ON THE SHORT PERIOD OSCILLATIONS OF 530.3 nm CORONAL LINE

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ABSTRACT. The profile of the 530.3 nm FeXIV coronal line is analyzed on the basis of a series of 86 photographs. The time variations of the four basic parameters, total emission, central intensity shifts, halfwigth and asymmetry, of the profile are studied using three statistical methods, namely, power-spectrum analysis, the periodogram method and maximum entropy spectral analysis. Statistically significant oscilations with periods of 280 and 360 s are present in the four parameter time series, though most strongly manifested in total emission. Shorter periods of 120 and 60 s can be observed but there are not as conspicuous.

О КОРОТКОПЕРИОДИЧЕСКИХ ОСЦИЛЛЯЦИЯХ КОРОНАЛЬНОЙ ЛИНИИ 530.3 нм. На основе серии фотографий сделан анализ профиля корональной линии Fe XIV 530.3 нм. Временные вариации четърех основных параметров - общей эмиссии, смещения центральной интенсивности, полуширины и ассимметрии профиля, исследованы при помощи трех статистических методов: честотно-временного спектрального анализа, периодограмного метода и метода максимальной энтропии. Статистически значимые осцилляции с периодами 280 и 360 с можно определит у всех четърех параметров, но они наиболее выражены для полной эмиссии. Более короткие периоды - 120 и 60 с - тоже можно заметить, но они менее значительны.

O KRÁTKOPERIODICKÝCH OSCILÁCIÁCH KORONÁLNEJ ČIARY 530,3 nm: Na základe série fotografií je analyzovaný profil koronálnej čiary Fe XIV, 530,3 nm. Časové variácie štyroch základných parametrov - celkovej intenzity, vlnovej dĺžky, pološírky a asymetrie profilu sú analyzované pomocou troch štatistických metód:

frekvenčnej spektrálnej analýzy, metódy periodogramov a metódy maximálnej eutrópie. Štatisticky významné oscilácie s periodami 280^s a 360^s boli zistené u všetkých štyroch parametroch, ale najvýraznejšie sú pre celkovú intenzitu. Boli zistené aj kratšie periódy: 120^s a 60^s, ale sú menej výrazné.

1. INTRODUCTION

The problem of short period oscillations of the solar corona is being discussed. Until now no significant effects pointing to the existence of waves in the white-light corona have been detected. However, spectroscopic observations show that in some cases it is possible to detect such waves in the 530.3 nm Fe XIV coronal line. For example, periods of 300 s (Tsubaki, 1977) and 378 s (Minarovjech et al., 1983) were obtained from the variations of the doppler shift of the wavelength, while from the variations of the halfwidth and central intensity of the line, Egan and Schneeberger (1979) obtained a period of 306 s. Besides these oscillations, close in period to the 5-minute oscillations in the middle chromosphere (Athay and White, 1979), there are reasons to believe that Doppler velocity oscillations of periods of 80 and 43 s (Koutchmy, 1981) exist in the corona.

The power-spectrum analysis is applied to almost all investigations of short-period oscillations in the solar corona. Though this method has been established as fundamental in analyzing time series, it should be noted that satisfactory results can be obtained only if the time series is sufficiently long. In most cases of coronal observations short-time series are obtained (for example, in Tsubaki (1977) $N = 41$) and the power-spectrum estimates have very wide confidence intervals, providing a rather uncertain spectrum interpretation. In some cases the time interval Δt between two consecutive frames makes it impossible to observe fluctuations of periods shorter than 100 s.

2. METHOD AND RESULTS

In this study we apply three methods, namely the power-spectrum analysis, periodogram method and maximum entropy spectral analysis, in order to detect periods of 50 to 600 s. We analyze the time series of the profile parameters of a sequence consisting of 86 frames of the Fe XIV 530.3 nm coronal line spectra, obtained with the 20-cm coronograph it the Lomnický Štít coronal station. The observational material, of sufficient quality for the present purpose, was obtained during 29 minutes with a constant interval of 20 s between individual frames and with 6 s exposure time. For more details concerning both the observations and the devices used, see Minarovjech et al. (1983).

The 33-mm high-speed film was digitized every 25 μm in the direction of dispersion, and spaced at intervals of 100 μm by means of an MDM 6 Joyce-Loebl microdensitometer at the Rozhen Astronomical Observatory. The individual frames were coaligned, and the 530.3 nm line profile was approximated by

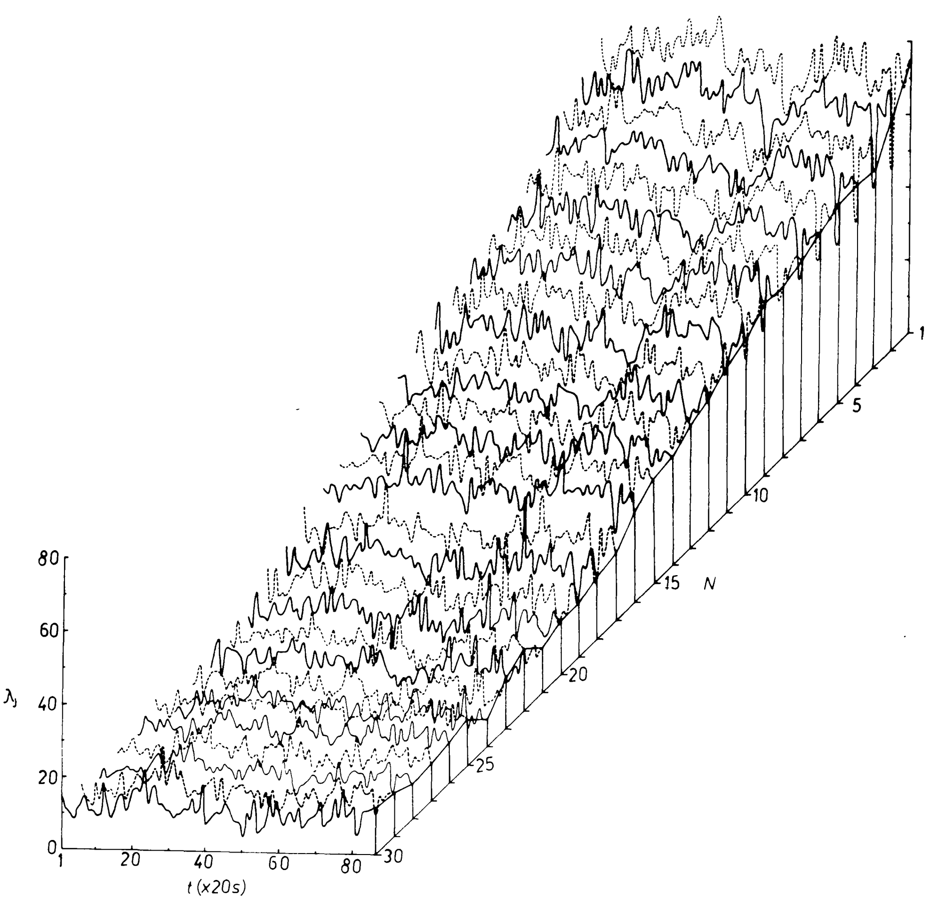

Fig. 1: Total emission as function of time (t) and height above limb (M)

a Gauss function at each height and time. The method of processing is described in detail by Rybanský et al. (1986). The resulting data - total emission, line centre shift, Doppler width and asymmetry of the line profiles, were obtained as functions both of limb position and of time. Figure 1 illustrates the spatial and time distribution of the total emission. Here, the abscissa denotes the time, the left-hand side ordinate represents the integrated line emission, and the third coordinate is the number of consecutive scans.

The time series of the line profile parameters were examined at each individual height above the limb, and as a spatially averaged data set by means of three statistical methods. Below we present briefly these methods, as well as the most significant results, referring mostly to spatially averaged time series.

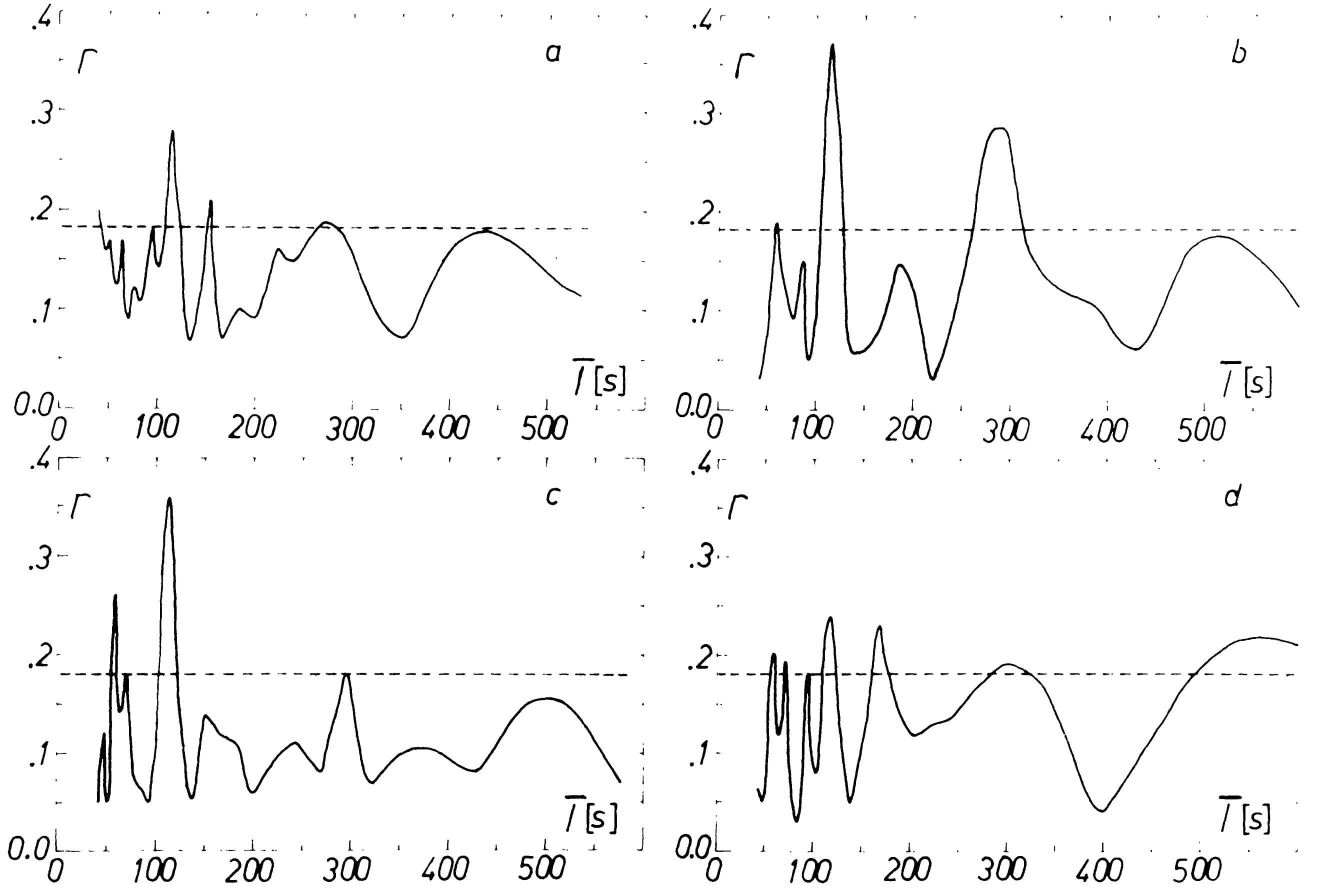

Fig. 2: Correlograms by the periodogram method: a/ line center shifts, b/ asymmetry of the profile, c/ total emission, d/ Doppler width.

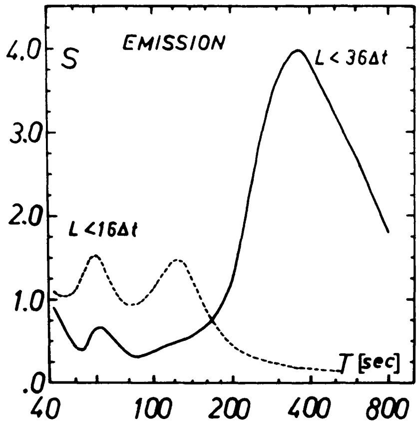

Fig. 3: Power spectrum of total emission by maximum entropy method.

1/ The periodogram method is based on the idea of approximation by the least-squares method with a function of the type

$$\varphi(t) = A\cos\frac{2\pi t}{T} + B\sin\frac{2\pi t}{T} + a_0 , \qquad (1)$$

where T is a given preliminarily period, which can be varied in steps. Figure 2 shows the correlograms obtained with this method. The statistically significant period of 280 s is indicated only by the asymmetry of the profiles. A shorter period of 120 s for all four parameters is suggested, but it is most explicitly manifested in the total emission and asymmetry.

2/ In methods of maximum entropy spectral analysis (Burg, 1967) the power-spectrum density is expressed as

$$S(f) = 2\Delta t \sigma_a^2 \left| 1 - \sum_{j=1}^{M} \alpha_{M,j} \exp(-i2\pi f \Delta t_j) \right|^{-1} \qquad (2)$$

where f is the frequency, σ_a the prediction error under time extrapolation by one step forward, $\alpha_{M,j}$ coefficients of the autoregressive model of M order, describing the time series.

Figure 3 shows the power spectrum of the total emission after the preliminary filtering of the time series by a high-frequency filter of passobands $L_1 \leqslant 16\,\Delta t$ and $L_2 \leqslant 20\,\Delta t$. The autoregressive model minimizing Akaike's criterion (Akaike, 1969) goes up to the 10th order. In this case, preliminary high-frequency filtering is of decisive importance, since the initial time series have strongly unstable components of periods equal to the time series length

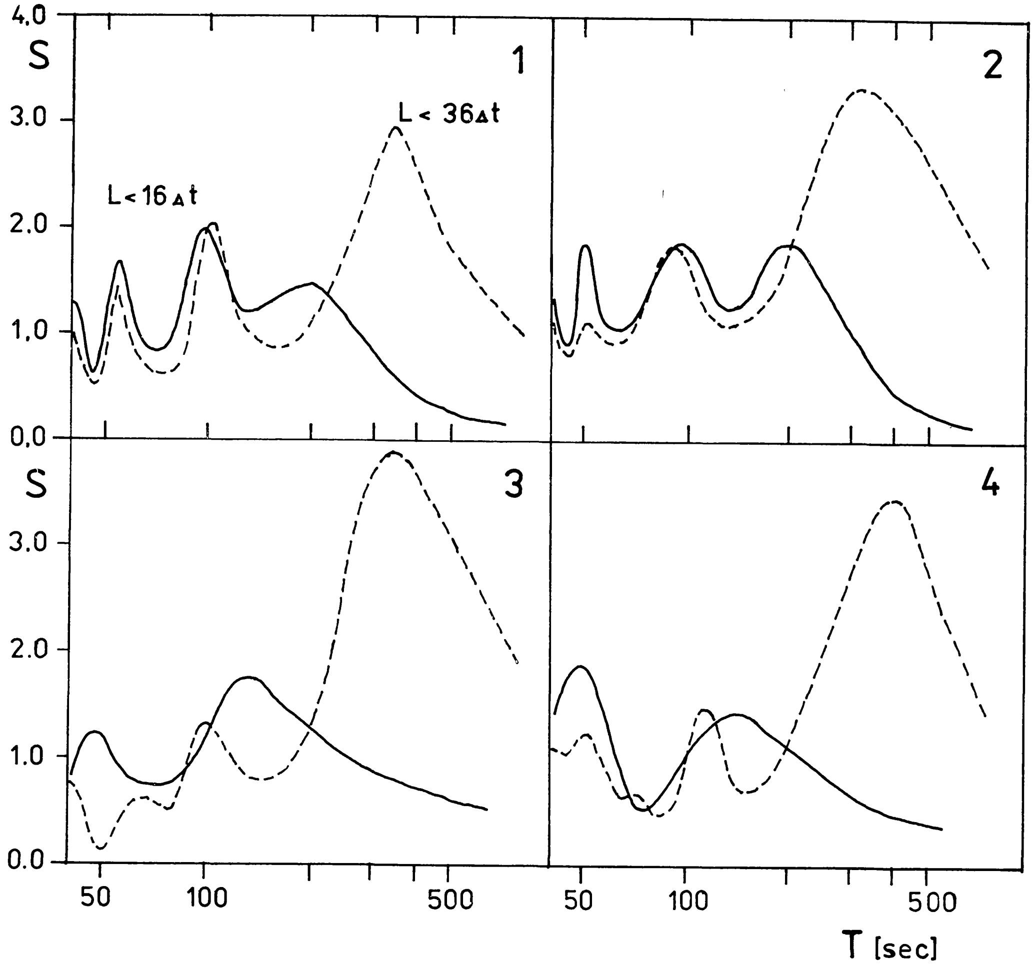

Fig. 4: Power spectra of total emission for four consecutive heigths above limb.

and even longer. These two power-spectra can be used to determine periods of 60, 120 and 360 s.

It is interesting to note that in the power spectrum obtained by using a high-frequency filter ($L \lesssim 30\Delta t$) the period of 360 s predominates, while the short-period range is manifested only slightly. This indicative of the small amplitude and random nature of short period components. In Figure 4 the power spectra of the total emission time series are plotted for four consecutive spatial steps after being filtered at passbands $L \leqslant 16\Delta t$ and $L \leqslant 30\Delta t$. One can see that the periods remain unaltered only for the first two consecutive spatial steps, whereupon they begin to increase gradually. The short-period

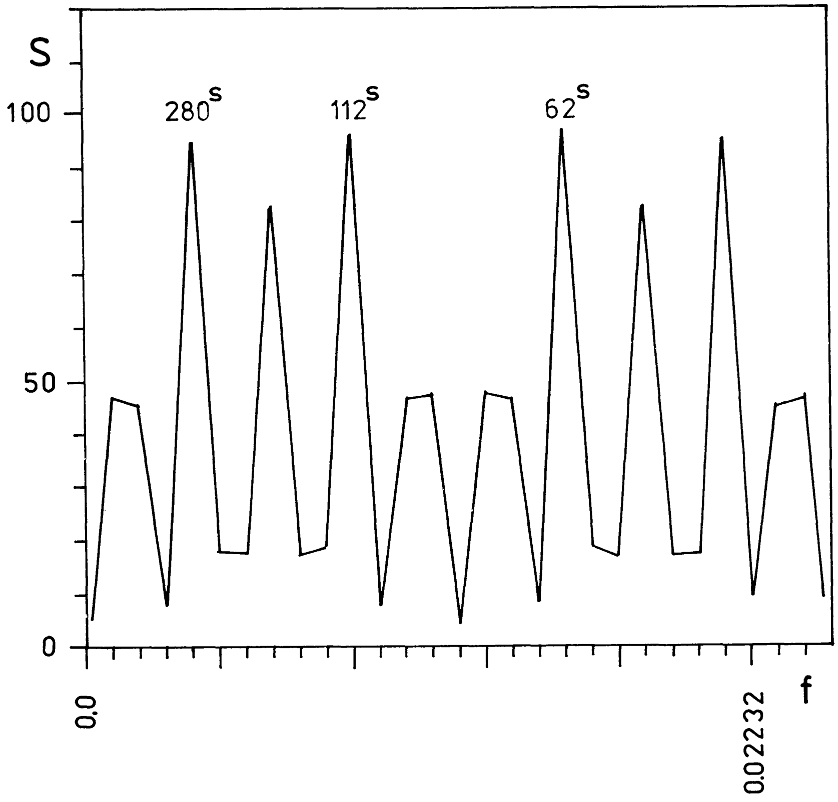

Fig. 5: Power spectrum of total emission.

components not only have small amplitudes, but are probably phase-shifted in space as well. It should be noted that the decisive factor determining the power spectrum type is the order of the autoregressive model, chosen according to the second minimum from Akaike's criterion. This minimum is most manifested for the total emission and, to a certain extent, for asymmetry. As for the other parameters, its manifestation is insignificant and, therefore, we cannot decide whether the above-mentioned periods actually exist in these time series. Presumably the corresponding oscillations are either of very small amplitudes or do not exist. This can be tested by using longer time series, describing the wave generation process in the corona.

3/ The power spectrum analysis, usually applied to such studies, does not yield satisfactory results, the time series usually not being sufficiently long. This is illustrated in Figure 5, showing the total emission power spectrum, obtained at the cut-off point L = 14 after filtering by a high-frequency filter. It is obvious that the confidence intervals are quite wide so that the spectrum cannot be defined reliably. Yet there are suggestions of the existence of periods of 62.2 s, 112.0 s and 280 s.

In conclusion, we may say that the space-averaged total emission oscillates with periods of 280 s, 120 s and 60 s, the most clearly manifested of which is 280 s. Further investigation of the problem by means of appropriate statistical methods would require the study of oscillations in spatially consecutive time series. Thus, it would be possible to get more information about coronal wave development, of assential importance for the elucidation of the mechanism of mass and energy transfer in the solar corona.

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