SPECULATION ON A SOLAR CHRONOMETER FOR CLIMATE

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ABSTRACT

Solar activity has been correlated to climatic fluctuations and has been postulated as a major factor in quasi-periodic global climatic change. However, correlations are not explanations of physical mechanisms and do not couple cause with effect. A mechanism for a chronometer for solar output variability is proposed based on relations between properties of thermonuclear fusion, nuclear magnetic moment, and nuclear magnetic resonance.

A fundamental oscillation of a nucleus with a net nuclear magnetic moment (NMM) is the precession of its axis of rotation when subjected to a magnetic field. Nuclear magnetic resonance (NMR) is the preferred frequency of precession for a nucleus of a particular isotope when placed in a magnetic field of specific intensity. The NMM for those isotopes involved in the proton-proton (p-p) chain pathway for solar fusion varies from strong positive to strong negative. Individual fusion events, for hydrogen and helium isotopes which release varying amounts of energy, may be controlled by NMR frequencies. The pulses of energy from fusion events occurring at NMR frequencies in the solar interior may be transformed into pressure or gravity waves that emerge as gravity or acoustic waves at the surface. Dictated by spherical harmonics, certain wavelengths may be reinforced and reenter the solar interior to modulate the fusion process. Qualitative analysis of solar and climatic data support the interaction of the three basic components of the chronometer, magnetic activity, oscillation frequency, and solar energy output.

INTRODUCTION

Thermonuclear fusion within the Sun is the major source of energy for the solar system. However, only the outermost layers of the Sun can be studied directly from Earth. The interior is hidden from view, and only indirect methods of observation, such as solar seismology[1], give clues to its structure and processes. The "standard" models of solar evolution indicate that the solar output has increased with time, being 30 percent greater now than 4.6 billion years ago[2]. Calculations using this increased solar output indicate that the Earth would have been totally covered with ice for nearly one-half of that time, preventing the development of life in the oceans. Nonstandard models of the Sun, which involve periodic mixing of helium and hydrogen, indicate that mixing episodes may have set off major glacial advances[3,4].

The most well known solar periodicities are the approximate 11-year sunspot cycle, and the Hale double-sunspot cycle in which the polarity of the sunspots goes through an approximate 22-year cycle. Also, the maximum sunspot number for each 11-year cycle, follows an approximate 80- to 90-year cycle[5].

Sunspot disturbances were once considered to be inherently only roughly periodic, with observed intervals of maximum activity ranging from 7.3 to 17.1 years[6]. Later, Kiepenheuer[7] described the rise and fall of the number of sunspots as an eruption phenomenon, the end result of a number of practically independent individual processes. The idea that each cycle represents an independent eruption of the Sun taking about 11 years to die down implies a random walk in the cycle phase. This random walk seems to agree with the Babcock theory and subsequent modifications in which the poloidal magnetic field remnant of one half-cycle (approximately 11 years) provides the seed field for the generation of the toroidal magnetic field of the next half-cycle by differential winding[8]. Dicke found no support for the existence of a large random walk in the phase of the sunspot cycle. Instead, he noted that "both sunspots and the (D/H) weather indicator seem to be paced by an accurate clock inside the Sun.[8]"

Could this accurate clock or chronometer be paced by internal oscillations of the Sun? The relatively new field of helioseismology has revealed that the Sun apparently oscillates throughout a range of discrete frequencies. Analysis of these oscillations shows very distinct patterns in frequency-spacial scale diagrams which indicate that the longer the period of oscillation, the deeper the Sun is being penetrated[9]. Observed oscillations of the Sun range in frequency from minutes to decades. Recent work has shown possible oscillations of approximately 80 years[10,11].

The well documented 160-minute solar oscillation has been described as "a g-mode driven by a seismonuclear process in the solar core"[12]. This hypothesis is supported by an apparent solar cycle dependence in Davis's solar neutrino experiment[13,14]. It appears that the inverse correlation between the 11-year sunspot cycle and neutrino flux may be linked to activity within the Sun[15].

Could it be that internal oscillations of the Sun are manifested as gravity waves at the surface, which are reinforced or destroyed as a function of spherical harmonics? In turn, the reinforced modes could penetrate the solar interior to modulate the fusion process, systematically varying the production of neutrinos and energy.

What is the basic oscillation and how is it related to thermonuclear fusion and magnetic activity? The answer may be found in nuclear scale vibrations.

THE SOLAR CHRONOMETER

Solar activity may be driven by a high-frequency oscillation on the nuclear scale. There are three interrelated physical processes that are presented in this paper that could control a chronometer within the Sun's interior--(a) the difference in energy production between hydrogen fusion and helium fusion, (b) the interaction of nuclear magnetic resonance frequencies of hydrogen and helium in varying magnetic fields, and (c) the nuclear magnetic moments of the hydrogen and helium isotopes.

The first process considered is the difference of energy production in the stages of solar fusion. Hydrogen and helium are the predominate constituents of the Sun. The conversion of mass into approximately 99 percent of the energy in thermonuclear fusion within the Sun is believed to follow the proton-proton (p-p) chain pathway given below[16]:

(1) $^{1}H + ^{1}H > ^{2}H$ + positron + neutrino

(2) $^{2}H + ^{1}H > ^{3}He$ + gamma ray

(3) $^{3}He + ^{3}He > ^{4}He + (2)^{1}H$

where

^{1}H is hydrogen-1,

^{2}H is hydrogen-2,

^{3}He is helium-3, and

^{4}He is helium-4.

Steps 1 and 2 of the conversion pathway for 6 initial hydrogen-1 nuclei release 13.870 million electron volts of energy. Step 3 releases 12.859 million electron volts of energy[17]. About 52 percent of the total energy in the proton-proton chain pathway is released in steps 1 and 2--the "hydrogen-fusion" phase. The remaining 48 percent is released in step 3, the "helium-fusion" phase.

Hydrogen fusion can occur at a lower temperature and pressure than helium fusion because the force holding the two hydrogen nuclei apart is less than the force holding the two helium-3 nuclei apart. (The coulomb force is less for lighter nuclei.) Therefore, either a higher temperature or greater pressure is required for helium fusion than for hydrogen fusion.

The second process considered is that of nuclear magnetic resonance. Nuclear magnetic resonance (NMR) is the ability of the nucleus of an atom to vibrate at a unique frequency when subjected to a certain magnetic field[18]. This vibration is actually a precession of the axis of spin of the nucleus at an angle also dependent upon the magnetic field intensity. The predominate nuclei involved in solar thermonuclear fusion are hydrogen-1, hydrogen-2, helium-3, and helium-4. Of these four isotopes, all are active in NMR except helium-4, which has magnetic symmetry and does not resonate. However, hydrogen-1 and helium-3 are the most sensitive resonators of all the elements involved in solar fusion[19], with hydrogen-1 being more than twice as sensitive as helium-3, and 100 times more sensitive than hydrogen-2. Sensitivity could be interpreted as the relative strength of vibration.

One characteristic of NMR is that the resonant frequency of oscillation is dependent upon the magnetic field in which the atom is placed. If the magnetic field is increased from 1,180 gauss to 10,000 gauss, the NMR frequency for hydrogen-1 increases from 5 to 42 megahertz[18]. The response is a linear function. Helium-3 has a similar response with a slightly slower increase of NMR frequency with an equal increase in magnetic field.

The third process involves the nuclear magnetic moments (NMM) of the hydrogen and helium nuclei, and their effect on the composite magnetic field of a parcel of solar material. The magnetic moment of hydrogen-1 is +2.79268 nuclear magnetons (μn). Hydrogen-2 has a value of +0.8574 and helium-3, -2.1274 μn[19]. A nuclear magneton is equal to 5.0505 x 10^{-24} erg per gauss. The magnetic moment of helium-4 is zero because its nucleus is magnetically symmetric.

Consider a parcel of hydrogen-1 in a uniform magnetic field proceeding through the three steps of the proton-proton chain. The composite magnetic moment of that parcel will vary according to the concentration of each isotope. A schematic diagram of the proton-proton chain is shown in figure 1.

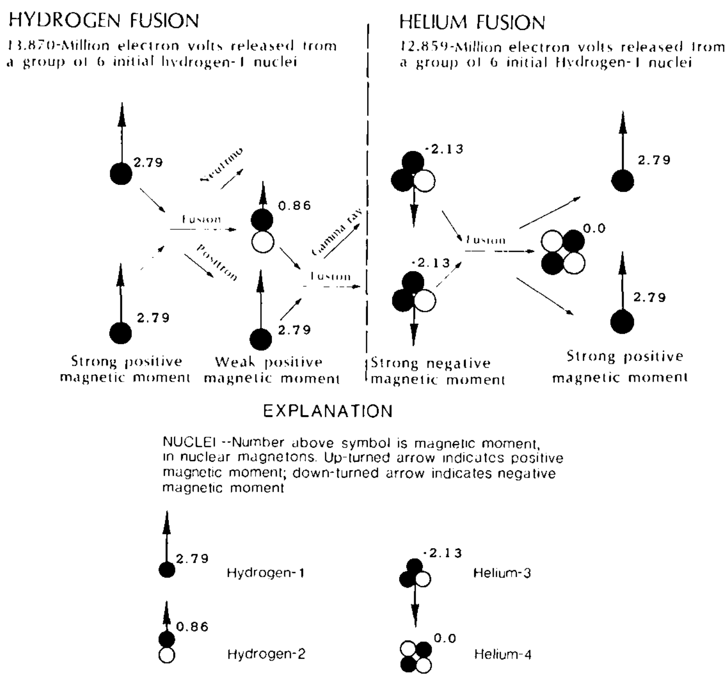

Figure 1. *Energy production and relation among nuclear magnetic moments for hydrogen-1, hydrogen-2, helium-3, and helium-4 in solar thermonuclear-fusion process*[17,19].

For illustrative purposes, positive magnetic moment is depicted by arrows pointing up, negative pointing down. As step 1 begins, the abundant hydrogen-1 nuclei are responsible for the strong positive composite magnetic moment of the parcel. The high composite magnetic moment should allow the nuclei to vibrate at a high NMR frequency. As hydrogen-2 is produced, the composite magnetic moment begins to weaken and NMR frequencies begin to lower. When temperature and pressure increase to the point as step 2 proceeds, the addition of helium-3 nuclei further decreases the parcel's composite magnetic moment, and NMR frequencies continue to decrease. As step 3 begins and the helium-3 is at its greatest concentration, the parcel's composite magnetic moment reaches its minimum value, which can be negative. This not only affects NMR frequencies within the parcel, but also affects the magnetic field and the resultant frequencies in the neighboring parcels. As step 3 progresses, the helium-3 nuclei are fused into helium-4, having no magnetic moment, and hydrogen-1, having a high moment, increasing the composite magnetic moment of the parcel and increasing NMR frequencies. Therefore, when hydrogen nuclei are abundant during hydrogen fusion (steps 1 and 2), NMR frequencies are higher than during helium fusion (step 3), when there is a higher concentration of helium-3 nuclei and NMR frequencies are lower.

CONVERTING NUCLEAR VIBRATIONS TO SOLAR CYCLES

To support the solar chronometer theory, an explanation of the mechanism for the progression from high-frequency NMR vibrations to lower-frequency solar-activity oscillations must be provided. This explanation is based on NMR properties and the assumption that a spinning hydrogen or helium nucleus is not a true sphere but is instead a rounded disk. Recent work has shown structural anomalies in the nucleus of helium-3[20].

Consider a group of nuclei in the core of the Sun that are subject to a magnetic field, and are very near the temperature and pressure needed for fusion. The distance between the centers of mass of the nuclei would remain nearly constant through an NMR oscillation cycle. However, the disk edges have a minimum distance (dm), which occurs twice during each precession cycle (fig. 2). As the centers of mass of the nuclei become closer as a result of higher temperature and pressure, fusion would occur when dm reaches the critical value.

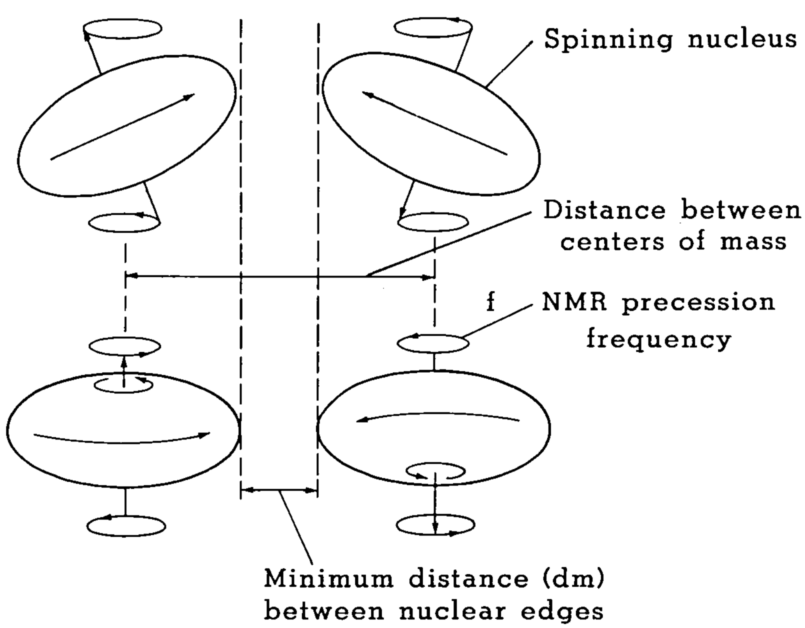

Figure 2. *Nuclear magnetic resonance precession of nuclei and relation of minimum distance between nuclear edges.*

After the first fusion event in that group of nuclei, thermodynamic adjustments would be made in the group of nuclei to accommodate the energy released and the presence of a heavier nucleus. The next fusion event for the group could be several precession oscillations later. If these fusion events proceeded at frequencies lower than the NMR frequency within a group of nuclei, pressure waves could develop, further enhancing fusion at the lower frequencies. The interference of pressure waves created by hydrogen-1 fusion and helium-3 fusion at different locations within the solar core would result in even lower frequency pressure waves, which could propogate to the Sun's surface. NMR frequencies of hydrogen-1 and helium-3 nuclei are hypothesized to be responsible for the basic frequency on which the other solar-activity cycles are based. Hydrogen-2 is a much weaker resonator[19] than hydrogen-1 by a factor of 100, and its effect on the beat frequency should not be significant.

As the pressure waves emerge from the solar interior, they may be transformed into acoustic or gravity waves at the surface. Dictated by spherical harmonics, certain gravity waves are reinforced and can reenter the solar interior. Gravity waves reaching the solar core modulate the hydrogen and helium fusion, completing the circle. The interaction of NMR frequencies of hydrogen-1 and helium-3 could be the chronometer that sets the tempo of the Sun and all stars that are burning hydrogen and helium.

The linear relationships for hydrogen-1 and helium-3 NMR frequencies are shown in figure 3. Beat frequencies between hydrogen-1 and helium-3 are also plotted in figure 3, and the equations are given below:

$$f(^{1}H) = 4.2552\,B + 23.440; \qquad (1)$$

$$f(^{3}He) = 3.2429\,B + 4.0811; \text{ and} \qquad (2)$$

$$f(Beat) = 1.0124\,B + 19.3595; \qquad (3)$$

where

f is in kilohertz, and B is in gauss.

Unlike the individual frequency-magnetic intensity relations for hydrogen-1 and helium-3 which have steep slopes, the slope of the beat frequency is relatively flat. A doubling of the magnetic intensity from 2 to 4 gauss increases the frequency by only slightly more than 10 percent, and doubling from 6 to 12 gauss increases the frequency by about 25 percent. As magnetic intensity increases, the period of oscillation should become shorter, and as magnetic intensity decreases, the period of oscillation should become longer. Increased magnetic field intensity would be associated with hydrogen fusion and greater energy production. Decreased magnetic fields would be associated with helium fusion and less energy production.

IMPLICATIONS OF THE SOLAR CHRONOMETER THEORY

The three interrelated components of the solar chronometer involving nuclear properties of hydrogen and helium can be used to qualify observed solar activity. With increasing magnetic fields, the NMR frequency increases and the reciprocal, period (cycle length), decreases. The hypothesis of the solar thermonuclear chronometer theory is that NMR governs solar cycles of all time periods. Therefore, if the magnetic field within the Sun increases, the NMR frequency increases, and the solar cycles should become shorter. This feature has been noted in the sunspot record. The sunspot cycles with a larger number of spots, which indicate greater magnetic activity, are usually shorter than cycles with small numbers and less magnetic activity.

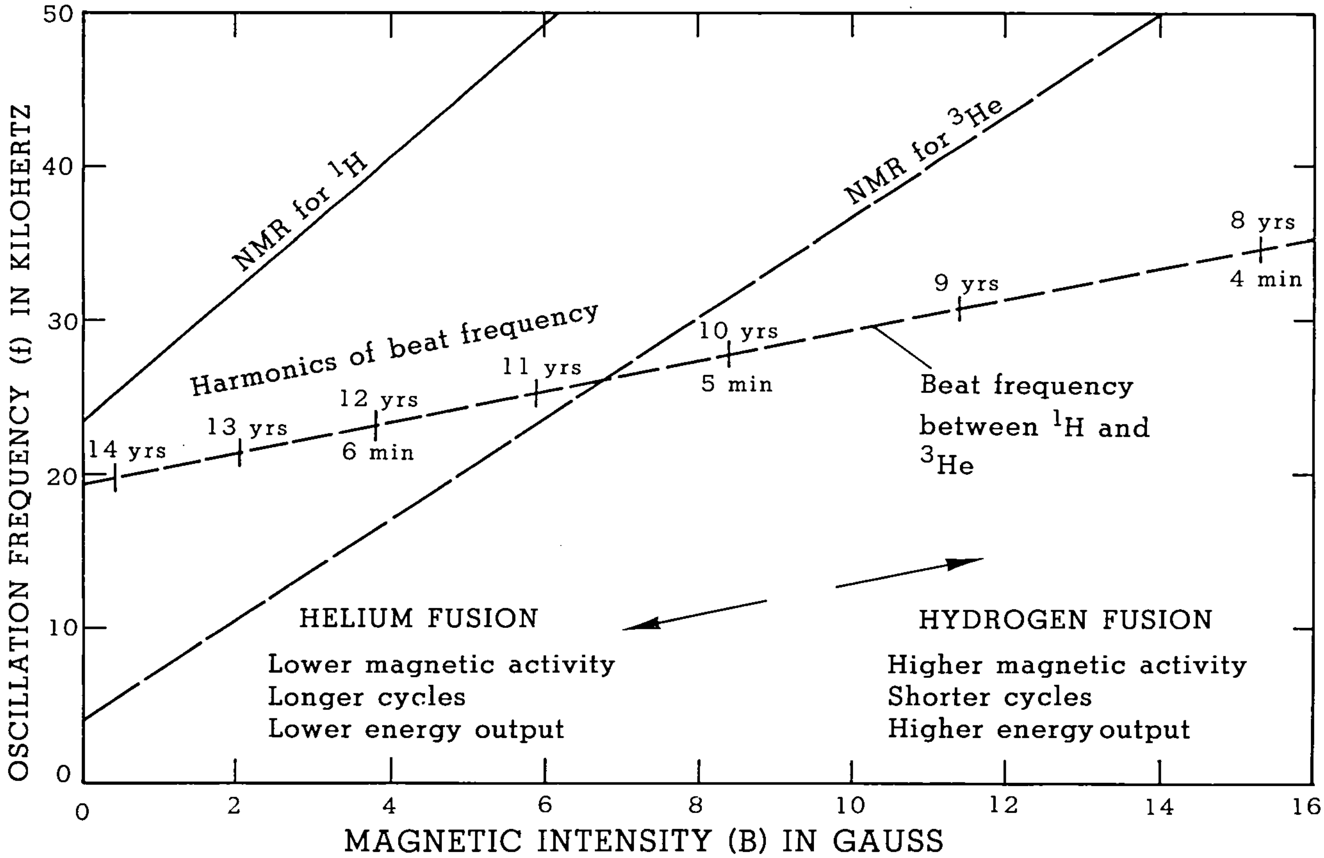

Figure 3. *Nuclear magnetic frequencies for hydrogen-1 and helium-3 and "beat" frequencies for various magnetic intensities.*

The same relationship between magnetic activity and solar oscillation period has been noted in the last two centuries. From 1810 to 1913 the average sunspot cycle length was 11.4 years with an average cycle maximum sunspot number of 91.3. Between 1913 and 1986, the average cycle length was 10.4, and the average cycle maximum was 127.9. A more magnetically active Sun corresponds to shorter solar-cycle lengths. The association of solar energy output to this fluctuation may be inferred from North American annual temperature departures reconstructed using tree rings[21]. The interval 1810 to 1913 had an average departure of nearly -0.4 degrees Celsius from the period 1913 to 1986.

A similar relationship between magnetic activity, oscillation period and solar output can be demonstrated on a shorter time scale. Woodward and Noyes[22] have reported a slight but systematic decrease in frequencies of low-degree solar p-modes (acoustic modes in the 5 minute band of oscillation) from 1980 to 1984. Roberts and Campbell[23] argued that the frequencies of both p- and g-modes are modified by a magnetic field within the solar interior which evolves over the solar cycle. From 1980 to 1984 the sun was becoming magnetically less active as the last 11-year solar cycle was ending. During the same period, a general decrease in the solar constant was measured by the Solar Maximum Mission's active cavity radiometer experiment[24].

The range of the sunspot cycle and the p-mode, 5 minute band has been inserted on the beat frequency line in figure 3. The 5 minute oscillation coincides with a sunspot cycle length of 10 years, the value of the last full cycle (cycle 20). These values are both harmonics of the nuclear beat frequency. If the nuclear vibrations of the solar thermonuclear chronometer do control the frequency of all solar oscillations, then periods in which the sunspot cycle lasts, for example 11 years, the preferred p-mode oscillations would be expected to be closer to 5.5 minutes.

CONCLUSIONS

The Sun and its total output of electromagnetic energy, charged particles and magnetic force fields are not static. The standard models of solar evolution can not adequately describe its quasi-periodic behavior which has been evident in the geologic record and in recent measurements of solar activity. Helioseismology is revealing the many modes of oscillation possible within the Sun.

This paper presents a mechanism for the genesis of a basic vibration for a solar chronometer, which can set the tempo of the other solar oscillations. That vibration frequency is a function of: (1) nuclear magnetic resonance of hydrogen and helium nuclei, (2) the composite magnetic moment of those nuclei through the proton-proton chain solar-fusion steps, and (3) the difference of energy of fusion for each step. The interaction of these three components of the solar thermonuclear chronometer allow a range of energy production and oscillation period length. Hydrogen fusion releases a greater total amount of energy and results in a stronger composite magnetic field which dictates a higher frequency nuclear vibration than does helium fusion. The higher vibrational frequency associated with hydrogen fusion results in shorter period solar oscillations than does helium fusion.

These high frequency oscillations may originate in the solar interior and propagate to the surface and emerge as gravity or acoustic waves. According to spherical harmonics, certain wavelengths may be reinforced and penetrate the solar interior to modulate the fusion process.

Qualitatively, observations of the sun support the solar thermonuclear chronometer. Shorter sunspot cycles tend to be more active magnetically with a greater number of sunspots. A greater number of sunspots is believed to result in greater solar output. Also, the frequency of the 5-minute band of acoustic waves on the Sun tend to decrease as the Sun becomes less active magnetically, accompanied by a decrease in solar output. The Sun is constantly changing and adjusting itself to preferred modes of oscillations. Total instantaneous output is probably a summation or superimposition of many cycles of output. Earth intercepts this seemingly noisy output and climatically resonates at its preferred frequencies.

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