

Long period oscillations in sunspots

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Introduction

Oscillations in sunspots are the subject of intensive investigation (for a review, see, e.g. Bogdan 2000) and various kinds of oscillations have been observed: umbral chromospheric oscillations, with periods of 3 minutes (thought to be slow magnetoacoustic waves), umbral photospheric oscillations, with periods of 5 minutes (which may be a response to driving by the p-modes) and longer period oscillations, with periods of several hours to several days.

Most of the work on sunspot oscillations to date has focused on the short period oscillations. Long period sunspot oscillations are interesting for various reasons, including their association with dynamical processes in the solar interior and their role in solar coronal dynamics.

The “shallow” sunspot model of Solov’ev & Kirichek (2008) has been proposed to explain such long period oscillations. According this model, a sunspot can oscillate like a raft in water, with the frequency determined by the ratio of the sunspot depth to the Alfvén speed. For typical values of sunspot magnetic field strength, surface mass density and depth, the oscillation period of the global mode was estimated to be $P \approx 90$ min.

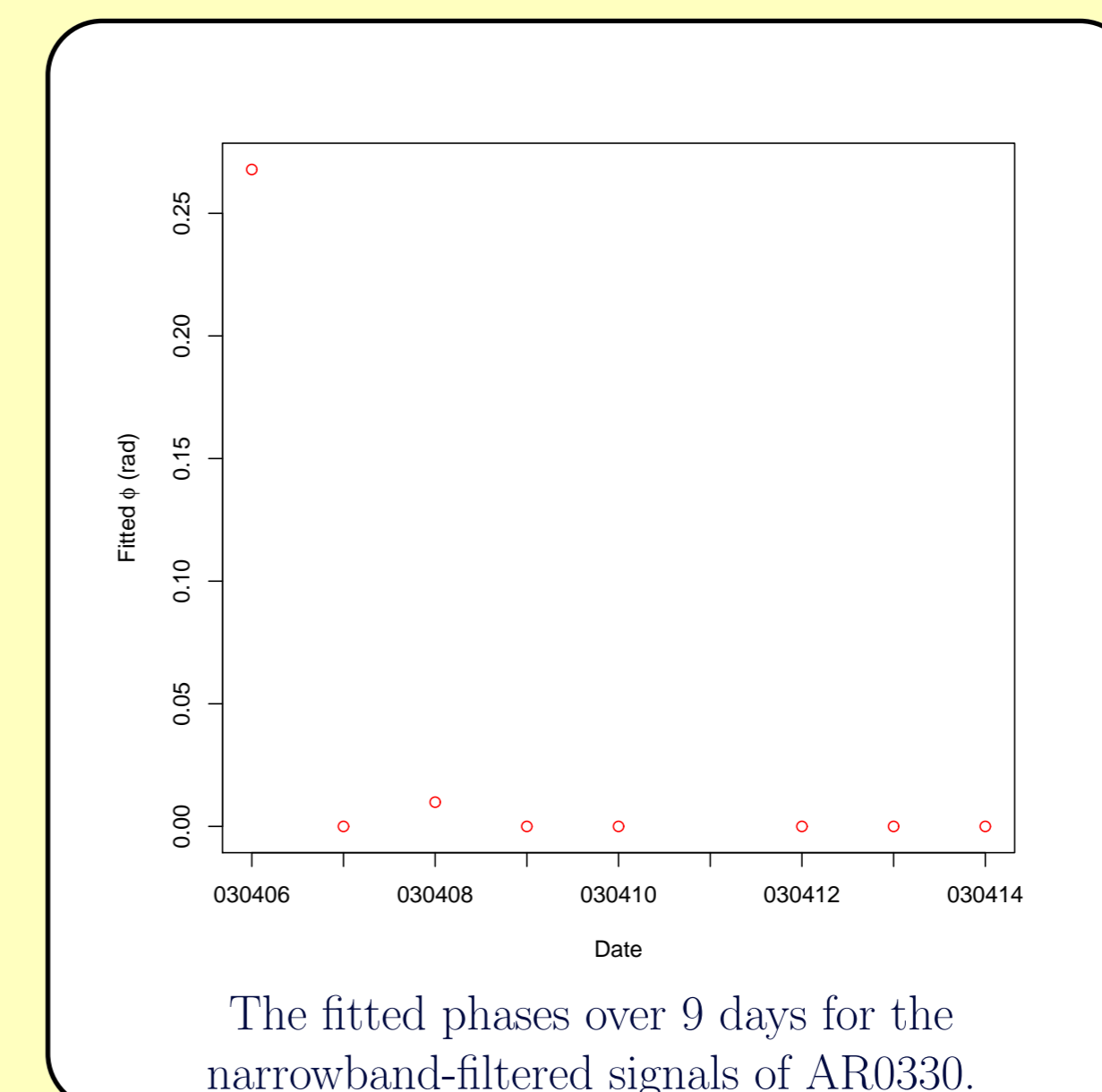
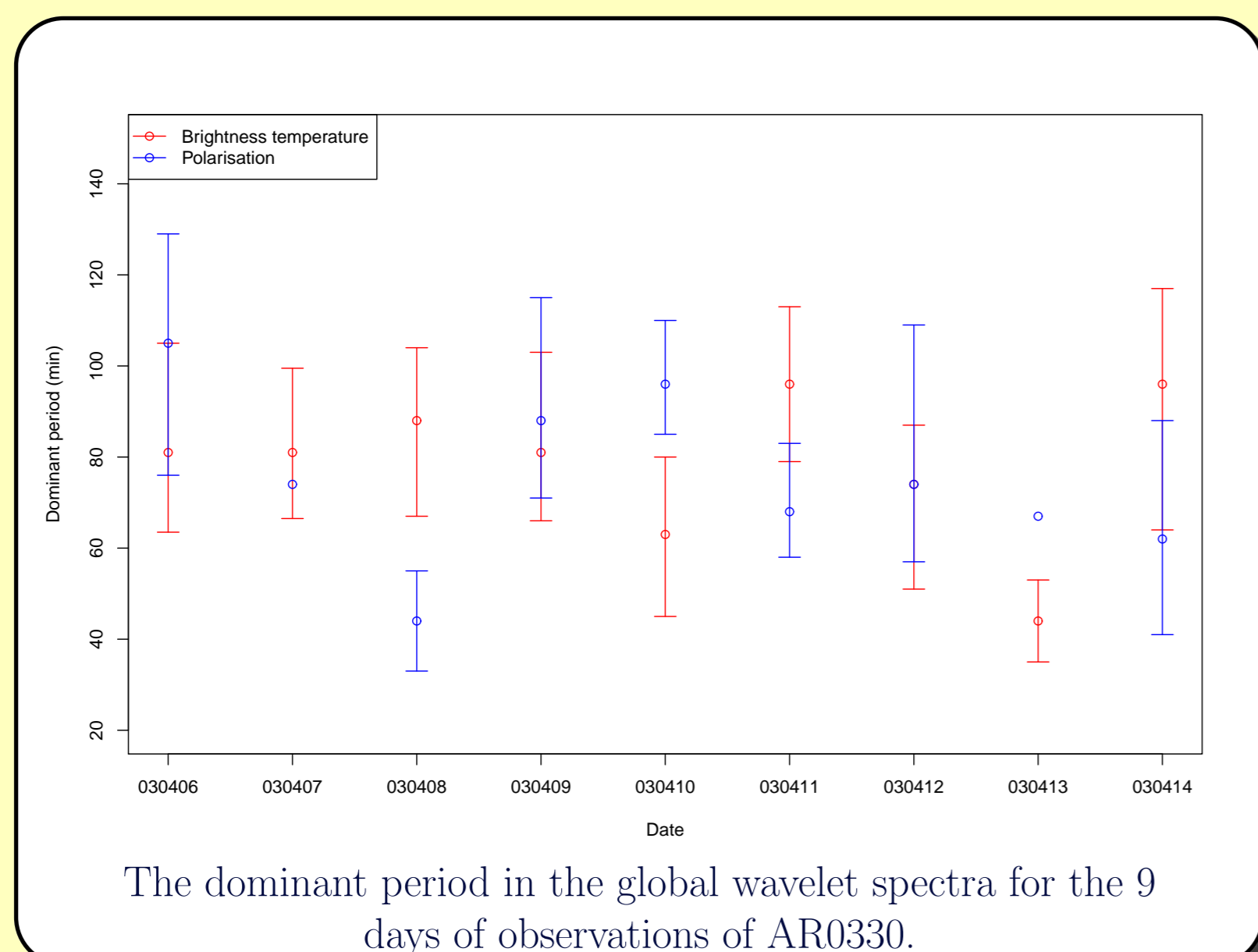
Here, we present a study of long period sunspot oscillations in the radio band, utilising both temporal and spatial information. In addition, we present preliminary results related to the lifetime of the oscillations in one sunspot.

References

- Bogdan, T. J. 2000, Sol. Phys., 192, 373
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 Inglis, A. R., Nakariakov, V. M., & Melnikov, V. F. 2008, A&A, 487, 1147
 Nakariakov, V. M. & King, D. B. 2007, Sol. Phys., 241, 397
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Lifetime of the oscillations

- Nine days of NoRH observations of AR0330 were analysed, following the sunspot’s passage across the solar disk.
- Scargle periodograms revealed the presence of long period oscillations (periods of several tens of minutes) in all 9 signals.
- Signals for all 9 days were narrowband filtered to contain typical long periods of interest (70-85 min). Harmonic functions were then fitted to determine the phases of the oscillations.

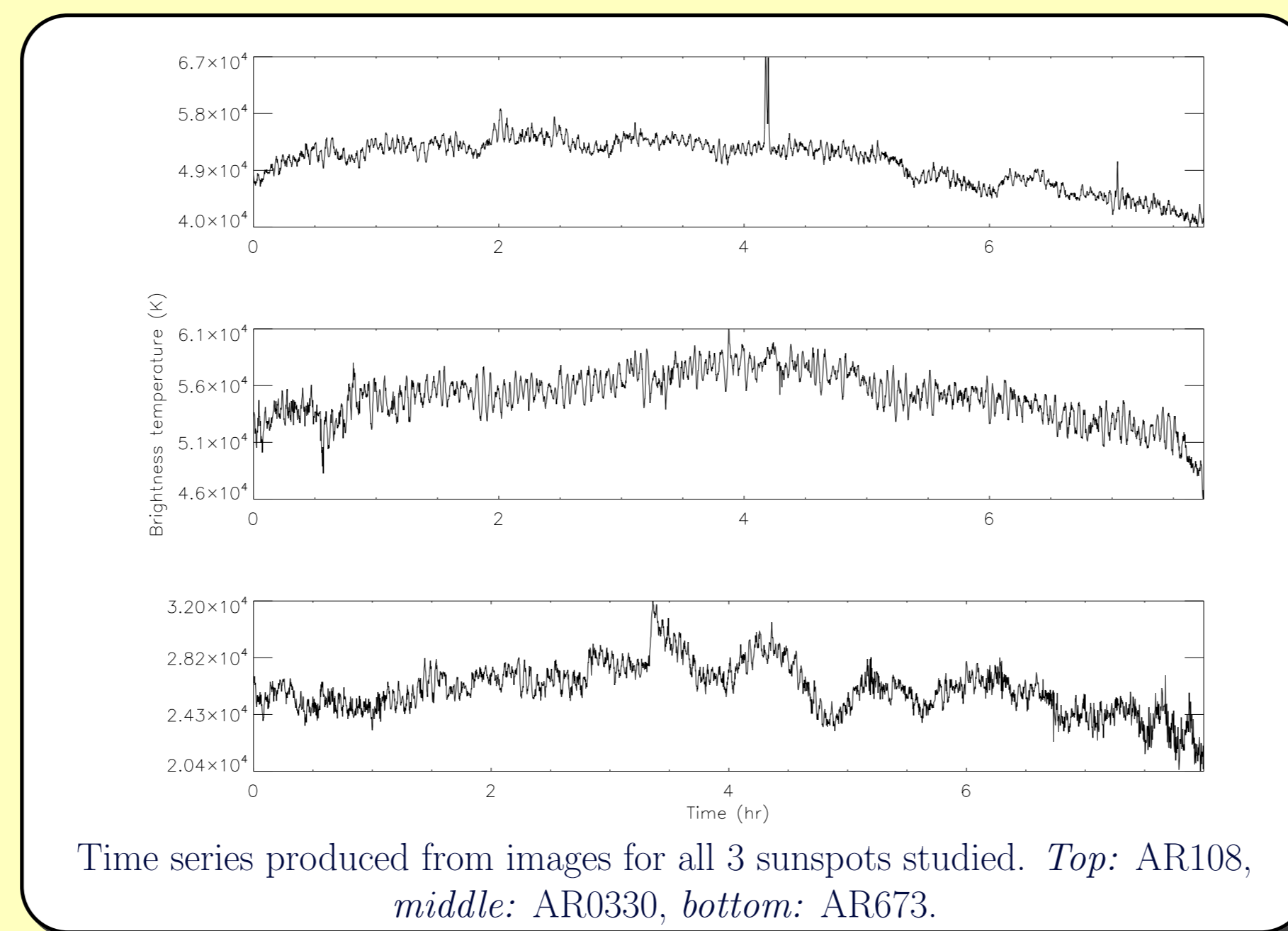


Conclusions

- Significant long period ($P \approx 16-88$ min) oscillatory components are present in the time signals for all 3 analysed sunspots.
- The spectra for all the sunspots show at least two such components, which in general have higher power than the 3 minute oscillations.
- The periodicities stay constant during the observations, without any significant drift.
- Spatial analysis reveals regions of higher power in the umbral region and regions of coherent oscillation, oscillating both in phase and in anti-phase with a master (reference) pixel.
- The long period oscillations seen in AR0330 appear to be present over 9 days of observation and periods in the range $P = 70-85$ min appear to have similar phases.
- Observations are consistent with the “shallow” sunspot model of Solov’ev & Kirichek (2008).

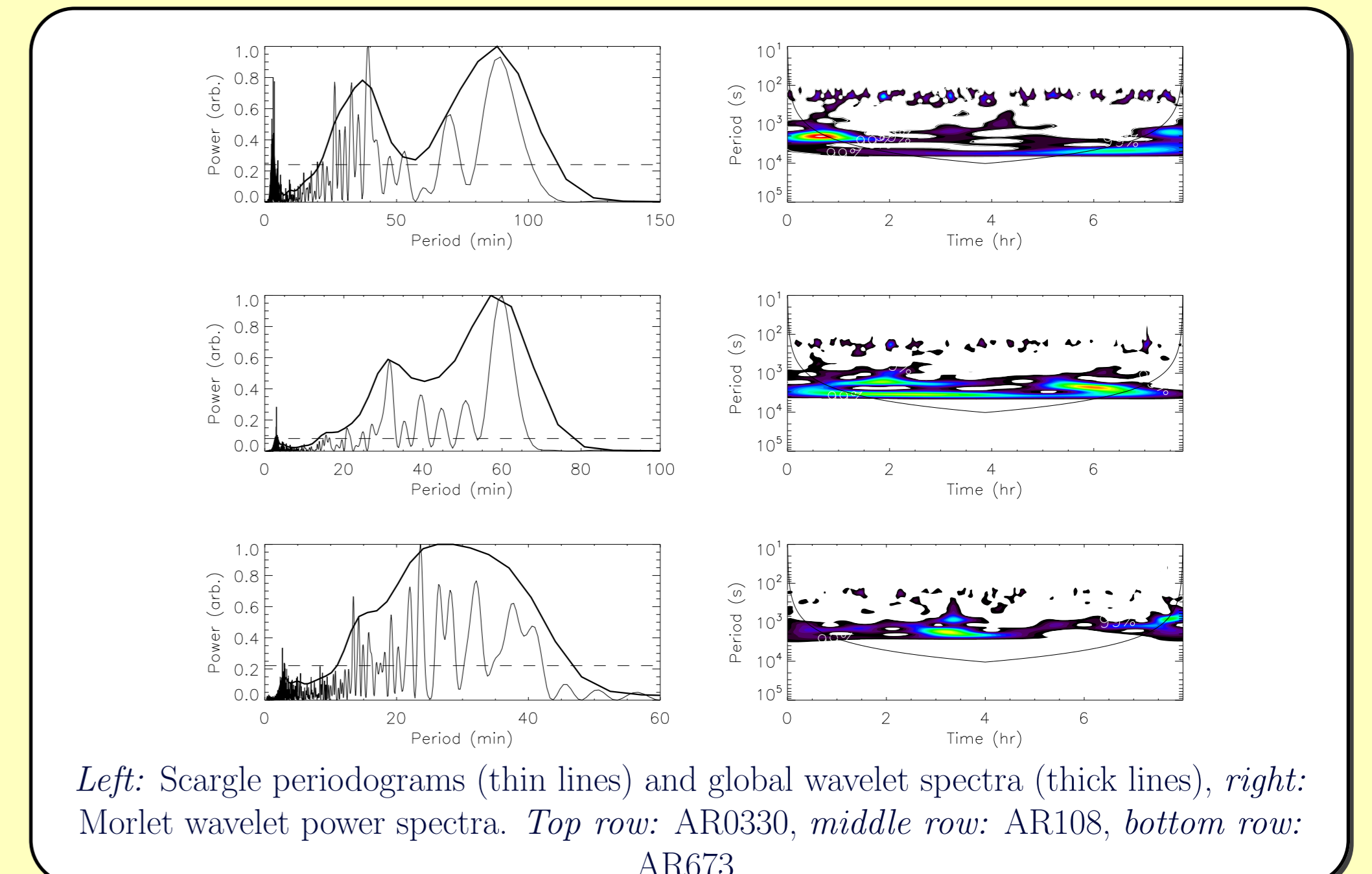
Observations

- Three sunspots were observed with the Nobeyama Radioheliograph (NoRH), operating at a frequency of 17 GHz: AR0330 (08-09 April 2003), AR108 (10-11 September 2002), AR673 (21-22 September 2004).
- Time series were generated from partial disk images by integrating over the field of view.



Temporal analysis

- Signals were detrended with a 4th order polynomial and then filtered to remove ultra long, slow varying dynamics.
- Scargle periodograms (Scargle 1982) and wavelet power spectra were computed for the signals after detrending and filtering.
- Clear evidence of two significant low frequency spectral peaks in all 3 analysed sunspots. The long periods are seen to be persistent throughout the observations.



Spatial analysis

- Global wavelet spectra show 2 distinct low frequency peaks for AR108 and AR0330.
- Datacubes were filtered to contain each period separately and then subjected to period, power, correlation and lag map analysis (for full details, see Nakariakov & King 2007; Inglis et al. 2008; Chorley et al. 2010).
- The power is seen to be concentrated in the umbral regions and regions of coherent oscillation can be seen (this is most evident in the fourth map in the second figure below).

