399-Day Variations in Solar Wind Parameters

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Abstract: Based on a large series of data (N=14038) of daily solar-wind densities, we obtained the fluctuation power spectrum. The spectrum shows that the 399-day variation (the synodic period of Jupiter) has the largest amplitude in the interval of periods from 20 to 800 days. The amplitudes of the 399-day variations in solar-wind density, temperature, and speed were determined by superposed epoch analysis:~0.5cm^{-3}~8000K, and 2.8 km. $^{s-1}$, respectively, at a more than 95% confidence level. This leads us to conclude that the Jupiter may affect the solar-wind parameters, since only it has a 399-day periodicity in our planetary system.

Introduction and Formulation of the Problem

The Jupiter is an intense source of high-energy (0.2 –40 MeV) electrons. The energy spectrum of the electrons is given in [1], which indicates that, on average, the injection of high-energy electrons by the Jupiter exceeds the injection of such particles by the Sun by several orders of magnitude. Many papers have been published in which it is pointed out that intense Jovian electrons manifest themselves in the vicinity of the Earth [2-8]. This indirectly suggests that the Jupiter can affect the solar wind parameters by injecting the considerable number of charged particles. This phenomenon has not yet been studied. Even the very fact of the manifestation of this effect has been barely covered in scientific literature. However, papers on this subject have appeared in recent years [7-9].This paper is devoted to the detection of a correlation between the solar wind parameters and the Jupiter's synodic period (399 days).

Analysis of Data

Below, we analyze the data to reveal a 399-day variation in some of the solar wind parameters and to determine its amplitude and phase characteristics. For this purpose, we used the experimental series of daily solar wind densities (cm $^{-3}$), temperatures (K),and speeds (km s $^{-1}$)for the period from July 26,1965 through December 31,2003[10] Each series consisted of N =14 038 daily values. Since these data had gaps, we wrote a program that allowed the segments with gaps to be replaced by the values obtained by linear interpolation between the gap ends. The gap lengths were mainly several days; i.e., they were considerably shorter than the Jupiter 's synodic period and even shorter than the period of the 27-day variations. Since we are interested in time intervals comparable to 399 days, one might expect the gaps to have no effect on the results of our analysis. Ten points are enough to describe the 399-day variation. Even in the presence of gaps, the number of points that describe the 399-day variation is more than three hundred. After this preliminary processing of data, we obtained the mean values for the solar wind density, temperature, and speed 7.45 cm $^{-3}$, 115 790 K, and 442 km s $^{-1}$, respectively. Figure 1 shows the power spectrum constructed from the experimental data for the solar wind density fluctuations after this preliminary data. As we see from the Figure 1, the 399-day variation has the largest amplitude in the interval of periods of 20 –800 days. It is second in magnitude only to the secular,22-,and 11-year variations and their higher modes. For comparison, this Figure shows the 27-day and semi-annual (183 days) variations. The amplitude of the annual variation is much lower than that of the semi-annual one. It shows up as a dip before the 399-day variation (due to its low amplitude, the annual variation is not marked in the Figure, but it is noticeable). Interestingly, the 399-day variation, like other variations, is seen in Fig.1 not as an isolated pulse, but as a packet of pulses distributed near the true value. This is because we observe the 399-day variation through the response of the medium, whose properties change all the time during the Jupiter's synodic period. In each individual period, the response can be delayed by a greater or smaller value. Besides, the synodic period itself changes by .1 –2%. If the computational scheme has a high resolution, then we will always have several pulses distributed near the true value due to such fluctuations. This effect is prominent, for example, in the 27-day variation. This variation is associated with the formation of active regions on the Sun. They can be formed at any point along the circumference of the Sun from 0 to 2 π radians almost uniformly. For their uniform distribution, the mean interval of the fluctuations in the period of the 27-day variations is equal to half the length of the circumference of the Sun, i.e., π radians, or, on the scale of Fig.1, ~.13 days. Indeed, the half-width of the envelope around the 27-day variation is approximately equal to this value. The period of the 11-year variations also fluctuates about its mean value. However, the fluctuations do not show up in Fig.1, because the resolution of any computational scheme decreases considerably at low frequencies (long periods). The superposed-epoch technique averages out the small fluctuations of the periods. As a result, when the series in which the period fluctuations about their mean values manifest itself is processed by this technique, the mean period itself will be distinguished reliably, because all of the values are averaged during the superposition. In addition, in contrast to spectral analysis, this technique allows the amplitude, phase, and overall shape of the effect (a sine wave, a trident, an isolated pulse, etc.) to be determined. Therefore, in what follows, we will analyze the data by the superposed-epoch technique to determine the amplitude and phase of the effect. In this case, the fluctuations, the 27-day variations, the Forbush effects, flares, etc., should be taken into account. The entire class of pulsations with periods up to ≈100 days (class-I variations)is of no importance in revealing the 399-day variation. However, if these pulsations are not removed, then, when the epochs are superposed, most of the pulsations will necessarily “leak ”into the interval near the 399-day period. The class-II variations (the secular, 22-, and 11-year variations and their higher modes) have periods

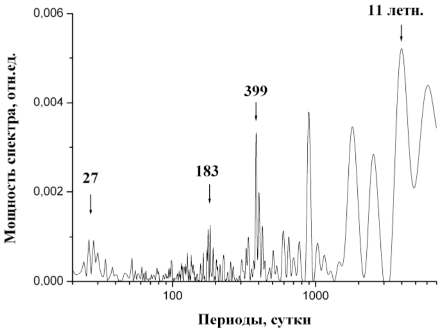

Fig.1. Fluctuation power spectrum for the solar wind density in relative units.

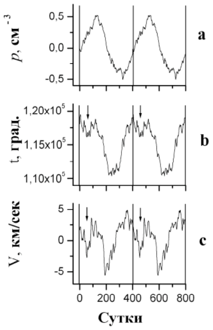

Fig.2. General view of the effects obtained by the

superposed-epoch technique:(a)the solar wind particle density in the Earth 's orbit,(b)the solar wind particle temperature, and (c)the solar wind speed.

of ≈700 days or longer and exhibit a high power. If they are not subtracted, then they will necessarily affect the superposition results. To remove these "unnecessary "variations, we have filtered all of the experimental data. The chosen filtering interval was 100 –700 days. The filter is quite simple; it is the difference between two probabilistic trends with averaging over ≈100 and ≈700 days (this corresponds to the parameters of probabilistic trends with ó =25 days and ó =175 days). The periods of the annual and 399-day variations differ by only .10%. To eliminate the annual variation, it was first found by the superposed-epoch technique in the filtered data for one period. Subsequently, using software, we obtained a series of 365-day variations (N =14038), which was subtracted from the filtered data set. In this way, we treated the data in all parameters. As a result, we obtained data sets, in which the 399-day variation dominated and the 365-day variation was absent. To implement the superposed-epoch technique (in determining the 399-day variation), we first compiled a list of reference points, i.e., determined the ordinal numbers of the Jupiter –Earth opposition dates by taking July 26,1965,as the first number. This list compiled from data of the *Astronomical Yearbook* for 1965 –2002 [11]. If we take the differences of the ordinal numbers (reference-point numbers),then we will obtain periods that, as can be seen from the table, will vary in the interval from 394 to 403 days, i.e., within 1.2% relative to the 399-day period. Such variations also introduce the additional number of small peaks to the "packet effect "in the spectrum of Fig.1.Therefore, the number of such peaks near the 399-day period will increase even further It is this picture that is seen in Fig.1:a series of small peaks with different amplitudes is present in the vicinity of the 399-day period. We perform the superposition relative to the reference point by assuming it to be the first number by a 399-day interval. Figure 2 shows the result (for clarity, two periods are shown). Figure 2a presents the superposition results for the solar wind density, Fig.2b reflects the sum of the temperature in the superposition effect and its mean value, and Fig.2c illustrates the effect on the solar wind speed. The solid vertical lines mark the opposition dates. We estimated the effect of the neighboring variations as follows. We constructed sine waves with periods that differed from 399 days by 2,5,and 10% with a series length of 14 038 values. Subsequently, we superposed them on the 399-day period. As a result, we found that their amplitudes decreased by factors of 3,33,and 40, respectively. This means that the nearest variations that differ in period by 10%or more will decrease by more than a factor of 40 when superposed on the 399-day period. We carried out our calculations with and without the subtraction of the annual variation and obtained almost identical results. This is because the annual variations decreased by a factor of 40 when superposed on the 399-day period, while they were small anyway. As we see from Fig.2a, the total effect in the density variation is 1cm $^{-3}$ (this corresponds to a maximum variation amplitude of .0.5 cm $^{-3}$).The temperature (Fig.2b)varies over the range (1 .1 –1 .2) _10 K, and the solar wind speed (Fig.2c)varies about 5.6 km s $^{-1}$ (.2.8 km s $^{-1}$). As percentages, these variations are .13 (6), .5 (2.5),and .1.3%(0.6%), respectively, for the above quantities. The errors were calculated using a technique that was specially developed for superposed-epoch technique [12]. In Figs.2a, 2b, 2c,they are ±0 .13 cm $^{-3}$,±2107 K, and ±0 .8 km s $^{-1}$, respectively. The effects shown in Fig.2 exceed the errors by a factor of 4 (i.e., their amplitude is twice the errors). According to Jamison and Regal (1982),it thus follows that the above results were obtained at a more than 95% confidence level. Thus, based on our analysis of the experimental series for the solar wind density, temperature, and speed, we can assume that Jupiter 's influence manifests itself in the solar wind parameters with a confidence higher than 95%.

Conclusions

(1)The synodic period of the Jupiter is 399 days. No other source or process that produces this period is known to date. Since the 399-day variation manifests itself with a 95%confidence in some of the solar wind parameters, we conclude that the Jupiter may affect the solar wind.

(2)The amplitudes of the 399-day variations in the solar wind density, temperature, and speed are 62.5, and 0.6%, respectively.

Acknowledgments

This work was supported in part by INTAS (grant no.03-51-5359),the Russian Foundation for Basic Research CONACyT, Mexico (project 45822, PERPJ10332); RFBR (project nos. 07-02-01405,06-02-96008, 06-05-96034, 06-05-64225, 05-02-39011); The programs of basic researches of Presidium of RAS N6 and 16

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