MARTIAN PRECESSION AND NUTATION

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ABSTRACT. In this paper, the recent progress on studies of Martian precession is reviewed. The research work on Mars nutation is divides into three aspects: the rigid Mars nutation series, the Martian internal structure model constructed by the physical parameters which are determined from the space exploration, the Mars normal mode and the non-rigid Mars transfer function. They are discussed respectively.

1. INTRODUCTION

Mars is a terrestrial planet. It shows Earth-like properties in many aspects. The motion of Mars pole in space depends directly on Martian precession and nutation. Martian precession and nutation, on the one hand, can be modeled by theory, on the other hand, are restrained by the observational data acquired from the space exploration. The comparison between the observational data and the theoretical results on the motion of Mars' pole is an important means for checking the Martian internal structure. It also provides the basis for improving the theory of Martian precession and nutation.

2. MARTIAN PRECESSION

By analogy with the Earth, Martian precession is composed of the "lunisolar" precession and the planetary precession. The "lunisolar" precession for Mars can be determined with the Earth-based methods or the space-based methods.

The first attempt to calculate Martian "lunisolar' precession rate was made by Struve (in 1898). Hilton (1991) took the effects of various sources into account in calculating the precession rate. He obtained the value as (-7".296 ± 0".021)/y. Folkner et al. found the observational value from the Mars Pathfinder spacecraft. Their value was (-7".576± 0".053)/y.

Bouquillon and Souchay (1999) obtained the Martian planetary precession as $\chi = 1".74571$ / y. The value of geodesic precession is obtained as $p_g = 0".0067547$ / y.

3. RIGID MARS NUTATION SERIES

The rigid Mars nutation theory is the basis of constructing the non-rigid Mars nutation theory. At present, like the rigid Earth, the methods of deriving the rigid Mars nutation series

can be divided into three categories: the torque approach, the Hamiltonian approach and the tidal potential approach. Different author used different approach respectively.

Roosbeek's theory of rigid Mars' nutation (1999) was based on the calculation of torque produced by the Sun, Phobos and Deimos. The rigid Mars nutation series for the angular momentum axis were computed. Finally, the nutation series including six fundamental arguments of astronomical parameters were obtained. With the 0.1 mas truncation level, 24 waves in longitude and 10 waves in obliquity were found.

4. MARTIAN INTERNAL STRUCTURE MODELS

The study of the space exploration may acquire the physical shape, the mean density and gravitational field of Mars. When the mean density and the polar moment-of-inertia coefficient of Mars were known, Martian internal structure models can be constructed.

The basic structure of Mars model is similar to the Earth's. It includes a shell, an elastic mantle and a core. At present, the distribution law of Martian rheological parameters in the planetary interior are not known exactly. The value of C/MR^2 is also not determined reliably. Hence, some simplified assumption for Mars has to be made. The initial values of central density, central rigidity, rigidity of the core and radius of the core are adopted. With solving the Emden equation and taking the boundary condition into account, the Martian parametric model is constructed (e.g. Zhang, 1994). Different observational values and various approaches will lead to different Mars internal structure models.

5. NORNAL MODE AND TRANSFER FUNCTION OF MARS ROTATION

Normal mode expansion theory shows that a hydrostatic, unstressed, elastic, rotating planet with a solid mantle and a liquid core is subject to three oscillatory modes: the tilt over mode (TOM), the Chandler wobble (CW) and the nearly "diurnal" free wobble (NDFW). If the core of Mars is a fluid core, Mars is also subject to these modes.

	Cause of formation	Period
TOM	The motion of Martian mean axis of rotation about its instantaneous rotation axis	identical to the rotating period of Mars
CW	Free wobble of instantaneous rotation axis with respect to the body-fixed reference frame axis	191-225 days *)
NDFW	The result of spheroidal liquid core	near the rotating period of Mars

*) The Eulerian period for rigid Mars is about 178.7 days

The value of CW period depends on the Mars dynamical flattening and Love number, also on the core radius and the polar principle moment of inertia. The NDFW corresponds to the free core nutation (FCN) if it is observed in inertial space. The FCN period ranges about from -330 to -220 days. The FCN period is extremely useful in determining the size of Mars core.

The TOM, the CW and the NDFW are three natural modes of oscillation of Mars. The forced nutation components of Mars are the driven oscillations of the planetary motion. The ratio between theoretically the rigid Mars nutation amplitudes and actually the observed nutation amplitudes should be a result of the resonance between the driven oscillations and the nature modes of oscillation of the planet. Theoretical nutations for a non-rigid model of Mars are computed from a convolution of rigid Mars nutations with transfer functions accounting for geophysical parameters influencing the Mars response. Hilton (1992) used the normal mode expansion method on the basis of the rigid Mars nutation model. He considered some disturbing

effect in his modelling and derived the non-rigid Mars nutation series, which were in keeping with the motion of the actual Mars pole.

6. CONCLUDING REMARKS

From the preceding review it is obvious that a lot of factors are uncertainties in the studies of Martian precession and nutation as well as the free wobble, such as, the polar moment-of-inertia coefficient C/MR^2 , the distribution of the rheological parameters in the Mars interior, the size and property of Mars core and Mars Love number of the second degree et cetera. At present, various authors derived different non-rigid Mars' nutation models by using different approaches. The recognized Mars precession-nutation model does not exist yet. The space exploration is undoubtedly the most effective means in order to clarify these uncertain factors. The results of the space exploration not only include the effects of the Sun, the Mars satellites and the other planets on Mars, but also represent the physical activities in the interior of Mars. Therefore, they reflect the comprehensive phenomenon of various objective factors.

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