STUDY OF LONG PERIOD GLOBAL OSCILLATIONS OF SUN THROUGH SPHERICAL HARMONIC FOURIER ANALYSIS OF SUNSPOT ACTIVITY

M.H.Gokhale
Indian Institute of Astrophysics
Bangalore 560034 India

ABSTRACT. A spherical-harmonic-fourier analysis of the maximum areas of sunspot groups listed in Ledgers I and II of Greenwich photoheliographic results for 1933-1954 yield significant peaks at the 11y periodicity for some spherical harmonic modes: especially the mode (ℓ = 6, m = 0). A similar analysis of the daily areas of the spotgroups during 1944-1954 yields 11y periodicity peaks only for some non-axisymmetric modes. These results suggest that the sunspot activity may be physically related to long period global oscillations of the sun.

1. INTRODUCTION

We present here results from two studies constituting spherical harmonic fourier (SHF) analysis of sunspot activity as a function of heliographic coordinates and time. In the first study each sunspot group is considered as resulting from a strong magnetic structure produced inside the sun at the heliographic location and time where and when the sunspot group is 'born'. The maximum observed area of a sunspot group during its entire lifetime, including recurrences if any, is taken as a measure of the magnetic flux in the structure and is subjected to SHF analysis. The data from Ledgers I and II of the Greenwich photoheliographic results during 1933-54 is used in this study. The second study consists of SHF analysis of the daily values of the sunspot areas during 1944-54. In this second study each day's area of each spotgroup gets treated as an independent event.

2. METHOD OF ANALYSIS

In the 'first' study, the time t_{ij} (in days and fractions, from the zero hour of 1st January 1933) of the first observation of each spotgroup 'i' and its heliographic coordinates (θ_{ij} , ϕ_{ij}) at that time are taken as approximations to the epoch and location of the 'birth' of the spotgroup. Spotgroups first observed more than 80° eastward of the central meridian are omitted owing to the large uncertainty in the longitude and time of their birth. A 'magnetic flux production function' is defined as:

J. Christensen-Dalsgaard and S. Frandsen (eds.), Advances in Helio- and Asteroseismology, 219–222.

$$\Phi(\theta,\phi,t) = \begin{cases} A_{max}(i)\,\delta(\theta-\theta_i, \phi-\phi_i, t-t_i) \text{ near } (\theta_i, \phi_i, t_i) \\ 0 \text{ elsewhere in } (\theta,\phi,t) \text{ space,} \end{cases}$$

and is subjected to SHF analysis using the data from 1281 spotgroups during 1933-43 and from 1389 spotgroups during 1944-54, separately and in combination.

In the 'second' study the areas A(i,j) corrected for foreshortening and the heliographic longitudes (θ_{ij}, ϕ_{ij}) of each sunspot group 'i', observed on each day 'j', are noted from the daily records of the Greenwich data. A 'sunspot activity function' is defined as:

$$\rho(\theta,\phi,t) = \begin{cases} A(i,j)\,\delta(\theta-\theta_{ij}, \phi-\phi_{ij}, t-t_{ij}) \text{ near } (\theta_{ij}, \phi_{ij}, t_{ij}) \\ 0 \text{ elsewhere in } (\theta,\phi,t) \text{ space,} \end{cases}$$

and is subjected to SHF analysis using 17000 data points available during 1944-54.

The SHF 'amplitudes' H_{cc}, H_{cs}, H_{sc} and H_{ss} for spherical harmonics of degrees ℓ = 0 to 9 and azimuthal orders m = 0 to ℓ are determined for frequencies ν = 0 to 9, (in units of 1/T), using:

$$H_{\substack{cc\\ss}}(\ell,m,\nu) = C_\ell^m \int_0^T dt \int_\Sigma f(\theta,\phi,t)\, P_\ell^m(\cos\theta) \begin{matrix}\cos\\ \sin\end{matrix}(m\phi) \begin{matrix}\cos\\ \sin\end{matrix}(2\pi\nu t)\, d\Sigma$$

where f(θ, ϕ, t) is the function to be analysed, T is the time span of the data, $d\Sigma$ is an element of area for interaction over the surface Σ of a unit sphere and C_ℓ^m are constants given by

$$C_\ell^m = \frac{1}{\sqrt{(2\pi)}}\,\frac{2\ell+1}{2\pi}\,\frac{(\ell-m)!}{(\ell+m)!} \quad \text{for } m \neq 0$$

$$\text{and} \quad C_\ell^o = \frac{1}{\sqrt{(2\pi)}}\,\frac{2+1}{4\pi}$$

The SHF 'powers' P_c and P_s are determined from:

$$P_c = (H_{cc}^2 + H_{cs}^2)^{1/2} \text{ and } P_s = (H_{sc}^2 + H_{ss}^2)^{1/2}$$

RESULTS

For several spherical harmonic modes, some of the fourier amplitudes H_{cc}, H_{cs}, etc, and/or powers P_c, P_s, show prominent peaks at $\nu = (1/11)y^{-1}$. These peaks are probably significant since none of the amplitudes or powers computed from a simulated data (cf. Gokhale, 1986) shows any significant peak at this frequency for any spherical harmonic mode.

In the 'first' study the data during 1933-1943 yields a peak at the 11y periodicity for the (6,0) mode whereas the data during 1944-54 yields

https://doi.org/10.1017/S0074180900158115 Published online by Cambridge University Press

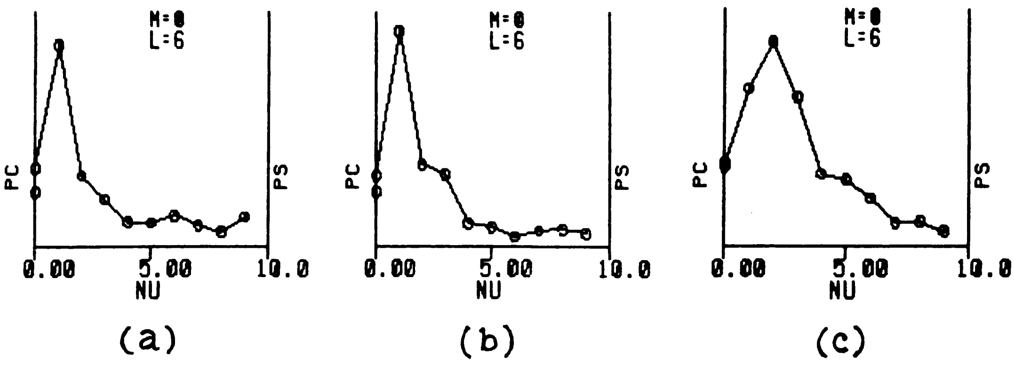

Fig.1. The 11y periodicity peaks in the plots of P_c $(6,0,\nu)$ obtained from the maximum areas of (a) : the 1281 spotgroups during 1933-1943, (b) : the 1389 spotgroups during 1944-1954 and (c) : the combination of (a) and (b). In (c) the unit of ν is $(1/22)y^{-1}$.

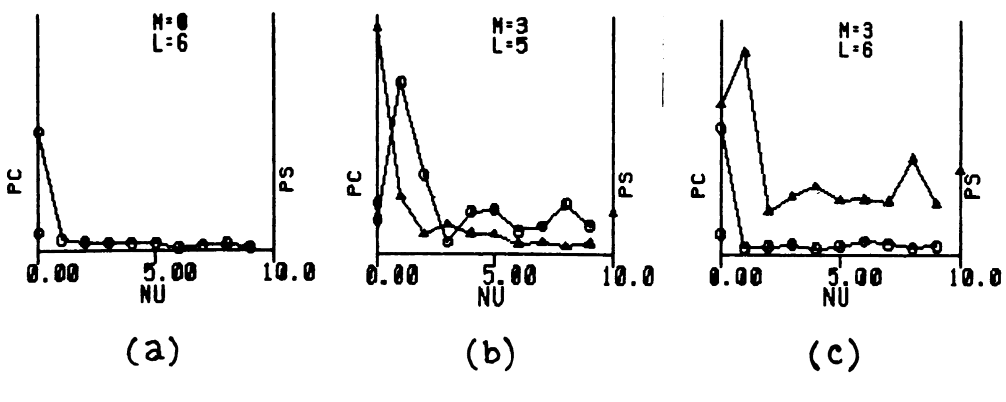

Fig.2. The plots of (a) : P_c $(6,0,\nu)$, (b) : P_c $(5,3,\nu)$ (-0-) and P_s $(5,3,\nu)$ (- Δ -), (c) : P_c $(6,3,\nu)$ (-0-) and P_s $(6,3,\nu)$ (-Δ-) obtained from the 17000 values of the daily areas of the 1389 spotgroups during 1944-1954.

https://doi.org/10.1017/S0074180900158115 Published online by Cambridge University Press

a peak at that periodicity for modes (1,0), (3,0), (5,0), (6,0) and (7,0). The combined data (1933-54) gives the 11y peak only for the (6,0) mode (See Figure 1).

The 'second' study does not yield 11y peak for any of the axisymmetric modes; not even for (6,0). However it shows this periodicity for the non-axisymmetric modes (5,3), (6,3), (7,5), (7,6) and (7,7). (See Figure 2 for illustration).

CONCLUSIONS AND DISCUSSION

The first study indicates that the sunspot activity may be originating in different slow global oscillations of the sun during different sunspot cycles and that the mode (6,0) may always be contributing. The second study indicates the effects of slow global oscillations on the sunspot magnetic structures after they (the structures) reach the surface. In this, the effects of axi-symmetric modes (eg. those detected by Howard and Labonte, 1980) seem undetectable. It will be interesting to see if, and how, the modes indicated by the first study are related to those detected by Stenflo and Vogel (1986) in the photospheric magnetic field. However the tentative conclusions of the present studies must be verified first by a more detailed analysis of a longer data series.

REFERENCES

Gokhale,M.H.: 1986, J.Astrophys. & Astron. (in press).
Howard,R. and Labonte,B.: 1980, Astrophy. J (Lett.) **239**, L33.
Stenflo,J.O. and Vogel,M.: 1986, Nature **319**, 285.