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Lifetimes and sizes of supergranular cells

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Abstract. Supergranulation is the surface manifestation of large scale solar convection. Since there is a strong correspondence between supergranulation pattern and Ca K chromospheric network, lifetimes and sizes may be obtained from the temporal and spatial autocorrelation functions (ACF), calculated from Ca K filtergrams of the Sun. We have developed a program to study the lifetimes and spatial scales of supergranulation through an extensive digital analysis. The temporal ACF was calculated from a 106 hour time-sequence of the data obtained from Antarctica. The lifetimes of quiet cells were found to be about 24-34 hours while that of active cells were about 58-61 hours. The temporal autocorrelation function sometimes showed an oscillatory pattern which may be due to long-term intensity variations or length scale changes associated with the network. The cell sizes were obtained from Ca K spectroheliograms belonging to the solar minimum phases of 1913-1974 from Kodaikanal Solar Observatory. The average cell size was found to show a curious dependence on solar latitude.

Key words : Sun, solar corona, supergranulation

1. Introduction

Supergranulation represents the large scale solar convection. The lifetime estimates of supergranular cells from various measurements range from 20 to 50 hours (Simon and Leighton 1964, Rogers 1970, Duvall 1980, Wang 1988, Singh et al. 1994). Lifetimes and spatial scales are also possibly dependent on the activity level (Singh and Bappu 1981, Singh et al. 1994). We have developed a digital method to obtain the lifetimes and spatial scales which is similar in principle to the usual analogue photographic correlation (Simon and Leighton, 1964), but simpler and more accurate. The lifetime of supergranular cells is obtained from the temporal ACF (Title et al. 1989), calculated from spatially aligned image sequence of Ca K (Raju, Srikanth and Singh 1997). The sizes are obtained from spatial ACF which compares the same image with different spatial offsets and yields information about spatial scales (Raju, Srikanth and Singh 1998).

2. Data

The data for the lifetime studies of supergranular cells were obtained from Antarctica during January 1990. The present analysis used about 300 Ca K filtergrams with a time-lapse of about 10 minutes. The central regions of the filtergrams were digitized with a pixel resolution of 1.65″. Data for the size determination comes from Ca K spectroheliograms, obtained at Kodaikanal Solar Observatory. Sixty spectroheliograms belonging to the solar minimum phases during the period 1913-1974 having no plages were used in the present analysis. This is because the presence of plage regions may affect the evaluation of autocorrelation length-scales. The image strips were digitized in directions parallel to the solar equator with a pixel resolution of 1.6″ arcsec at every 5° interval in solar latitude from 50° N to 50° S.

3. Results

(1) The temporal ACF for a window sequence and the straight line fit are plotted in Fig. 1. The lifetime is obtained from the straight line fit by calculating the time interval for the correlation to reach the e^{-1} value of the y-intercept. The lifetime estimate of quiet region cells is 24-34 hours while that of active region cells is 58-61 hours and for semi-active regions, it falls in the middle. This shows that the lifetime estimate is strongly dependent upon the activity of the region. The differences in lifetimes of active, semi-active and quiet region cells could be due to the different diffusion rates of flux transport in various regions (Schrijver 1989).

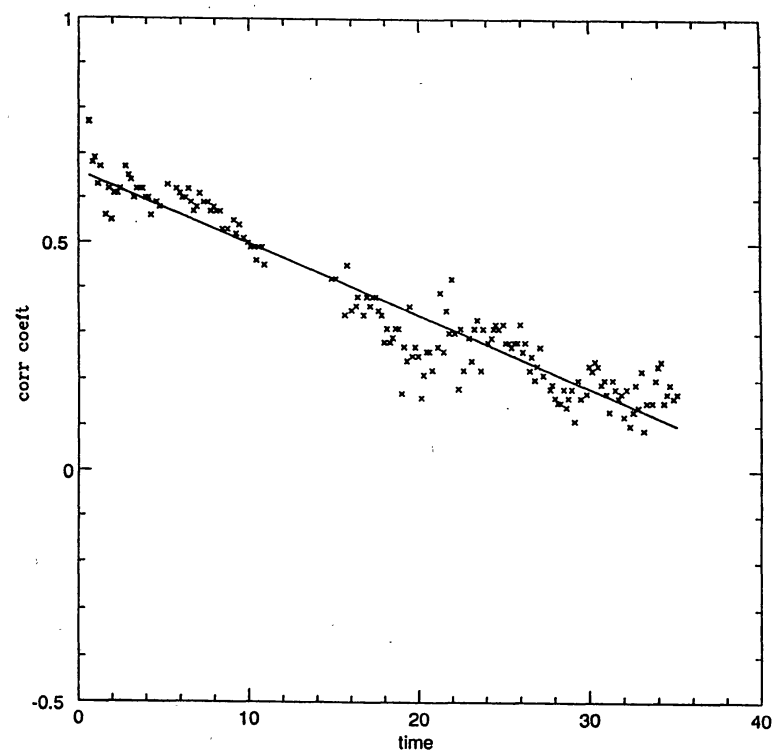

Figure 1. Temporal ACF for a window sequence. Correlation coefficient is plotted against time in hours. Solid line represents the least squares straight line fit.

(2) The temporal ACF shows a greater spread in quiet regions than in active regions. The spread in temporal ACF may be attributed to the short-lived structures inside the cell (Rogers 1970) and seeing-related atmospheric changes. The difference in spread in active and quiet regions could be then due to the stable cell features in active regions.

(3) The temporal ACF sometimes shows undulations which are weak in active regions and more prominent in quiet regions. They do not appear to be strictly periodic. The undulations observed by us may be due to some intensity variations associated with chromospheric network or intranetwork field elements (Zirin 1986) with durations of a few hours. Another possibility is that of changes in length-scales of supergranulation over an extended region.

(4) The average size of the network cells was found to have a dependence on solar latitude with a maximum variation of about 7%. The pattern (Fig. 2) shows an apparent north-south symmetry with two minima at 20° N and S. Further analysis with similar data also indicates the same trends. The various causes for such a behaviour, including that of magnetic fields, need to be further investigated.

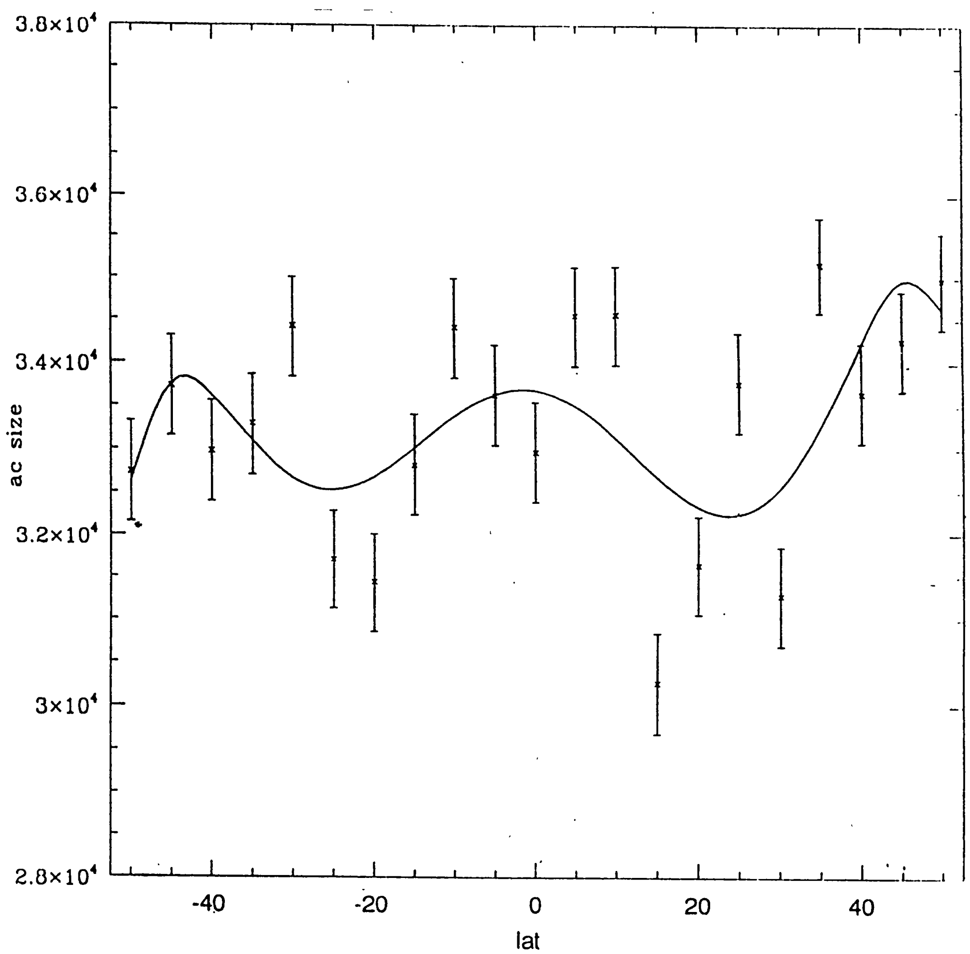

Figure 2. The mean autocorrelation size is plotted against latitude. The error bar indicates the probable error involved in the measurement of the mean. Solid line represents a sixth order polynomial fit.

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