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Periodicity Analysis of X-ray Light Curves of SS 433† ⋆

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Abstract SS 433 is sofar the unique X-ray binary that has the simultaneously detected orbital period, super-orbital period, and nutation period, as well as a bidirectional spiral jet. The study on its X-ray light variability is helpful for understanding the dynamic process of the system, and the correlations between the different wavebands. In this paper, two time-series analysis techniques, i.e., the Lomb-Scargle periodogram and weighted wavelet Z-transform, are employed to search for the periods in the Swift/BAT (Burst Alert Telescope) (15–50 keV) and RXTE/ASM (Rose X-ray Timing Explorer/All Sky Monitor) (1.5–3, 3–4, and 5–12 keV) light curves of SS 433, and the Monte Carlo simulation is performed for the obtained periodical components. For the 15–50 keV energy band, five significant periodical components are detected, which are P_1(∼6.29 d), P_2 (∼6.54 d), P_3 (∼13.08 d), P_4 (∼81.50 d), and P_5 (∼162.30 d). For the 3–5 and 5–12 keV energy bands, the periodical components P_3 (∼13 d) and P_5 (∼162 d) are detected in both energy bands. However, for the 1.5–3 keV energy band, no significant periodic signal is detected. P_5 is the strongest periodic signal in the power spectrum for all the energy bands of 3–5, 5–12, and 15–50 keV, and it is consistent with the previous result obtained from the study of optical light curves. Furthermore, in combination with the radio spiral jet of

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SS 433, it is suggested that the X-ray and optical variability of P_5 (∼162 d) is probably related to the precession of its relativistic jet. The high correlation between the X-ray and optical light curves may also imply that the X-ray and optical radiations are of the same physical origin. P_3 shows a good agreement with the orbital period (∼13.07 d) obtained by the previous study, and P_2 and P_4 are respectively the high-frequency harmonics of P_3 and P_5. P_1 is detected only in the power spectrum of the 15–50 keV energy band, and it is consistent with the nutation period of the system. As the energy of energy band decreases (from hard X-ray to soft X-ray), the number of detected periods becomes gradually less, this result verifies that the radiation in the high-energy band (hard X-ray) comes primarily from the jet, and the radiation in the low-energy band (soft X-ray) may be dominated by the medium around the binary system. The multiple X-ray periods obtained from the present study have provided a reliable basis for the further analysis of the multi-band data of SS 433, and the study on the dynamical mechanism of the system.

Key words stars: binary—period—methods: wavelet transform—Lomb-Scargle periodogram—autoregressive process

1. INTRODUCTION

The light variability indicates the variation of object's radiation flux with the time, the analysis of light variability is the common way to study the object's radiation mechanism, interior structure, and its variation. Especially for those remote compact objects, their dynamical information about the internal energy source can not be obtained directly by the imaging method, the analysis of light variability becomes particularly important. By analyzing the time series of object's light variation, we can obtain many useful physical parameters, such as the period, amplitude, phase of the light variation, the correlation and time delay between the light variations of two different wavebands, etc. These parameters are very helpful for revealing the underlying physical mechanism of the light variability, and for predicting the future trend of light variation. Particularly, by through the collection and time-series analysis on the light curve of a specific object, we can search and verify the characteristic period of luminosity variation of this object, and predict the time of the next "explosion" to organize the corresponding observations. Besides, by the observed period we can estimate the object's mass and other physical parameters, or discover the physical mechanism driving the periodical light variation. The similar study has been widely applied to the researches of X-ray binaries[1−3] and super-massive black holes[4,5].

SS 433 is positioned at the center of the supernova remnant W50. It is an X-ray binary system with a neutron star or black hole as its central compact object, and a late A-type star[6,7] as the companion star[8]. In the strong radio source catalogue named by Stephenson and Sanduleak, it is ranked at the 433-th position, in addition to the double initial S of the two names, it is called SS 433. Since SS 433 was discovered in 1978, the study on its extraordinary characteristics has become a hot point in astrophysics[9−12]. At

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