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Analysis of the Precision of Pulsar Time Clock Model† ⋆

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Abstract Millisecond pulsars have a very high rotation stability, which can be applied to many research fields, such as the establishment of the pulsar time standard, the detection of gravitational wave, the spacecraft navigation by using X-ray pulsars and so on. In this paper, we employ two millisecond pulsars PSR J0437-4715 and J1713+0743, which are observed by the International Pulsar Timing Array (IPTA), to analyze the precision of pulsar clock parameter and the prediction accuracy of pulse time of arrival (TOA). It is found that the uncertainty of spin frequency is 10^{-15} Hz, the uncertainty of the first derivative of spin frequency is 10^{-23} s^{-2}, and the precision of measured rotational parameters increases by one order of magnitude with the accumulated observational data every 4∼5 years. In addition, the errors of TOAs within 4.8 yr which are predicted by the clock model established by the 10 yr data of J0437-4715 are less than 1 μs. Therefore, one can use the pulsar time standard to calibrate the atomic clock, and make the atomic time deviate from the TT (Terrestrial Time) less than 1 μs within 4.8 yr.

Key words pulsars: general, time, methods: analytical

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1. INTRODUCTION

The pulsar is characterized by its small dimension (a radius of $\sim$ 10 km), high density ($\sim 10^{14}$ g/cm^3) and intense magnetic field ($\sim 10^{12}$ Gs) [1]. The intense magnetic field yields high-speed charged particles, and makes it emit electromagnetic radiation from the two ends of magnetic pole. Because of the deviation of magnetic axis from the rotational axis, while the electromagnetic wave sweeps over the earth, observers on the earth may detect periodic pulse signals. In 1982, Backer et al. found the first millisecond pulsar PSR B1937+21[2]. Observations demonstrated that the period of a millisecond pulsar is very stable, the first derivative of its period attains $10^{-18} \sim 10^{-20}\mathrm{s}\cdot\mathrm{s}^{-1}$. In 1991, Taylor suggested that a millisecond pulsar is the most stable clock in the nature, and that the millisecond pulsar might compare favorably with an atomic clock in terms of long-term stability [3]. Along with the discovery of more and more millisecond pulsars and the ceaseless improvement of observational capacity of radio telescopes, the timing observation of millisecond pulsars is rapidly developed, so as to promote effectively the application research of pulsars, such as the establishment of the pulsar time standard [4], the detection of ephemeris errors of planets in the solar system [5], the detection of gravitational wave of the remnant cosmic background [6], the spacecraft navigation by pulsars and so on [7]. The studies on the timing application of pulsars are all based on the rotation stability of pulsars, of which the rotational parameters may be precisely measured, for example, the period of J0437-4715 is 5.757451831072007(8) ms, and it can be measured precisely to the 15th decimal. The pulsar's characteristic of extremely stable rotation leads to the precise forecast of the TOA of the radiated pulse signal at the solar system barycenter (SSB). Hence, the measuring accuracy of pulsar rotational parameters determines directly the worth of pulsar applications, such as the stability of pulsar time, the accuracy of pulsar navigation, the detection accuracy of gravitational wave, and so on.

In this paper, an analysis is carried out on the accuracy of pulsar clock model based on the observational data published by the International Pulsar Timing Array (IPTA), including the analysis on the measuring accuracy of current pulsar parameters, the relation between the measuring accuracy of clock model parameters and the time span of observational data, the analysis on the prediction accuracy of pulse time of arrival (TOA), in which Second 2 presents the method for the establishment of clock model; Section 3 gives the accuracy of clock model parameters and the prediction accuracy of pulse TOA by through the analysis of observed dada; and Section 4 gives the conclusion and discussion.

2. METHOD TO ESTABLISH THE CLOCK MODEL

Pulsar is characterized by its extremely stable rotation, and is famed as the most stable astronomical clock in the nature. The time system established based on the period of highly-stable pulsar rotation is known as the pulsar time system. For a certain pulsar, the