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SOLAR 5-MIN OSCILLATIONS AT 2.23 μm

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INTRODUCTION

Large amplitude infrared 2.23 μm solar intensity oscillations were detected in photometer observations obtained at Oslo Solar Observatory in 1987 and 1988. Five wavelength regions ranging from 0.67 μm to 2.23 μm and 7 circular entrance apertures ranging from 0.5 to 4.3 arc min were observed simultaneously at all wavelengths with the same detector. The 2.23 μm region showed remarkably higher amplitudes than the other 4 wavelength-regions. The observed power was contentrated to the 2.5 - 3.5 mHz region suggesting that we observe the well known 5 min oscillations (Leifsen and Maltby, 1990).

OBSERVATIONS AND DATA REDUCTION

Two main questions arise from the photometer observations; one relates to the high power observed at 2.23 μm and the other concerns the nature of the power spectrum. We have choosen to address these questions by using the McMath telescope with its Fourier Transform Spectrometer at National Solar Observatory at Kitt Peak. Two observing modes were used: A 50 arc sec circular area at the solar disk center was observed using the McMath East Auxilliary Telescope. Spatially integrated light was observed using the McMath main heliostat and two flat mirrors. Active guiding was used in the imaged mode. Two timeseries were obtained in May 1991; one in the imaged mode at the solar disk center over a 4 day long period and one with integrated light lasting 6 days. These observations consist of timeseries of spectra separated in time by 1 minute and with a spectral resolution of 0.014 Å in the spectral range 2.0 - 2.5 μm. Each spectrum contains 825 Kilobytes of data. Twelve hours of observations result in 580 Megabytes of data. In order to handle these long timeseries each spectrum was divided in shorter spectral intervals (typically 630 Å for a timeseries of four days duration) and stored on several optical disks. Each series of intensity measurements in time at a given wavelength element was then treated as a separate timeseries. Each timeseries was normalized by dividing by a 20 min running mean, thus removing all long period variations, and cosine bells were added at the ends and before and after interruptions in the timeseries. Then power spectrum analysis was applied to each timeseries. Line identifications were taken from *An atlas of*

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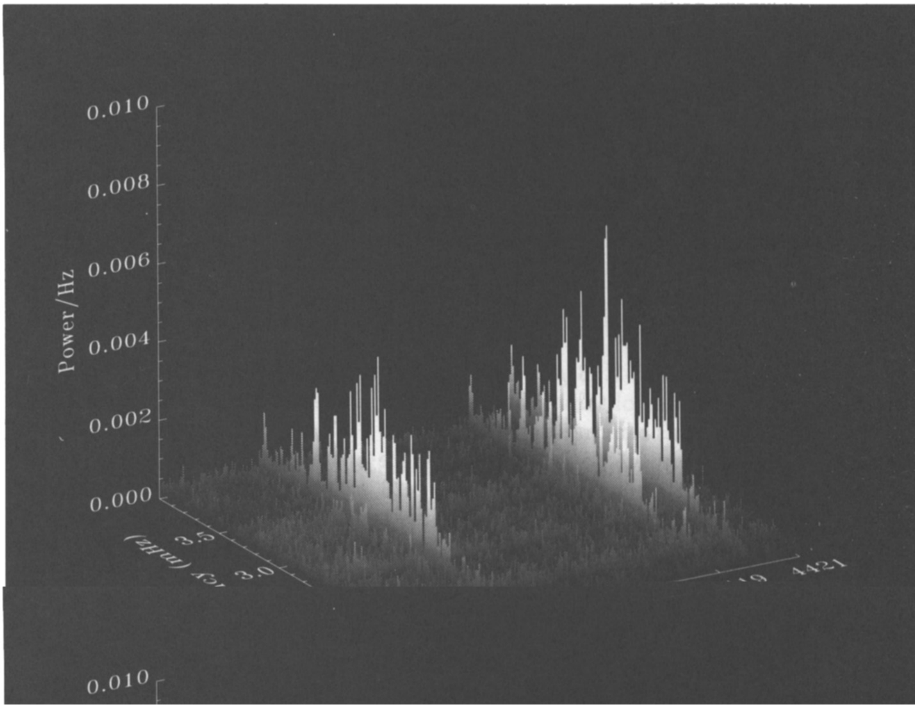

FIGURE I Power as a function of wavelength (x-axis) and oscillation frequency (y-axis) in a four day long time series at the solar disk center with a 50 arc sec entrance aperture. The ridges are solar intensity oscillations in solar Si (4410.7 cm^{-1}), CaI (4413.1 cm^{-1}), CaI (4413.6 cm^{-1}), CaI (4418.4 cm^{-1}), CaI (4418.7 cm^{-1}) and Fe (4419.7 cm^{-1}) lines. Note that terrestrial CH_4 lines in this spectral region show no intensity oscillations.

the Solar Spectrum from 1850 to 9000 cm^{-1} (Livingston and Wallace, 1991) and the Hall (1973) atlas for solar lines, and from the HITRAN molecular database (Rothmann *et al.*, 1992) for terrestrial lines. In order to study the variation of the power spectra as a function of wavelength, each powerspectrum was plotted in a 3-dimensional shaded-surface image (Figure 1). The x-z plane represents power spectra at given wavelength elements. In this way we can study the variation of the power spectra by comparing the results obtained for solar atomic and molecular lines, the continuum and for lines formed in the Earths atmosphere.

RESULTS

A study of the four days of disk center observations revealed the following: A large number of spectral lines in the observed wavelength region show large intensity oscillations. A majority of these lines show a frequency distribution in the power spectrum that resembles the well known solar p-mode oscillations. A few lines show a distinctly different frequency distribution, with some power in

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the 2-4 mHz region but also with the power increasing strongly towards lower frequencies. These lines were indentified as water vapor lines originating in the terrestrial atmosphere. All the other lines showing high power were identified as solar lines. There are several hundred solar spectral lines in the observed wavelength region, including the 2-0 and 3-1 bands of CO and several atomic lines. Figure 1 shows a power spectrum of an extract of the solar spectrum containing several atomic lines. All terrestrial molecular lines (expect water vapor), i.e. mainly CH_4, show no intensity oscillations above noise. This excludes the possibility of bands of terrestrial lines as the source of the observed high amplitude oscillations. The wavelength region shown in Figure 1 includes several CH_4 lines. None of these show intensity oscillations. Even though water-vapor lines in the region show intensity oscillations, they are far to few and have a distinctly different power distribution to account for the observed intensity oscillations. A comparison of timeseries integrated over wavenumber both including and excluding the water-vapor lines show that the water vapor lines have little or no influence on the observed power spectra. The main reason for this is that relatively few water vapor lines contribute to the power and they tend to be concentrated to the edges of the 2.23 μm window. Both molecular and atomic solar lines also show velocity oscillations with the familiar p-mode power distribution. We are currently analysing the velocity data and the phase between the velocity and line intensity oscillations. There is no doubt that the observed intensity and velocity oscillations in the solar lines are of solar origin.

CONCLUSION

The new observations, obtained with different equipment at an other site show intensity oscillations of solar origin in the 2.23 μm region. This conclusion is strengthened by the fact that terrestrial spectral lines (except water vapor) show no sign of oscillations above noise. The possible influence of water vapor absorption in the Earth's atmosphere is of minor importance due to the fact that the wavelength region in question contains only a few lines. The disk center observations show both intensity and velocity oscillations in solar lines from the CO 2-0 and 3-1 bands as well as in atomic lines in the wavelength region. We are currently working on velocity - intensity phase studies.

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