SEARCHING FOR G-MODES AT THE SOLAR LIMB

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Abstract. We have used a differential technique to look for the signature of g-modes at the limb of full-disk intensity images of the Sun. Our spectra show tentative evidence for a set of peaks that are equally spaced in period, as predicted by asymptotic theory. The period spacing that we find is ~ 27.5 minutes. If interpreted as $\ell = 1$ g-modes, this implies $T_0 \sim 39.0$ minutes.

1. Introduction

Unlike p-modes, g-modes are expected to have large amplitudes in the deep interior of the Sun. This makes them significantly more sensitive to the structure of the Sun's central regions than the p-modes, and, potentially, a powerful diagnostic of those parts of the Sun. However, because g-modes are evanescent in the Sun's convective zone, only small amplitude oscillations survive to the surface.

The common way to look for g-modes is to search for peaks that are equally spaced in period as predicted by asymptotic theory. To first order the period $T_{n\ell}$ of a mode (m=0) is given by $T_{n\ell} = T_0[n + \ell/2 + \delta][\ell(\ell + 1)]^{-1/2}$ where T_0 is the asymptotic period spacing and δ is a constant $\simeq -0.25$. Since the frequencies expected for g-modes are very low, solar and terrestrial atmospheric "noise" seriously hamper any measurement efforts.

A recent calculation predicts that the g-mode signal in intensity should peak very close to the solar limb (T. Toutain, private communication). Therefore, we have developed a technique which differences the signal in a narrow annulus at the limb from the signal in an adjacent (interior) annulus in order to reduce the background "noise" signal and thus enhance the probability of detecting g-modes.

2. Observations and Reductions

The data used for this project was obtained at the South Pole during the austral summer of 1994/95. The full solar disk in the Ca K-line was recorded with ~ 2 arc sec pixels every 42 seconds. In total there are ~ 62 days of observations with a fill factor of $\sim 47\%$.

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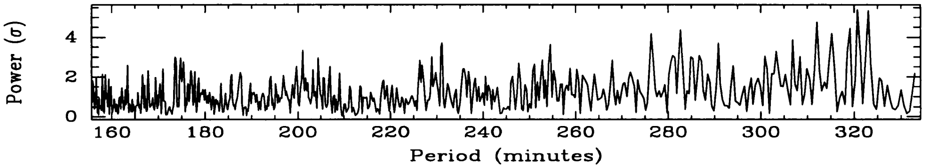

Figure 1. The ℓ=2 power spectrum plotted against period.

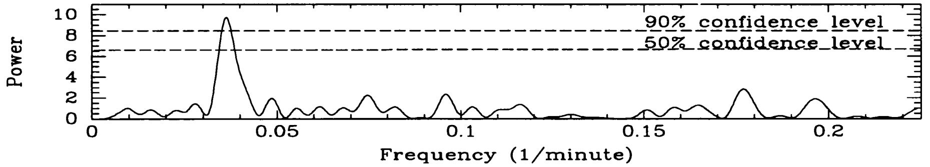

Figure 2. The periodogram of the spectrum shown in Figure 1.

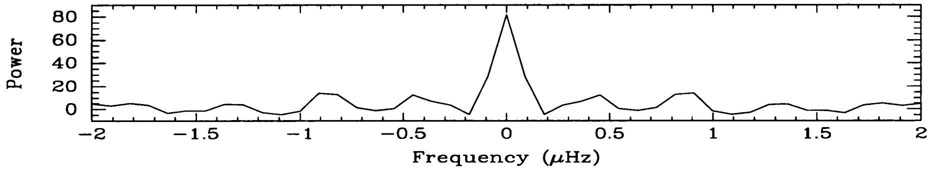

Figure 3. The autocorrelation of the spectrum shown in Figure 1.

The images were restored to a common blurring using a modification of the technique described by Toner *et al.* 1997. Each image was registered to a common size and orientation and the ratio $(Observed\ image - Reference\ image) \div Reference\ image$ was binned by azimuthal angle in two narrow annuli at/near the limb, then the annulus signals were differenced. Finally, the power spectrum was obtained using a 2-D FFT of the difference data.

3. Results

The $\ell = 2$ spectrum for $50 \leq \nu \leq 110$ μHz is plotted in Figure 1 as a function of period in minutes. While the spectrum is noisy, there is a suggestion of equally spaced "blobs" of power. We have used the periodogram program of Horne and Baliunas (1986) to see if there a periodic signal in the spectrum. The periodogram shows a strong peak at the $\sim$ 95% confidence level at a frequency corresponding to a peak spacing of 27.6 minutes (Figure 2). If interpreted as $\ell = 1$ g-modes ($\ell = 1$ signal will appear in ℓ =2 and 3 due to spatial leakage), this implies an asymptotic period spacing, T_0, of $\sim$ 39.0 minutes. The $\ell = 1$ and $\ell = 3$ periodograms show similar peaks at 27.4 minutes and 27.2 minutes, respectively. The $\ell = 3$ periodogram also has a peak at 15.9 minutes, which is consistent with the expected spacing for $\ell = 2$ g-modes for the same T_0. Figure 3 shows the autocorrelation of the spectrum shown in Figure 1. The peaks at lags of 0.45, 0.9, and 1.3 μHz may be the signature of rotational splitting. Further work is required to understand the spatial response function of our observations before we can comment on the validity of these signals.

References

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Horne, J.H., and Baliunas, S.L. 1986, *Astrophys. J.* **302**, 757.