Radio observations of long period oscillations in sunspots

N. Chorley, B. Hnat, A. R. Inglis & V. M. Nakariakov

Centre for Fusion, Space and Astrophysics, University of Warwick, Coventry CV4 7AL, UK

Introduction

• Sunspots: regions of intense magnetic field (~ 1 kG in the photosphere).

• They display various kinds of oscillations, e.g. 3 minute umbral chromospheric oscillations (Beckers & Tallant 1969).

• Knowledge of oscillations allows determination of physical parameters.

• Interest here is in using long period oscillations (P > 60 minutes) to probe the solar interior and dynamo.

• Long period oscillations also studied in other areas of solar physics, such as prominences (e.g. Wiehr et al. 1984) and filaments (e.g. Foullon et al. 2004). Could oscillations with similar periods in sunspot radio emission be connected to these?

• Magnetic flux tube of a sunspot could act as a waveguide for solar g-modes (oscillations for which the restoring force is gravity, P ~ 1-3 hours).

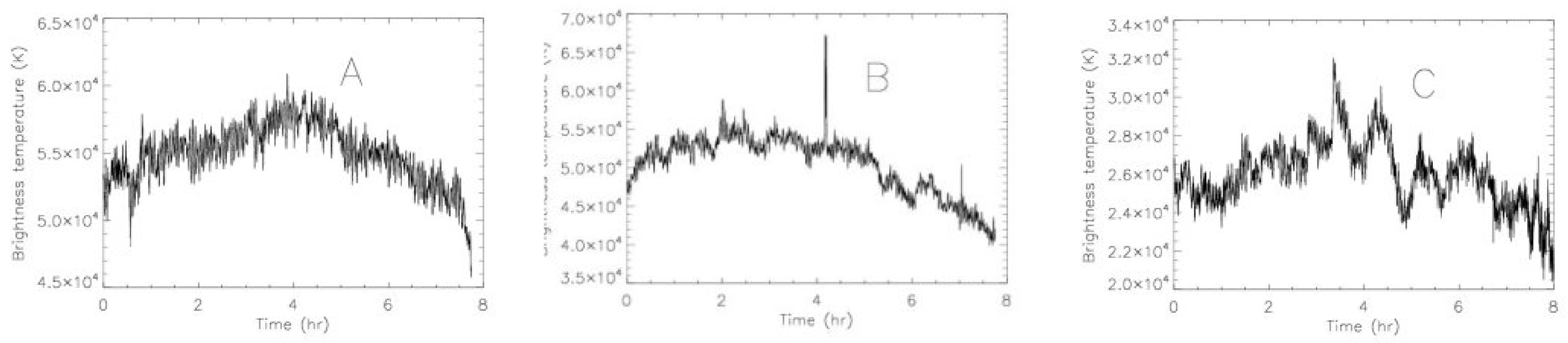
• **Aim: to confirm the presence of long period oscillations and to develop them as a tool for coronal seismology studies.**

Data

Time series generated from images for 3 sunspots observed by the Nobeyama Radioheliograph (NoRH, spatial resolution: 10″, temporal resolution: 1 s) are studied. The active regions were: A. AR0330 (08-09 April 2003), B. AR108 (10-11 September 2002), C. AR673(21-22 September 2004). The time series that we analysed are shown in the next column.

References

Beckers, J. M. & Tallant, P. E. 1969, Sol. Phys., **7**, 351
Foullon, C., Verwichte, E. & Nakariakov, V. M. 2004, A&A, **427**, L5
Huang, N. E., Shen, Z., Long, S. R., et al. 1998, Proc. R. Soc. Lond. A, **454**, 903
Nagovitsyn, Yu. A. & Vyal'shin, G. F. 1990, Soln. Dannye Byull., **9/90**, 91
Scargle, J. D. 1982, ApJ, **263**, 835
Wiehr, E., Stellmacher, G. & Balthasar, H. 1984, Sol. Phys., **94**, 285



Methods used in analysis

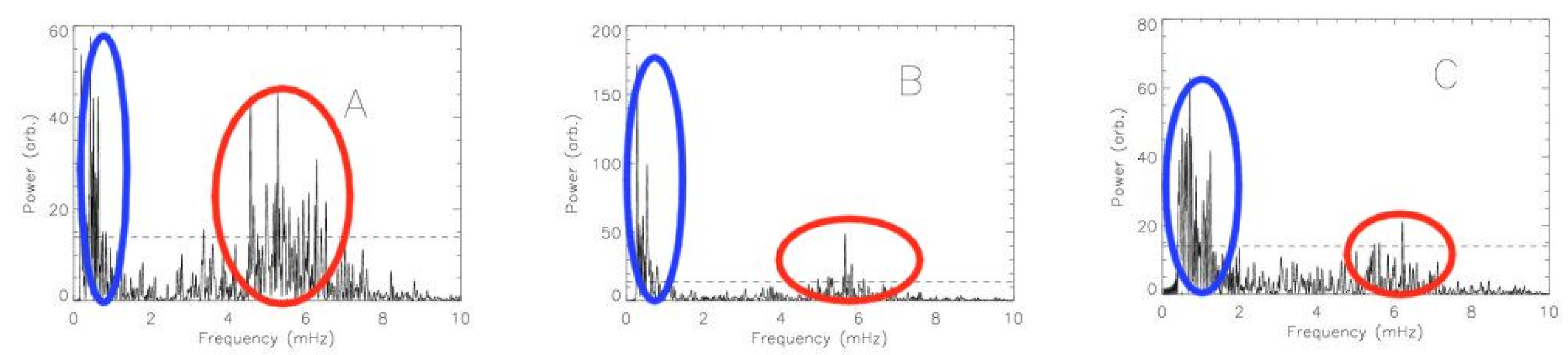
1. Trend removed by fitting 4th order polynomial and filtering out longest periods (oscillations with 3 periods or fewer).

2. Scargle periodogram (Scargle 1982) used for frequency analysis, since it allows simple estimation of significance level. Wavelets also used for time-frequency analysis.

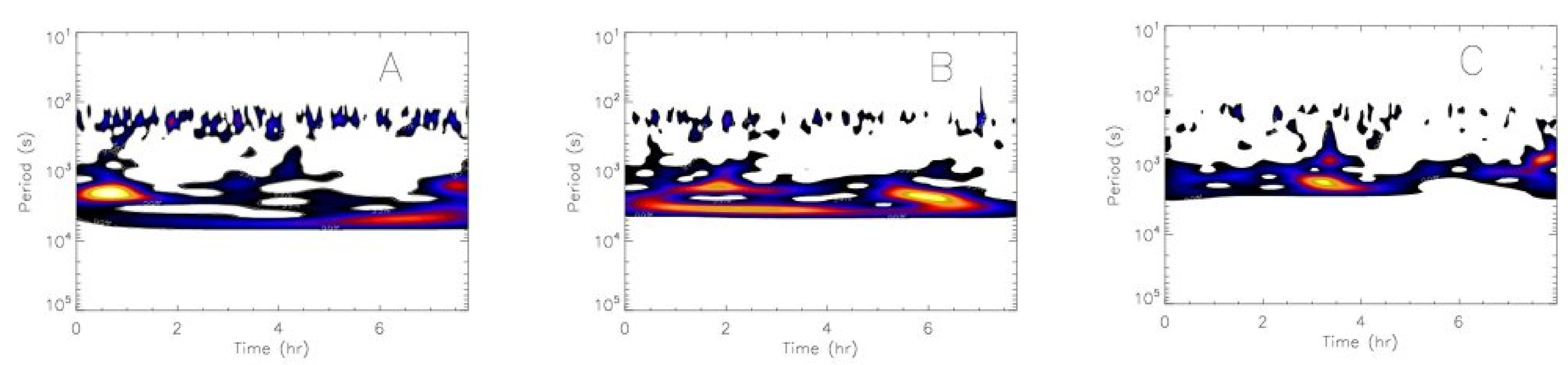
3. Empirical mode decomposition (EMD, Huang et al. 1998) used to check for presence of frequency modulation of the 3 minute oscillations by the longer periods. See also poster by J. M. Harris.

Results

1. Periodograms and wavelets

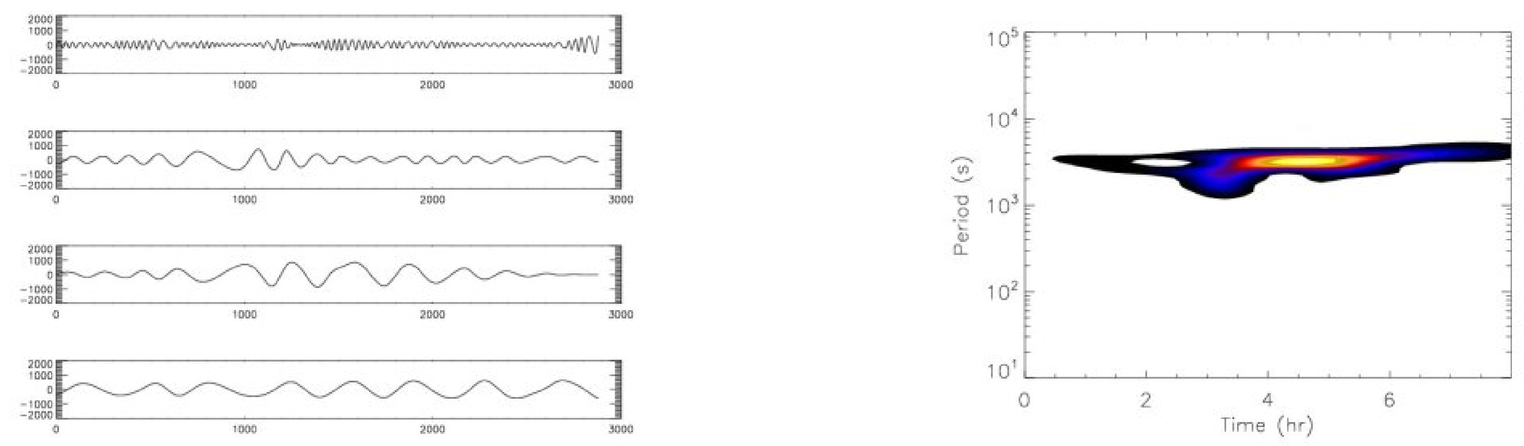


Blue ellipses: long period oscillations.
Red ellipses: 3 minute oscillations.



All three wavelet power spectra confirm the presence of the 3 minute oscillations seen in the periodograms above. Also, it is clear that the long period oscillations are present in all three datasets and that they are always present.

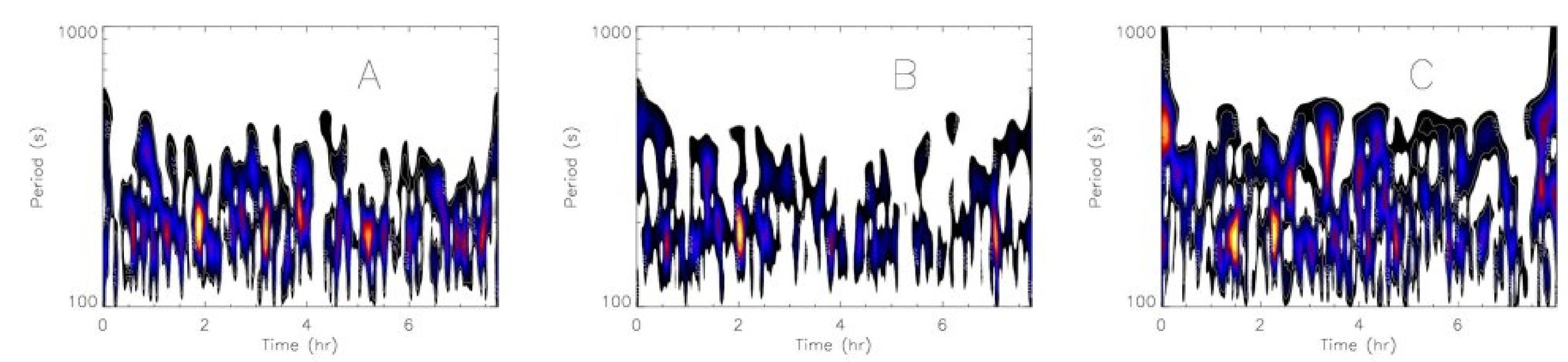
2. EMD + wavelets



Left: the highest amplitude intrinsic mode functions (IMFs) of the analysed signal, determined by EMD. The first signal is one of the "noise" components.
Right: Morlet wavelet power spectrum for the sum of the highest amplitude IMFs shown on the left.

3. 3 minute oscillation wavelets

In order to search for frequency modulation of the 3 minute oscillations by the longer periods, the frequency range [2, 10] mHz was investigated. Morlet wavelet power spectra for oscillations in this range are shown below. No wave train structure is present, as would be expected for frequency modulation.



Conclusions

1. Long period oscillations (several tens of minutes) are found to contain significant power in all three datasets.

2. The long periods persist throughout the observation periods and remain stable.

3. Evidence for frequency modulation of the 3 minute oscillations by the longer periods has not yet been found.

4. The periods found are consistent with those for the solar g modes and results are consistent with the white light results obtained by Nagovitsyn & Vyal'shin (1990).