

ACTIVITY CYCLE IN THE SOLAR CORE

ATTILA GRANDPIERRE

Konkoly Observatory, 1525 Budapest, P.O. Box 67, Hungary

ABSTRACT I analyze here the recent solar seismology data relevant to the core regarding the energetics. The result is that the magnetic torsional oscillations are hardly able to support the observed rate of change of the solar core rotation. Interpreting the solar neutrino data as directly coming from the core and showing the activity cycle of the core, the energetics of the core can be balanced. I show here a simple model for the global and local activity-related changes of the solar core. The parameters of this model are consistent with the values derived by the Convective Flare Theory. This model is able to interpret the anticorrelation of the sunspot number with the neutrino flux, the related changes in the rotation of the core and the first which interprets the observed activity-related element abundance anomalies with a model for the solar core.

ROTATIONAL ENERGY CHANGES OF THE CORE

Goode and Dziembowski(1991) inverting the solar seismology data suggest that the rotation of the solar core anticorrelates with the solar cycle. By their data the rotation rate of the solar core at 0.4 solar radius is $\omega_1 = 485$ nHz in 1986, near to solar minimum, and $\omega_2 = 430$ nHz in 1988, close to the solar maximum. I estimate here roughly the related changes in the rotational energy, ΔE_ω , of the core if the core rotates rigidly.

$$\Delta E_\omega = \frac{1}{2} \times \frac{2}{5} m R_c^2 \times (\omega_1^2 - \omega_2^2) = 4.3 \times 10^{40} \text{erg.}$$

Here m is the mass of the rotating core $R \leq 0.4 R_c$, $R_c = 0.4 R_\odot$. If we want to argue, that the rotational energy changes are supplied by the magnetic fields, we would need a value of $B = 100\,000$ G for the average magnetic field strength in the whole core! This magnetic field as a whole should have to be produced again in every cycle always with different polarities. This would give in an 11 year cycle a magnetic luminosity, assumed to be equal with the rotational luminosity, to be $1.2 \times 10^{32} \text{ergs/sec}$, 3% of the total solar luminosity! It is clear, that much more plausible to think, that the rotational changes of the core does not involve rotational energy changes.

A PULSATING CORE MODEL

Let us assume, that the rotation of the core is changing because of isobaric expansion and contraction of the core. In that case the temperature of the

core should have to change with the core radius. If the core really changes with the cycle, than the activity cycle has to have on origin from the core. This temperature change of the core has to be present in the thermonuclear reaction rates. I propose that exactly this temperature change is the cause of the observed anti-correlation of the sunspot number with the solar neutrino flux (shown by Bieber et al.,1990). Let us assume, that the core of the Sun consists from two parts with different character. One is the main part of the core, which is as a whole, expands and contracts, and small parts around its surface, which produce from time to time local thermonuclear runaways (Grandpierre, 1990, 1991). In this case the luminosity of the Sun is produced by these two parts together, by the luminosity, of the quiet core, L_c , and the luminosity of the flaring part of the core, L_f :

$$L_{\odot} = L_c + L_f.$$

The high energy neutrinos, detected by the Homestake neutrino detector, are produced with the 18th power of the temperature. For these neutrinos the observed neutrino flux Φ_{ν}^{obs} is about 1/4 of the theoretical value Φ_{ν}^{theor}

$$\frac{\Phi_{\nu}^{obs}}{\Phi_{\nu}^{theor}} \approx \frac{1}{4} \approx \left(\frac{T_{q.c}}{T_{c.st}} \right)^{18}.$$

where $T_{q.c}$ and $T_{c.st}$ are the average temperatures of the quiet part of the 'flaring core' and of the theoretical, standard core. The flaring part of the core does not produce neutrinos, because on these high temperatures the proton - proton cycle cannot be completed. One can estimate the luminosity of the quiet part of the flaring core assuming that the luminosity goes with the fourth power of the temperature,

$$L \propto T^4 \quad L_{q.c} \approx \left(\frac{1}{4} \right)^{\frac{4}{18}} \times L_{\odot} \approx 0.735 L_{\odot}.$$

The flare luminosity of the core L_f is the solar luminosity L_{\odot} minus the luminosity of the non-flaring part of the core,

$$L_f = L_{\odot} - L_c = L_{\odot} \times \left(1 - \left(\frac{1}{4} \right)^{\frac{4}{18}} \right) \approx 0.265 L_{\odot} = m \times \epsilon_f = \frac{4\pi}{3} r^3 \rho_c \times \epsilon_f,$$

where ϵ_f is the specific energy production coefficient of the flaring volume and its value is $5 \times 10^{17} \text{ erg/sec}$, m is its mass and ρ_c is the average density of the core, 60 g/cm^3 . From the ratio $\Phi_{\nu}^{obs}/\Phi_{\nu}^{theor}$ we got L_f , with m and ϵ_f we can get the linear size r of the flaring volume, and with the density its mass as

r (from the neutrino flux) $\approx 2 \times 10^4$ cm, and $m = 1.8 \times 10^{15}$ g.

And the change in the temperature is only $\Delta T = 7.4\%$.

These flares in the solar core are triggered by some kind of movement of electric charges in a local magnetic field (Grandpierre, 1990), e.g. by planetary tides. Then the runaway shoots up the material of the flaring volume when the local actual Rayleigh number surmounts the critical value of the Rayleigh number as the linear size of the flaring volume grows (Grandpierre, 1984). We can estimate the size of the flaring volume from this theory, too, as

$$d_{crit} = 2\pi \left(\frac{\kappa\nu}{g\alpha\beta} \right)^{\frac{1}{4}},$$

$$d_{crit} \approx 2\pi \left(\frac{2.64 \times 10^{11} \times 1.36 \times 10^{-3}}{2.4 \times 10^3 \times 10^{-7} \times 4 \times 10^{-4}} \right)^{\frac{1}{4}},$$

r (from the Convective Flare Theory) $\approx 2.45 \times 10^4$ cm.

We can see that the two values for the size of the flaring volume are in good agreement. In taking for $\Phi_{\nu}^{obs}/\Phi_{\nu}^{theor} = 1/3$ only 3% changes is necessary in the temperature of the core. At the same time, it is clear, that the flare luminosity of the core is large enough to initiate the observed changes in the rotation of the core.

This phenomenon of the flaring core is the one which is able to interpret the flare related chemical anomalies of the Sun as the enhancement of the He^3/He^4 ratio with a factor of 10^4 . The observed Fe-enhancement also calls for a process arising above $10^9 K$ and high density.

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