Frequency Shifts on Time Scales of Nine Days

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Introduction

Mode frequencies are thought to be associated with individual active regions that come and go continuously and hence one would anticipate that the frequencies also change continuously on any time scale. But due to the finite lifetime of the modes, the correlation between frequency and activity may depend on the length of the observing run. To test this, we study temporal variations in the frequency shifts and their correlation with solar activity. Using ten years of GONG data, we calculate *p*-mode frequencies on a time scale as short as nine days. The result is compared with MDI and standard GONG data.

Data and Analysis

- We use GONG time series of nine days length to produce the power spectra and process these through the GONG pipeline to measure the mode frequencies.
- The data consists of 424 nine-day sets and covers a period of ten years between May 7, 1995 and October 16, 2005.
- The mean frequency shifts are calculated by weighting the individual mode shifts by mode mass and the inverse of the errors.
- The correlation between the frequency shifts and activity indices are computed using four different activity indices:
  - (a) the integrated radio flux at 10.7 cm (F_{10}),
  - (b) the magnetic plage strength index (*MPSI*)
  - (a) the International sunspot number (R_I),
  - (d) Mt. Wilson Sunspot Index (*MWSI*).

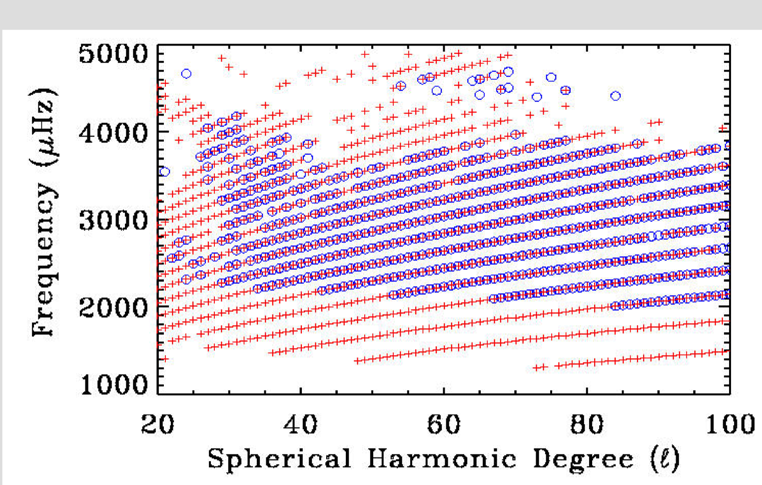

Figure 1: The ℓ-ν diagram showing oscillation modes for nine day samples covering the period September 16-24, 2004 and for the 108-day samples corresponding to the period August 8 – October 21, 2004.

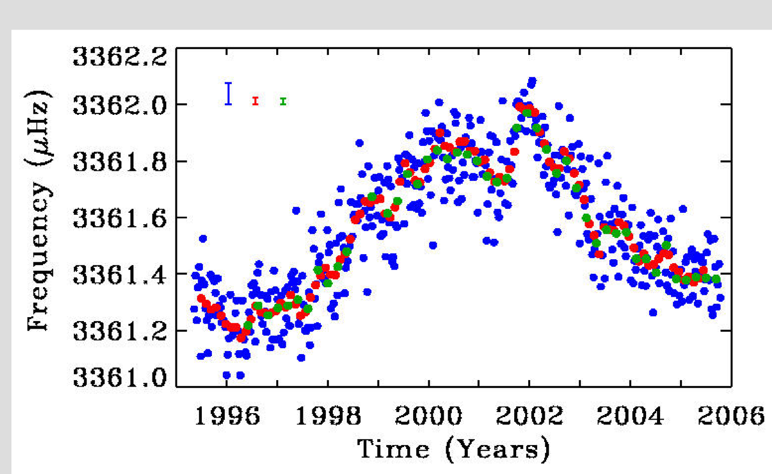

Figure 2: Variation of the central frequency for the n=9, ℓ=81 mode from nine and 108-day time samples from GONG and 72-day time samples from MDI. The uncertainties in the fitting are shown in the upper left corner.

Table I: Results of linear fits to different activity indices and correlation statistics for weighted frequency shifts from time series of different length. The slope which measures the shift per activity index (i.e. sensitivity of the shift) is higher for short duration observation while correlation coefficients are independent of the observing run.

Length (Days)	F_{10}		MPSI		R_I	
	Slope	P_p	Slope	P_p	Slope	P_p
9	2.44 ± 0.04	0.94	114.91 ± 2.04	0.94	2.40 ± 0.06	0.90
72 (MDI)	1.75 ± 0.04	0.99	79.45 ± 2.23	0.99	1.81 ± 0.07	0.97
108	1.76 ± 0.02	0.99	79.87 ± 1.33	0.99	1.84 ± 0.04	0.94

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Table II: Results of linear fits between frequency shifts and activity indices in rising and falling phases of cycle 23. Each phase consists of about four years of data.

Activity Index	Ascending Phase		Descending Phase		Sigma
	Slope	Pp	Slope	Pp	
F_{10}	2.53 ± 0.08	0.94	2.32 ± 0.08	0.92	- 2.78
MPSI	129.7 ± 3.7	0.95	106.8 ± 3.5	0.93	- 6.40
MWSI	358.3 ± 26.1	0.73	248.4 ± 24.5	0.62	- 4.34
R_I	2.3 ± 0.08	0.91	2.5 ± 0.12	0.85	1.86

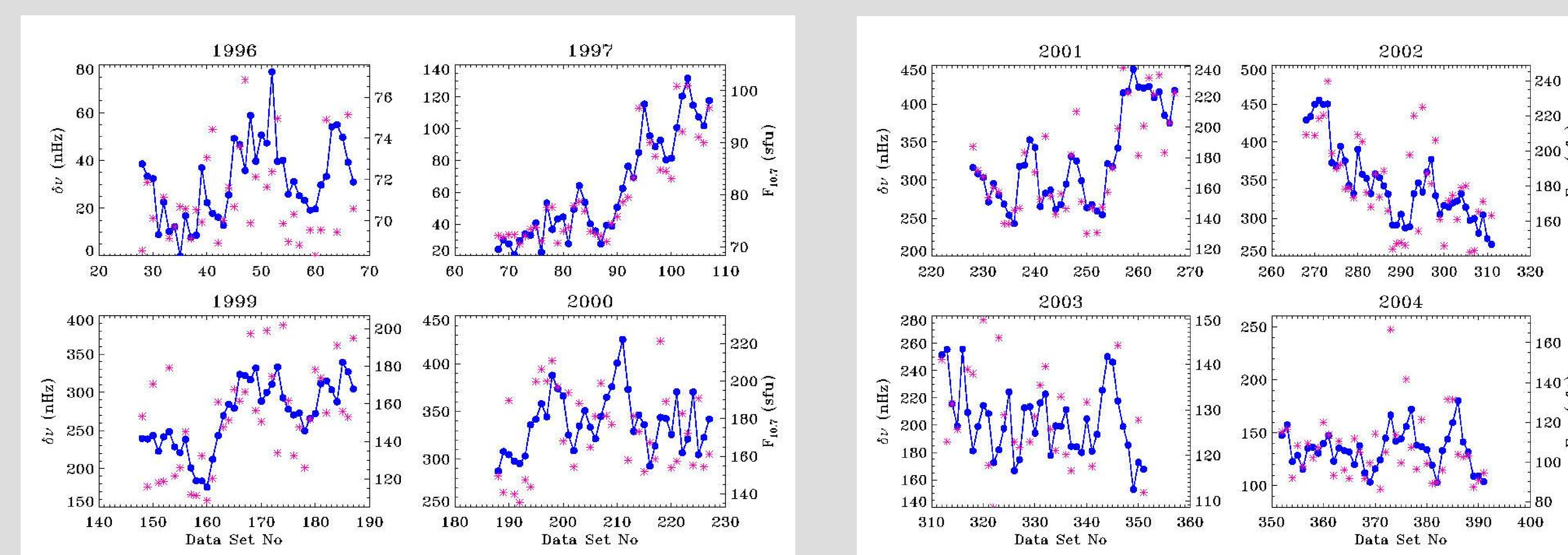

Figure 3: The blue lines denote the year wise distribution of frequency shifts obtained from nine-day frequencies. The pink symbols represent the variation in 10.7cm radio flux.

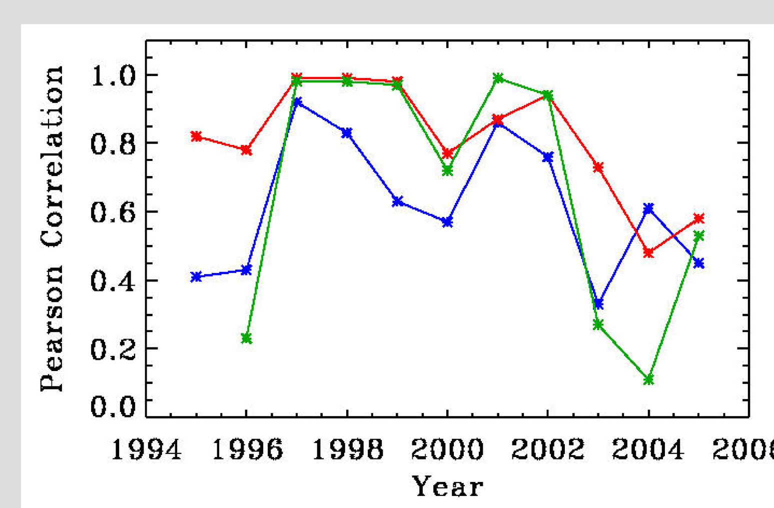

Figure 4: The Pearson correlation coefficients between 9-day and 108-day GONG frequencies and 10.7 cm radio flux. The correlation for MDI data is also shown.

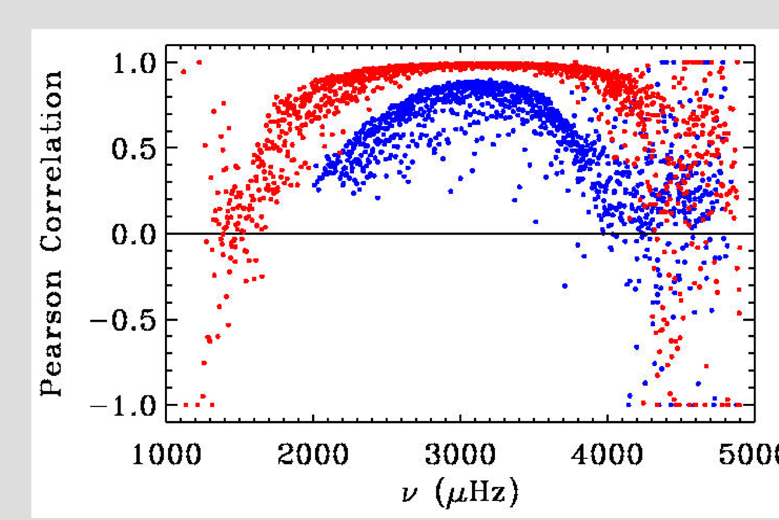

Figure 5: The Pearson correlation coefficients between frequency shifts and 10.7 cm radio flux for all modes present in the nine-day and 108-day frequency files.

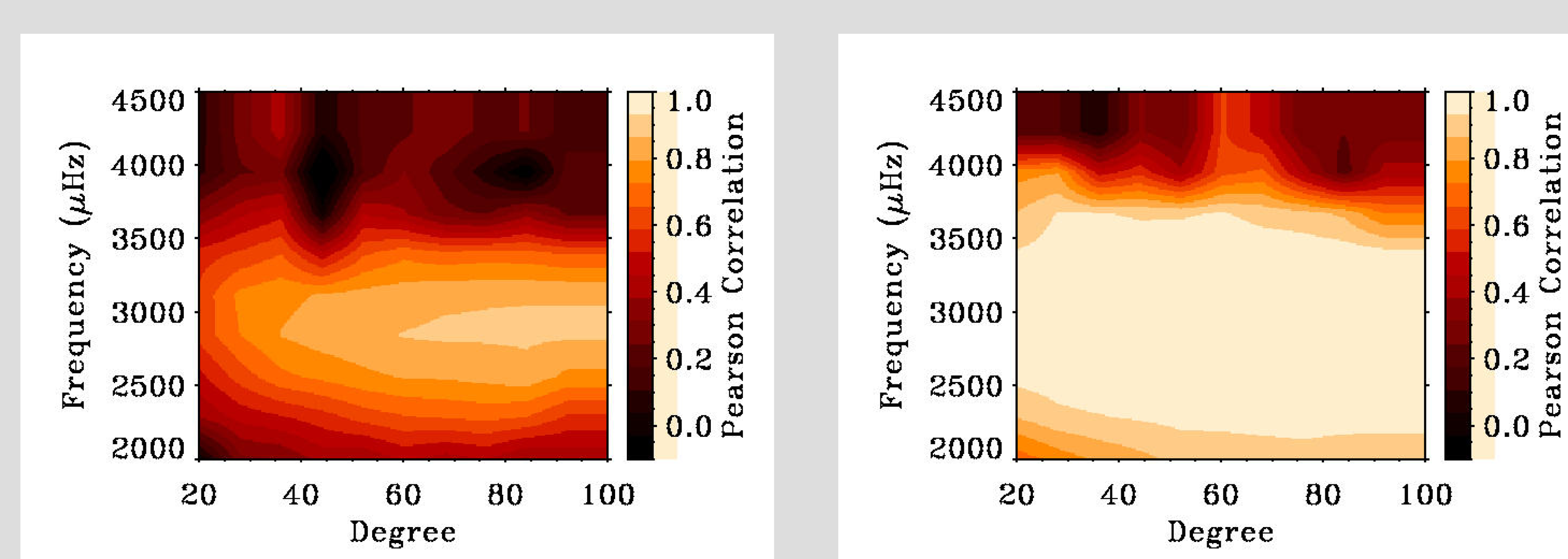

Figure 6: Correlation maps between 9-day (left) and 108-day (right) frequency shifts and 10.7 cm radio flux as a function of degree (ℓ) and frequency showing that the relation between frequency shift and activity is complex.

Summary

- Individual multiplets show significant temporal variations with solar cycle.
- Frequency shifts measured from nine-day are consistent with that derived from longer time series of GONG and MDI
- Correlation between frequency shift and activity indices varies on a yearly basis and is a function of the sensitivity factor. The correlation between different lengths of the observation is similar while the sensitivity factor is higher for frequencies obtained from short duration time series.
- The shifts also distinguish between ascending and descending phases of the magnetic activity cycle.
- The correlation between the frequency shifts and activity is more complex than thought earlier.