Wavelet Analysis of 27-day Variation in Cosmic Ray Intensities Observed at Beijing Neutron Monitor

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Abstract

The paper analyzes the time variations of amplitude and phase of 27-day periodicity in cosmic ray (CR) time series observed at Beijing neutron monitor (NM) station and compares with those of geomagnetic parameter Ap series, using the Morlet Wavelet for decomposition. The results show that the amplitude and initial phase are all the function of time.

1. Introduction

Solar activities have the periods around 27-day. Cosmic ray (CR) intensities modulated by solar activities also have the periods around 27-day. Many papers have been devoted to the study. Wavelet analysis has been used to analyze the periodic properties of CR series and many results have been obtained. This paper analyzes the amplitude and phase time variation of 27-day of CR intensities observed at Beijing neutron monitor station with cutoff 9.56GV. The paper also analyzes the amplitude and phase time variation of 27-day of geomagnetic parameter Ap. Finally we compare the two amplitudes and phases.

2. Data analysis

Firstly we present the daily CR intensities observed at Beijing neutron monitor (NM) station shown in Fig.1. We only give one solar cycle, namely from the year 1986 to the year 1996. Also we present daily Ap value shown in Fig.2. at Beijing geographic position:

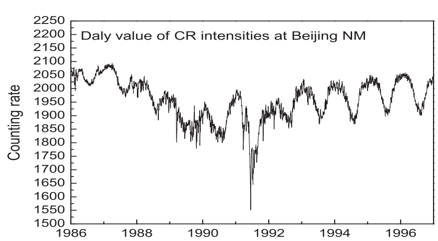

Fig. 1. The CR intensity series observed at Beijing NM station

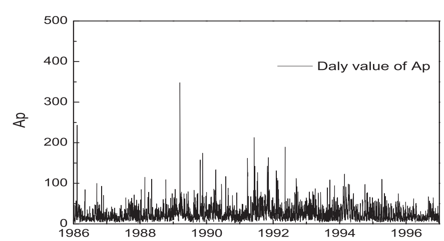

Fig. 2. The daily value of Ap series

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We analyze the amplitude variation of 27-day period of the GCR intensities. The wavelet selected to analyze the data series is Morlet wavelet. It has the form:

$$\psi(t) = \exp(-at^2)\cos(t) \tag{1}$$

Morelet wavelet satisfies the condition that a permission wavelet should satisfy: $\int_{-\infty}^{+\infty} \psi(t)dt = 0$. We can get local properties of the signal by wavelet analysis, but in this paper we just consider the 27-day periodicity of cosmic ray and Ap. The profiles of this periodicity are shown in Fig. 3 and Fig. 4 for CR series and Ap series, respectively. The amplitude of CR series for 27-day periodicity is relatively small around the year 1986 and the year 1996 and around the year 1991. The time of the biggest value of the periodicity is 1991.47, nearly close to the middle of the gap of 1991-1992. For amplitudes of 27-day periodicity of Ap series, the amplitude is relatively high during the epoch of maximum solar. From the Fig.3. and Fig.4., It is difficult to know how the phase variations of the two series are.

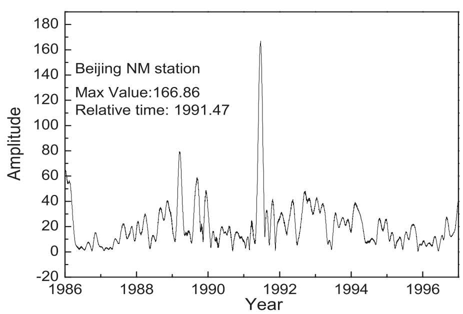

Fig. 3. The amplitude of 27-day periodicity of CR series

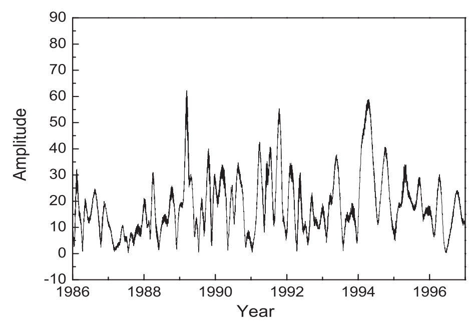

Fig. 4. The amplitude of 27-day periodicity of Ap series

We know that any definite signal can be write as:

$$f(t) = A(t)e^{i(\omega t + \varphi(t))} \tag{2}$$

where $A(t)$ is the amplitude of the signal, it is the function of time. ω is a given definite value, $\varphi(t)$ is the initial phase of the signal which is also the function of time. For the 27-day periodicity of CR series and Ap series we present the phase time variation for the interval 1986-1996 shown in Fig.5. and Fig.6., respectively. It is very difficult to see the phase time variation clearly because the phase data is two much. We just present the phase variation for the year 1986 and the year 1991 and compare with that of Ap series shown in Fig.7. and Fig.8., respectively.

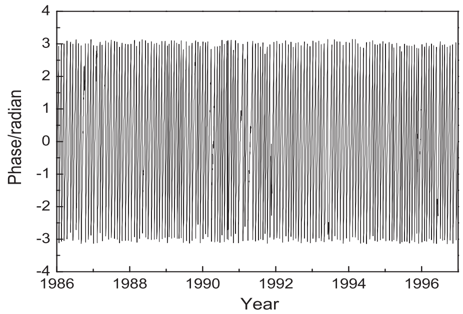

Fig. 5. The phase time variation of CR series

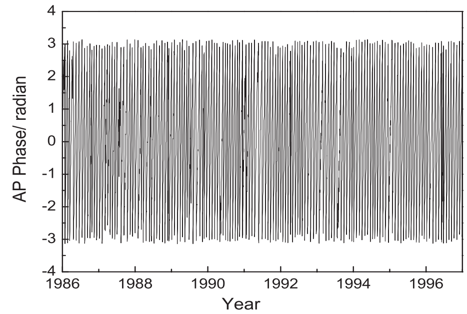

Fig. 6. The phase time variation of Ap series

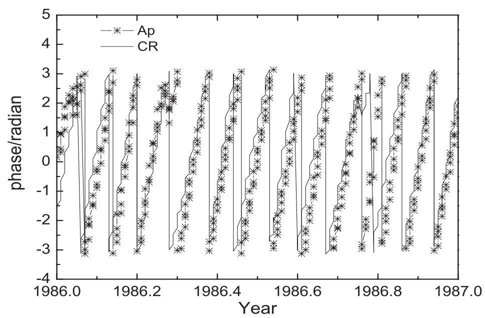

Fig. 7. The comparison between the two series for 1986

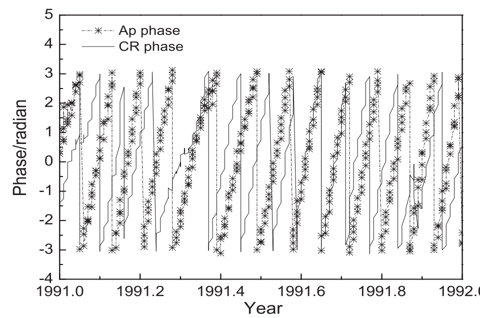

Fig. 8. The comparison between the two series for 1991

From Fig.7. we can see that the phase of CR series and the phase of Ap series is almost the same pace for the year 1986, while the phase of CR series and the phase of Ap series is almost antiphase except the time around 1991.6y. Because ω is a constant number for any given periodicity, so we can deduce that the initial phase $\varphi(t)$ is the function of time.

3. Summary

The analysis show that the amplitude of CR series changes with time. The amplitude of CR series is relatively low around the solar minima and gets its maximum at 1991.47. The difference between the phase of CR series and the phase of Ap are small for the year 1986, while the two phases are almost inverse except around 1991.6y for the year 1991. The amplitude is the function of time. The initial phase $\varphi(t)$ is also the function of time.

4. References

1. Alania, M. V., Baranov, D. G., Tyasto, M. I. And Vernova, E. S., The changes of 27-day variations in cosmic rays and geomagnetic activity, 1999, Proc.26th ICRC(Salt Lake City), SH3-2.13
2. Kudela, K., Yasue, S., Munakata, K. and Bobik, p., Cosmic ray variability at different scales: A wavelet approach, 1999, Proc.26th ICRC(Salt Lake City), SH3-4,7:163-166
3. Kudela, K., Storini, M., Rybak, J., Antalova, A., On the wavelet approach to cosmic ray variability, 2001, Proc.27th ICRC(Hamburg), SH3.2:3773-3786
4. Sabbah, I., Correlation of the 27-day variation of cosmic rays to the interplanetary magnetic field strength, 2001, Proc.27th ICRC(Hamburg), SH3.2:3784-3787