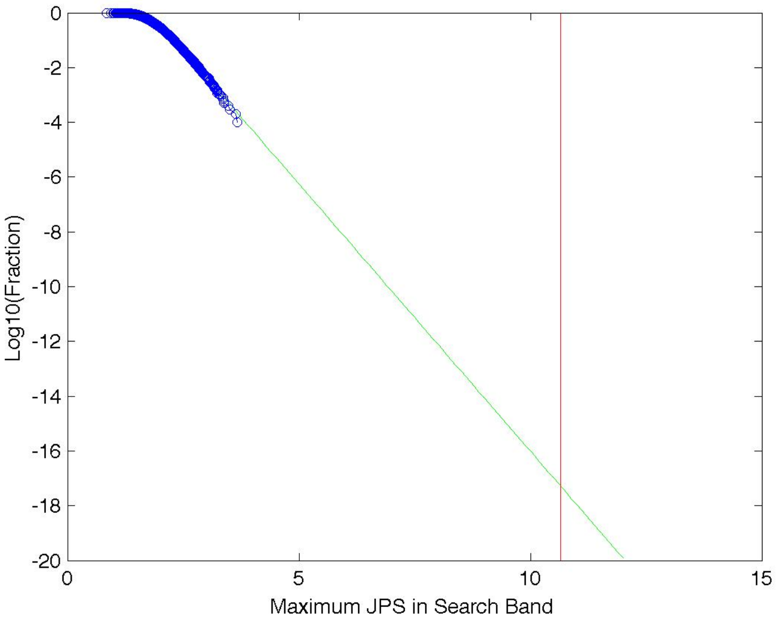
the JPS is given approximately by

$$J = \frac{1.943\,Y^2}{0.650 + Y}$$



Joint power spectrum formed from BNL and PTB running-mean power spectra. Peak at 11.23 yr^{-1}





Histogram of peak value of joint power statistic formed from 10,000 shuffle simulations of peak power in the search band 10 – 15 year^{-1} of BNL and PTB running-mean power spectra.

Logarithmic plot of peak value of joint power statistic. The probability of getting 10.65 or more is less than 10^{-17}.

R-MODE OSCILLATIONS

These are fluid-dynamical oscillation (related to “Rossby waves”).
For a sidereal rotation frequency ν_R
and for spherical harmonic indices l, m, the frequency is given by

$$\nu(l,m) = \frac{2m\nu_R}{l(l+1)}$$

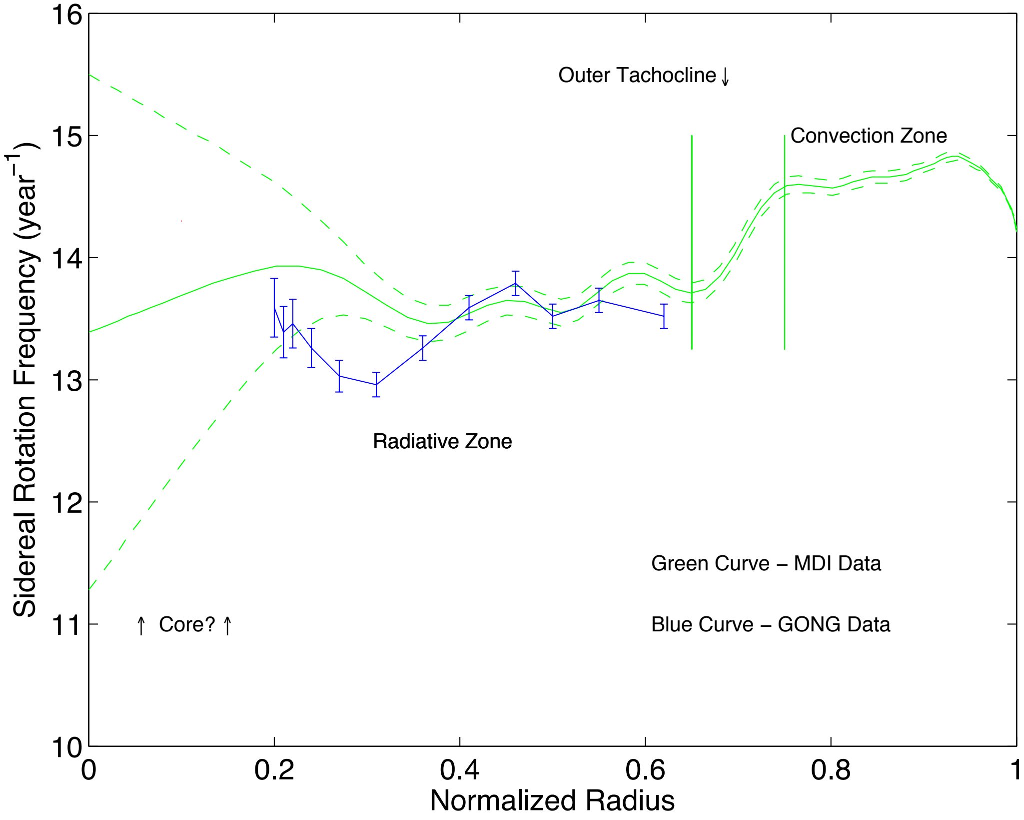
A “tachocline” is a thin region where there is a sharp gradient in rotation rate.

A tachocline separates the radiative zone from the convection zone.

The rotation rate there is 14.2 year^{-1}.
For l = 3, m = 1, nu = 2.37 year^{-1} (a period of 154 days).

This is known oscillation in solar physics as the “Rieger” Oscillation.

SOLAR INTERNAL ROTATION



SEARCH FOR AN r-MODE (RIEGER-TYPE) OSCILLATION

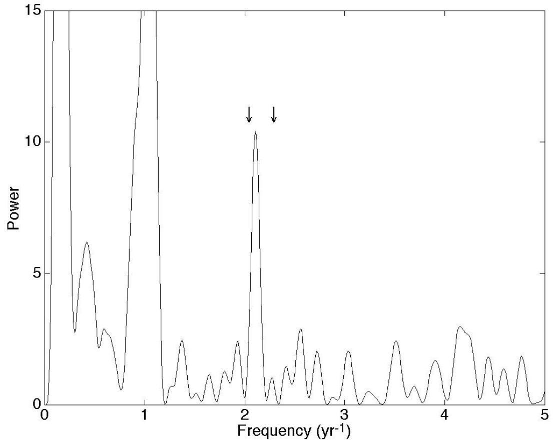
Our analyses have led to estimates 11.0 – 12.8 year^{-1} for the synodic rotation frequency (as seen from Earth).

This corresponds to a sidereal frequency of 12.0 – 13.8 year^{-1}.

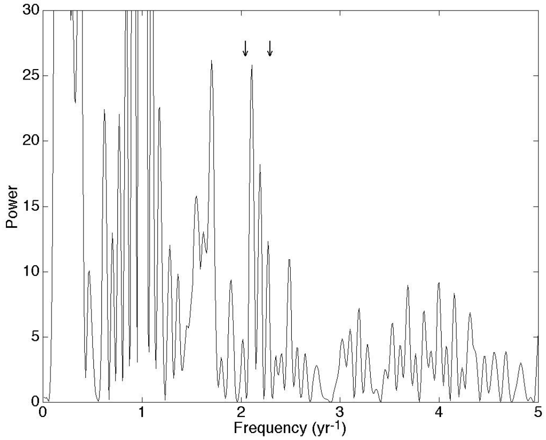
Suppose this refers to a second (inner) tachocline separating the core from the radiative zone (at about 0.25 R).

Then, for $l = 3$, $m = 1$, we arrive at a *predicted* r-mode frequency in the range 2.0 to 2.3 year^{-1}.

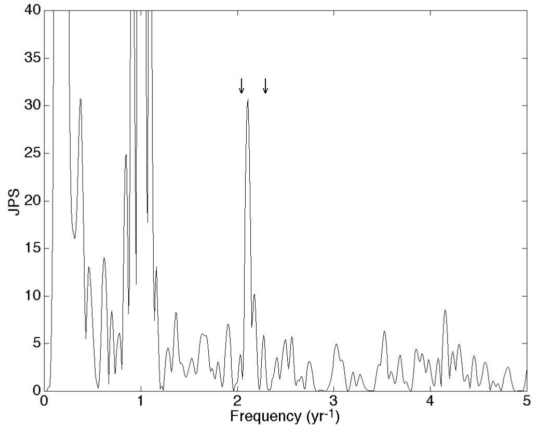
We therefore examine BNL and PTB power spectra to see if there are any peaks in this frequency range.



BNL power spectrum
Search band 2.0 – 2.3 year^{-1}
Peak at 2.11 yr^{-1}
with power S = 10.1



PTB power spectrum
Search band 2.0 – 2.3 year^{-1}
Peak at 2.11 yr^{-1}
with power S = 25.8



Joint Power Statistic
formed from BNL and PTB
power spectra
Search band 2.0 – 2.3 year^{-1}
Peak at 2.11 yr^{-1}
with power J = 30.6

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Rieger01

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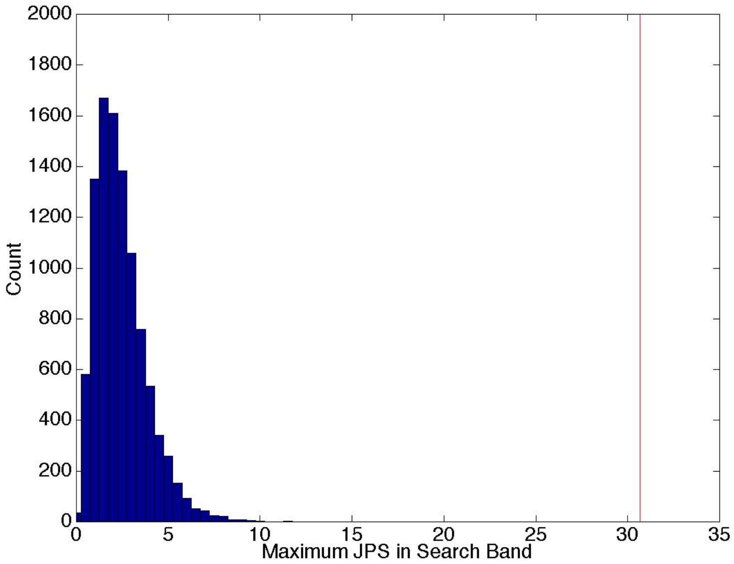
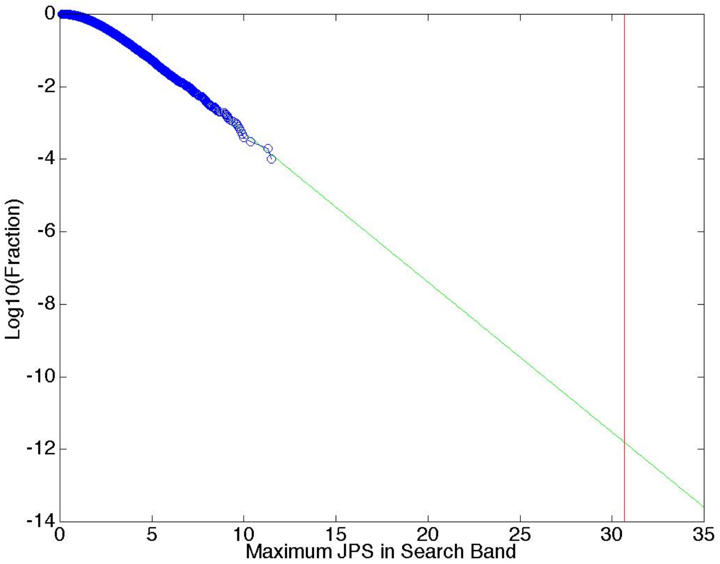




Histogram formed from 10,000 shuffle simulations of the joint power statistic formed from the BNL and PTB power spectra

Logarithmic plot.

Probability of getting 30.6 or more is about 10^{-12}.

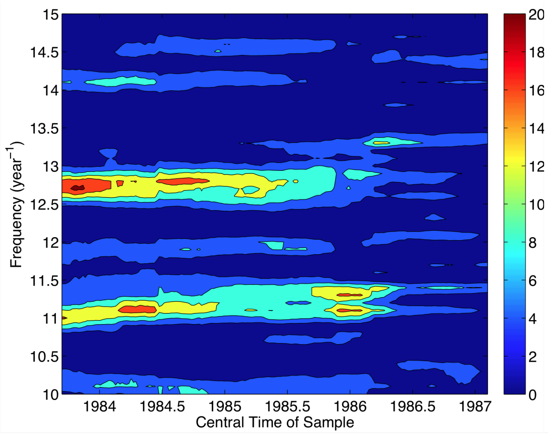
REQUIREMENTS OF A THEORY

- NUCLEAR DECAY RATES ARE NOT IMMUTABLE
- DECAY RATES ARE INFLUENCED BY SOME FORM OF RADIATION FROM THE SOLAR CORE
- THE RADIATION CAN TRAVEL THROUGH THE SOLAR INTERIOR WITHOUT BEING ABSORBED.
- HOWEVER, THE RADIATION CAN BE MODULATED IN SOME WAY, AND MAINTAIN THAT MODULATION IN ITS TRAVEL TO EARTH.

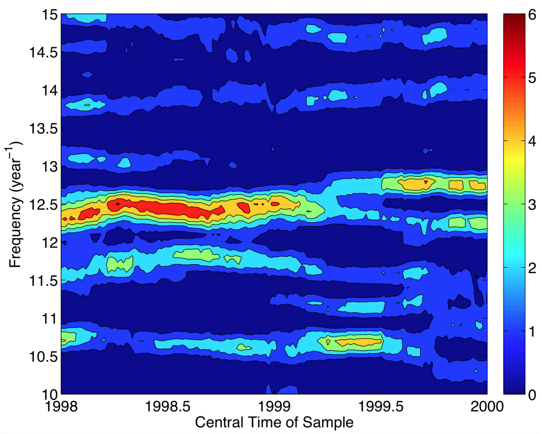
NEUTRINOS?

- NEUTRINOS CAN TRAVEL WITHOUT SIGNIFICANT ABSORPTION.
- THE “MODULATION” CAN BE ITS FLAVOR.
- THE FLAVOR CAN BE CHANGED BY MAGNETIC FIELD DUE TO THE RSFP PROCESS.
- BUT HOW DO NEUTRINOS INFLUENCE BETA DECAYS?

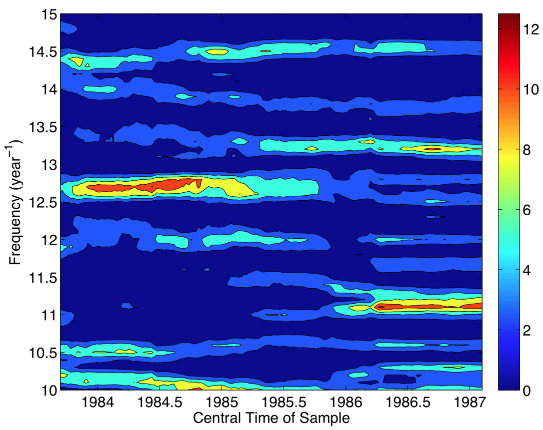
Spectrograms formed from Decay Data and from Solar Neutrino Data



Spectrogram formed from BNL ^{36}Cl Data



Spectrogram formed from Super-Kamiokande Solar Neutrino Data



Spectrogram formed from BNL ^{32}Si Data

Note the common modulation at about 12.5 year^{-1},
And the weaker modulation at about 11 year^{-1}.

RSFP - Resonant Spin Flavor Precession

Resonance Condition $G_F \sqrt{2}\left(N_e - N_n\right) = \dfrac{\Delta\left(m^2\right)}{2E}$

Fermi Constant $G_F = 10^{-37.03}\ eV\,cm^3$

N_e = electron density, N_n = neutron density

Super-Kamiokande data shows evidence of r-mode oscillations in the **Outer Tachocline** (r = 0.7R)

Adopting E = 5 MeV, we find that $\Delta\left(m^2\right) = 10^{-6.9}\ eV^2$

Inner Tachocline (r = 0.25R): **For this values of DEL(m^2)**
We find that E = $10^{4.9}$ eV = 80 keV

This is an estimate of the energy of neutrinos that influence decay rates.

S1207A12

RSFP - Resonant Spin Flavor Precession

Adiabaticity Condition $(\mu/\mu_B)B > 10^{-11.51}(N_e - N_n)^{1/2} H^{-1/2}$

Bohr magneton $\mu_B = 10^{-7.23}\ eV\, G^{-1}$

N_e = electron density, N_n = neutron density, H = scale height

Outer Tachocline, If B = $10^{4.9}$ G, then $\mu/\mu_B = 10^{-9.3}$

If $\mu/\mu_B = 10^{-10}$ then B = $10^{5.6}$ G = 400 kG

Inner Tachocline, if $\mu/\mu_B = 10^{-10}$ then B = $10^{6.1}$ G = 1.3 MG

If $\mu/\mu_B = 10^{-9.3}$ then B = $10^{5.4}$ G = 250 kG

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SIGNIFICANCE FOR PARTICLE PHYSICS

- Nuclear Decay Rates are Not Immutable

- Decay Rates are Influenced by Some Form of Radiation from the Solar Core –
Possibly a Neutrino Flux [Electron, Muon or Tau]
Possibly a New Species of Particles [“Neutrellos”]

There may be an Interaction Between Neutrinos [via “Neutrellons”?]

- The Particles do not Travel Freely Through the Solar Interior. This Could be due to the RSFP Effect.

- Any Revision of Neutrino Theory Could Have Implications for Supernova Theory and Possibly other Topics of Astrophysics.

SIGNIFICANCE FOR SOLAR PHYSICS

- The Solar Core is Probably Not Spherically Symmetric, and not in a Steady State [Magnetic Field?]

- The Solar Core Appears to Rotate More Slowly than the Radiative Zone

- There may be an "Inner Tachocline" Between the Core and the Radiative Zone

- If There is an "Inner Tachocline," There may also be an "Inner Dynamo," Which Could Conceivably Contribute to the Sun's internal Magnetic Field

- There is Evidence for a Relationship Between Changes in Decay Rates and Solar Flares [J.H. Jenkins And E. Fischbach, Perturbation Of Nuclear Decay Rates During The Solar Flare Of 2006 December 13, *Astroparticle Physics, 31, 407-411 (2009).*]

- Such a Connection, if Established, Might Prove to have Predictive Value

A Force Diagnostic Concerning a Possible Influence of Solar Neutrinos on Nuclear Decay Rates

An energy transfer per event *to* the nucleus of ΔE_{eV} (in electron volts), leads to a transfer of momentum (in g cm s^{-1}, anti-solar direction) of $\Delta p = c^{-1} 10^{-11.80} \Delta E_{ev} = 10^{-22.28} \Delta E_{ev}$

If T_{yr} (in years) is the half-life,
Γ is the fraction of the decay rate that is due to the Sun,
M (g) is the mass of the sample, and
A is the atomic weight, then the total force (in dynes) is given by

$$F = 10^{-6.16} \Gamma A^{-1} T_{yr}{}^{-1} \Delta E_{ev} M$$

For ^{54}Mn, A = 54.9 and T_y = 0.81. Adopting $\Gamma = 0.01$

we find $F = 10^{-9.9} \Delta E_{ev} M$

For instance, if $\Delta E_{eV} = 10^6 \left(1\,\mathrm{MeV}\right)$ and $M = 10^{-6} \left(1\ \mathrm{microgram}\right)$

Then $F = 10^{-9.9}$ (dynes)

A Torque Diagnostic Concerning a Possible Influence of Solar Neutrinos on Nuclear Decay Rates

Consider a cylinder suspended by a long thread.

The mean torque (g cm^2 s^{-2}) per active atom is

$$H_1 = \Gamma \gamma \frac{1}{2} h = 10^{-34.14} \Gamma T_{yr}{}^{-1}$$

where $\Gamma (\approx 0.01)$ is the fraction of decays due to solar influence, T_{yr} is the half-life in years.

If K_A is the fraction of the total mass due to the radioactive nuclide,

A the atomic weight, and Θ is the maximum solar elevation,

the amplitude of the daily oscillation in radians is

$$\phi_0 = 10^{-1.78} K_A \Gamma A^{-1} T_{yr}{}^{-1} R^{-2} \sin(\Theta)$$

For ^{54}Mn, A = 54.9, T_{yr} = 0.81, and $\Theta = 45$ deg, $\phi_0 = 10^{-3.58} K_A R^{-2}$

For R = 10 micron, $K_A = 10^{-3}$, $\phi_0 = 10^{-0.58}$ radian ≈ 14 deg.