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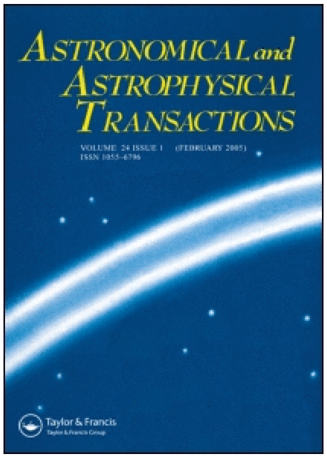

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Physical conditions and velocity fields in coronal holes. i. radial velocity oscillations in and out of coronal holes

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PHYSICAL CONDITIONS AND VELOCITY FIELDS IN CORONAL HOLES. I. RADIAL VELOCITY OSCILLATIONS IN AND OUT OF CORONAL HOLES

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Power spectra of radial velocity in and out coronal holes were studied. Thirteen of spectra with temporal resolution 17–20 s were used for this investigation. The duration of each set varied from 1.5–2 h. We analysed two spectral lines: Si I 10827Å (photosphere) and He I 10830Å (chromosphere). The following conclusions have been draw.

(1) All power spectra in the frequency range 0.001–0.05 Hz have confident peaks in the range 0.002–0.010 Hz.

(2) The power of oscillations (the sum of squares of amplitudes in a power spectrum) in the frequency range 0.02–0.010 Hz increases from the photosphere to higher levels of the chromosphere.

(3) The power of oscillations in the chromosphere is higher inside coronal holes than out side.

(4) There are four peaks in the chromosphere power spectrum of a coronal hole and two in the spectrum of a quiet region. Peak frequencies for coronal holes differ from those for quiet regions. We did not find confident peaks in photosphere power spectra of coronal holes. There is only one high peak (0.00328 Hz) in the photosphere power spectrum of a quiet region.

KEY WORDS Solar coronal holes, power spectrum

1 INTRODUCTION

Research into solar oscillations has become one of the significant tasks of heliophysics in recent years. Besides global oscillations of the Sun as a whole, oscillations of various active elements in the Sun have been observed. So, oscillations in sunspots have been investigated in several works (Kentischer and Mattig, 1995; Lites, 1986). Oscillations in the quiet regions in the Sun and in weak plages are compared in Bocchialini *et al.* (1995). The change in oscillations with height in the quiet atmosphere of the Sun is investigated in Fleck *et al.* (1994). Research on short-period oscillations should help us to determine gears of heating and cooling of solar corona and the role of small-scale elements (spicules, microflares) in this

Table 1. Observations

No.	*Date*	*UT*	*dt*	*B*	*L*	*Object*
1	17.06.94	16:08	2499	43.0	96.9	Coronal
2	17.06.94	17:22	1222	13.4	98.8	holes (CH)
3	20.06.94	15:53	2459	12.0	93.1	
4	23.06.94	13:29	3529	61.4	350.5	
5	30.07.94	9:24	3766	58.4	214.1	
6	30.07.94	14:08	3197	58.4	214.1	
7	31.07.94	9:40	1285	61.8	220.2	
8	02.08.94	10:08	3122	60.3	220.5	
9	03.08.94	9:56	1013	11.3	193.3	
10	04.08.94	9:54	3435	47.8	151.4	
11	20.06.94	17:36	1240	6.3	64.3	Quiet
12	23.06.94	14:34	2421	2.0	359.8	regions
13	02.08.94	11:03	4537	5.9	190.5	outside CH

process (Venkatakrishnan, 1992; Zirker, 1993). Comparison of oscillations in the coronal holes with those of quiet regions will help us to establish the nature of coronal holes. So far such analyses have not been carried out. In order to redress this we have embarked on a study of power spectra of radial velocity in the photosphere using spectral line Si I 10 827.14Å and in the upper chromosphere using line He I 10 830.34Å in the regions of coronal holes and outside.

2 OBSERVATIONS

Oservations were carried out at the Crimean Astrophysical Observatory during the summer of 1994 using the solar tower telescope STT-2 ($d = 25$ cm, $f = 8$ m) with a spectrograph and spectrophotometer. We used a map of the Sun for line He I 10 830Å to define position for the coronal hole on the Sun. We then found the positions of the coronal hole and quiet region outside the coronal hole to record the sets of spectra. The spectra were recorded in the range 10 825–10 838Å with a step of 0.03 Å per pixel. The duration of recording for each spectrum was 17–25 s. The duration for each set was 1.5–2 h. We considered 13 sets of spectra recordings.

The information about observations is listed in Table 1, where UT is the time at the beginning of each set, at is the duration of the set in seconds, and B and L are correspondingly the latitude and Carrington longitude of a chosen site. A map of part of the Sun is shown in Figure 1.

3 PROCESSING OF OBSERVATIONS

All spectra were smoothed using a running mean over three pixels. All sets were smoothed using a running mean over three spectra. Further more, all spectra were

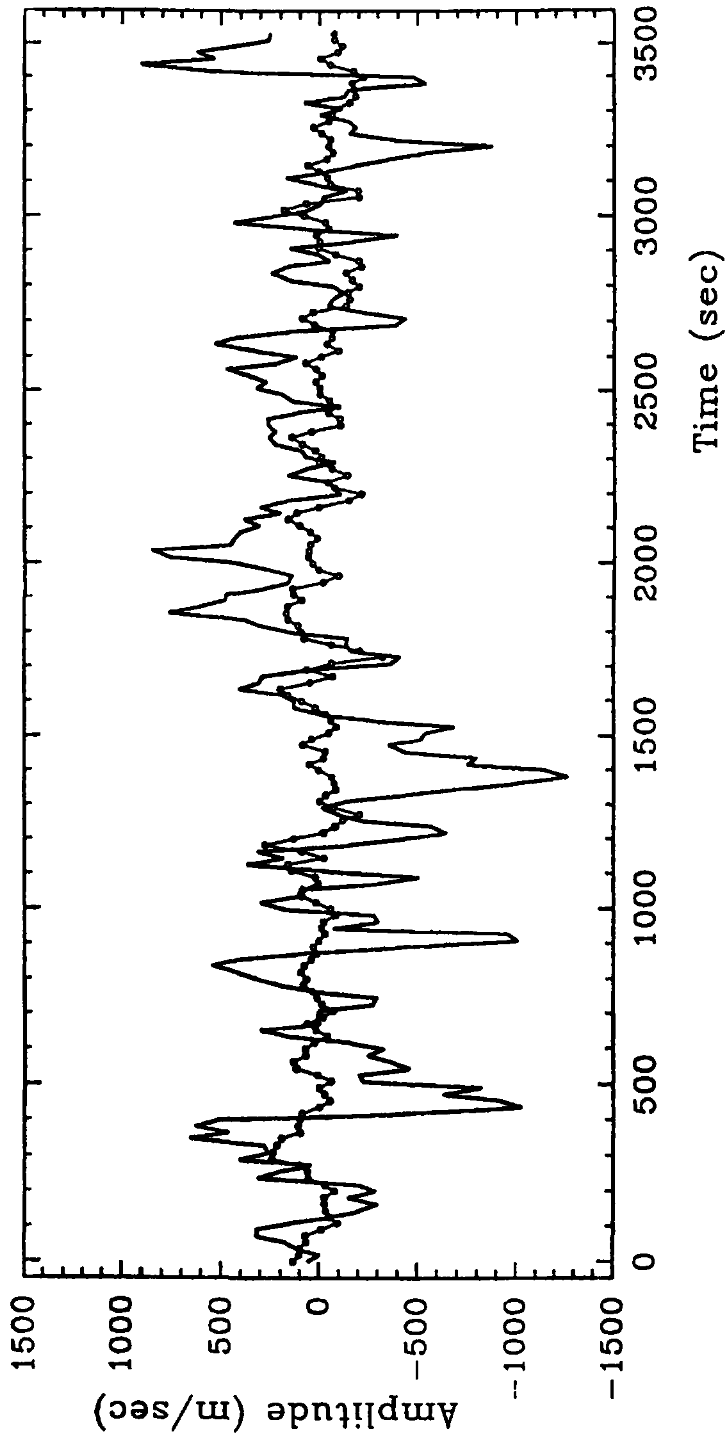

Figure 1 *N*-hemisphere of the Sun in the He I 10830Å (June 17, 1995).

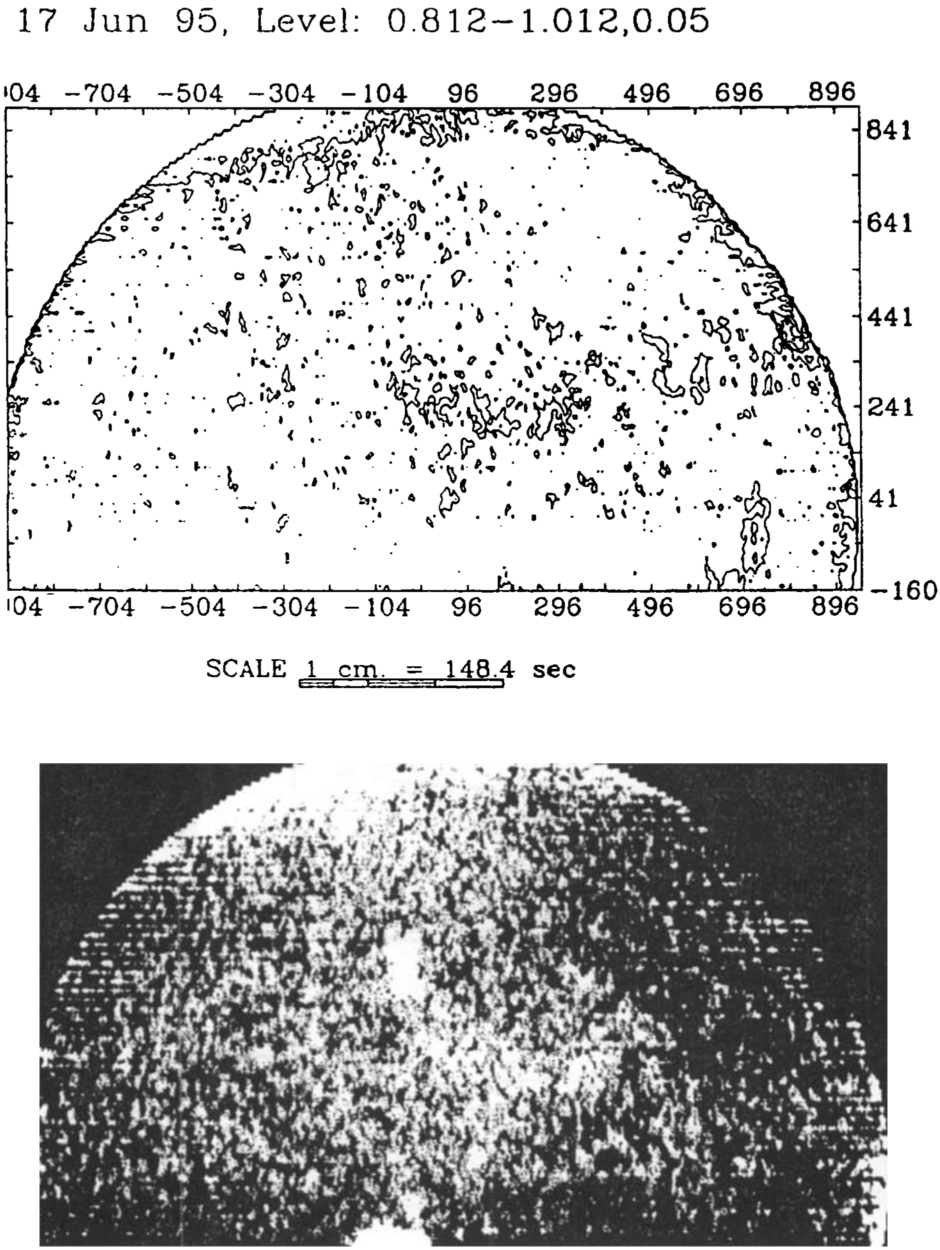

Figure 2 Deviation of solar lines from the atmospheric water line. The solid line is data for He I 10 830Å, the line with circles is data for Si I 10 827Å.

normalized to a continuous spectrum. Then centres of weight of three spectral lines (Si I 10 827.14Å, He I 10 830.34Å and atmospheric water line 10 832.11Å) were de-

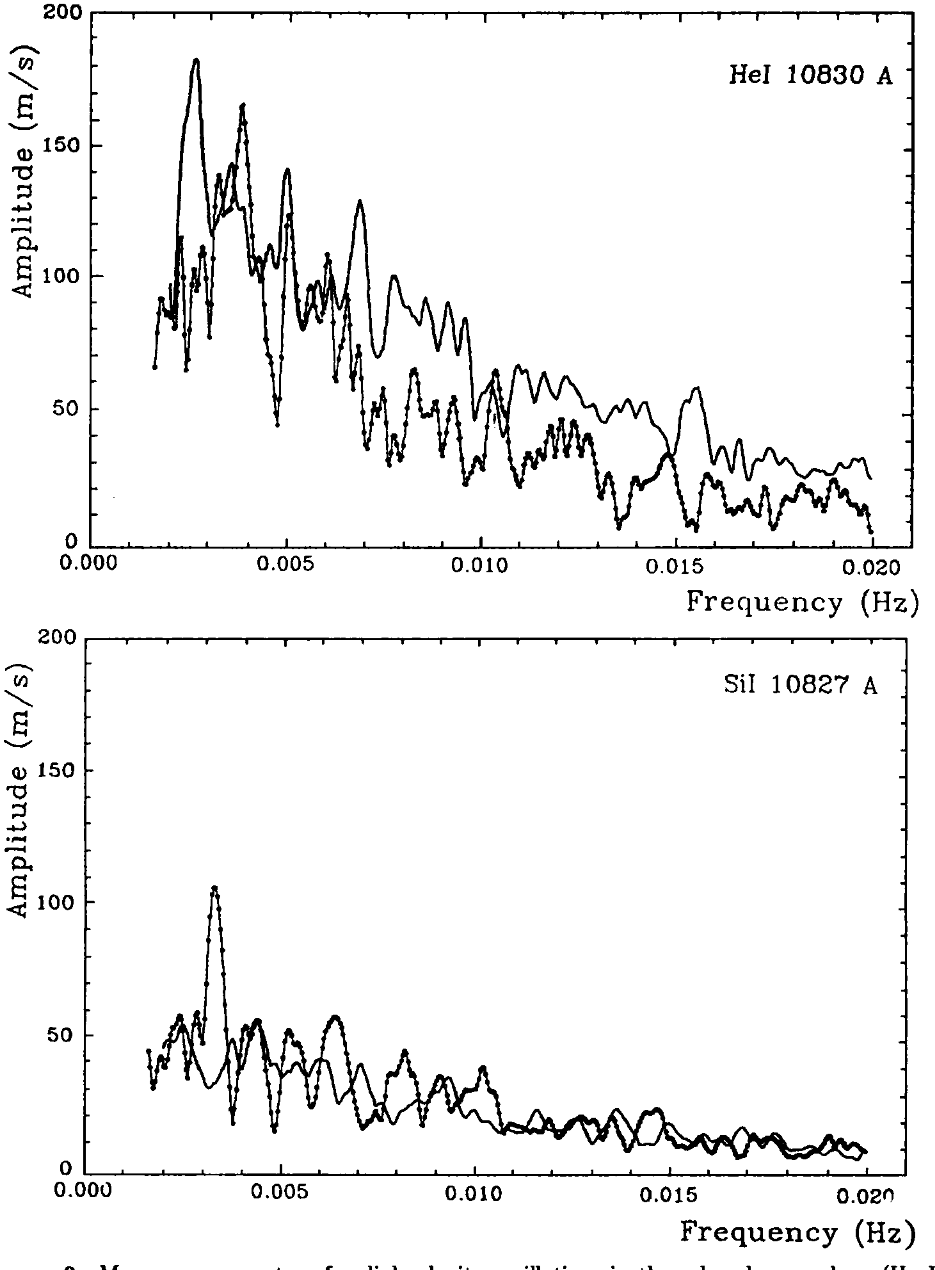

Figure 3 Mean power spectra of radial velocity oscillations in the solar chromosphere (He I 10830Å) and photosphere (Si I 10827Å). Data for coronal holes are shown by solid lines, those for quiet regions outside coronal holes are shown by lines with circles.

termined for the mean spectrum of each set. Deviations of the lines considered on each spectrogram in respect of the mean spectrum of the set were found using a cross-correlation method. Then the deviations of the solar lines from the atmospheric water line were found (see Figure 2). Amplitude power spectra were constructed for these data using the method of Deeming (1975) using the program PERIOD (Breger, 1990) in the 0.001–0.05 Hz frequency range. The upper limit of the considered frequencies was determined by the temporary resolution of the series and it was chosen equal to 0.05 for all series. The lower limit of the considered frequencies depended on the length of the observation interval. Mean power spectra for all observations of coronal holes and quiet regions for two levels of the solar atmosphere are shown in Figure 3.

4 RESULTS

All power spectra in the considered frequency range contain groups of appreciable peaks in the range 0.002–0.010 Hz. In the frequency range greates than 0.01 Hz, the peak amplitudes do not exceed the noise level. Analysis of results shows that the considerable peak at the period 302 s with amplitude 0.11 km/s is present in the mean power spectrum of quiet photosphere outside the coronal holes. This peak describes the known 5 min oscillations in the solar photosphere. In coronal holes at the photosphere level this peak is absent. Other peaks in the photosphere power spectrum have considerably less amplitude. The most appreciable peaks in quiet regions of the chromosphere are at periods 264 and 199 s. In the chromosphere of coronal holes, besides these peaks, there are two more appreciable peaks (periods 386 and 146 s).

The power of the oscillatory process (sum of squares of amplitudes in a power spectrum for interval of frequencies 0.002–0.01) in the photosphere of coronal holes is slightly less than that for the quiet regions of the photosphere. In the chromosphere the power of the oscillatory process in coronal holes is essentially higher, than outside of them.

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