ARE SOLAR P MODES CORRELATED ?

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Abstract. We have studied the statistical properties of the energy of individual p modes, extracted from 310 days of GOLF data near the solar minimum. The exponential distribution of the energy of each mode is clearly seen. The modes are found to be uncorrelated with a $\pm 0.6\%$ accuracy, thus supporting the hypothesis of stochastic excitation by the solar convection.
The same analysis performed on the same modes just before the solar maximum, using IPHIR data, rejects the hypothesis of no correlation at a 99.3% confidence level. A simple model suggests that $31.3 \pm 9.4\%$ of the energy of each mode is coherent among the modes studied in IPHIR data, corresponding to a mean correlation of $10.7 \pm 5.9\%$.

1. GOLF and IPHIR data sets

We have considered the set of p modes corresponding to $17 \leq n \leq 25$, $l = 0$ and 1, observed by GOLF between 11th April 1996 and 14th February 1997, filtered through a window of $\Delta\nu = 8\mu Hz$. The two m-components of the mode $l = 1$, however, are not separated. After removal of the data surrounding a gap in the series, the sample is made up of 210 points for each mode.
We have also extracted from IPHIR data the same 11 modes as Baudin et al. (1996) ($l = 0$, $19 \leq n \leq 23$, and $l = 1$, $18 \leq n \leq 23$). The size of the filtering window is reduced to 6μHz due to the higher level of noise. The sample is made up of 78 points after removal of the data surrounding two gaps in the series.

2. The distribution of energy of each mode is exponential

Following the picture of p-mode excitation by turbulent motions (Goldreich & Keeley 1977), we have compared the observed energy distribution of each mode with an exponential distribution (Woodard 1984).

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A first test measures the variance of the normalized distribution of energy. A second one considers the maximum distance between the observed and theoretical cumulative distributions (Kolmogorov-Smirnov test, hereafter KS). These two quantities are compared with those obtained from artificial exponential series, using a Montecarlo simulation of 10^5 trials.
The output of each test, denoted by $P_{|V|}$ and P_{KS} is therefore a probability that the observed value corresponds to the output of a Montecarlo simulation.
These tests agree very well with exponential distributions, both for GOLF and IPHIR.

3. Correlation coefficient

If excited by the granules, the exponentially distributed modes energies would be independent. The sum Υ_k of their normalized energies should then be distributed as a Gamma distribution Γ_k, which we test with the variance and KS tests. Both tests agree with this "null hypothesis" when applied to GOLF data: $P_{|V|} = 49.9\%$, $P_{KS} = 76.2\%$ for 9 modes $l = 0$, and $P_{|V|} = 95.8\%$, $P_{KS} = 66.5\%$ for 18 modes.
By contrast, the same tests applied to IPHIR data *reject the null hypothesis* with a 99.3% confidence level with the variance test, and a 95.7% confidence level for the KS test ($P_{|V|} = 0.7\%$, $P_{KS} = 4.3\%$).
A refined estimate of the correlation can be obtained by making some assumptions about the origin of the correlation. We build the distribution function Γ_k^λ where a fraction λ of the energy of each mode is due to a common random signal, added to the velocity of each mode, resulting in a correlation $\mathcal{C} = \lambda^2$. This "λ-hypothesis" is also tested with the variance and KS tests. The error bar of the correlation coefficient is defined as the range within which each test remains inside the upper 68.3% region. Both tests, applied to 18 modes of GOLF for various values of λ, give $\mathcal{C} \leq 0.6\%$, which is the sensitivity limit of the test. Applied to IPHIR data, the variance test obtains $\mathcal{C} = 6.1 \pm 3.3\%$, while the KS test obtains $\mathcal{C} = 10.7 \pm 5.9\%$.
No correlation was found between 11 windows of noise centered $20\mu Hz$ to the right of each mode, thus ruling out the possibility of a pointing noise origin.

4. Conclusion

The correlation found in IPHIR data reveals the existence of a source of coherent excitation of p modes, in addition to the well known granules excitation. The difference between IPHIR and GOLF data would indicate a change in the fraction of the energy coming from this additional source, varying from $\lambda = 31.3 \pm 9.4\%$ in IPHIR data to less than 8% in GOLF data. Details about our method can be found in Foglizzo et al. (1997). If related to the change in magnetic activity, a confirmation will be obtained by performing the same analysis on GOLF and VIRGO data when we approach the solar maximum, in a couple of years.

References

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