DYNAMICAL CONSTANTS AND REFERENCE PARAMETERS FOR MARS

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Abstract. Dynamical constants and other fundamental reference parameters for Mars have been derived from analyses of Viking lander ranging and Doppler tracking data covering a time span of nearly four years. Precise values have been obtained for the coordinates of the spin axis and for the rotation rate, suggesting that these Viking-derived values are definitive and are suitable for adoption by the IAU. Preliminary results have been obtained for a small seasonal variation in the rotation rate, and progress has been made toward a direct determination of the precession constant.

INTRODUCTION

Tracking data from the Viking Mars landers and orbiters have provided a wealth of information for analyses of properties of Mars and its environment (Michael et al., 1977). The lander Doppler tracking data are uniquely appropriate for determination of parameters of the physical ephemeris of Mars and two components of lander position. Ranging data are primarily used in determining the Earth-Mars ephemeris and the component of lander position parallel to the spin axis. Results of data analyses for time spans ranging from a few days to 16 months have been reported previously (Michael et al., 1976; Mayo et al., 1977; Michael, 1979). Reported here are results of the most recent analyses of the data available to date, covering a time span of 46 months. In general, these results have been obtained using analytical procedures and the tracking systems described elsewhere (Mayo et al., 1977; Michael et al., 1972). The stability and precision of the present and earlier solutions with continuously increasing data spans indicate that results for the Mars pole position and rotation rate are now definitive.

MARS POLE POSITION AND ROTATION RATE

Solutions for the coordinates of the north pole of Mars and for the rotation rate converged rapidly for even the short data spans of the

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early analyses of Viking data and have exhibited remarkable stability for successively increasing data spans. On the basis of this experience, it is not expected that these results will be significantly affected through incorporation of additional data.

The recommended values for the right ascension α and the declination δ of the Mars spin axis, referred to the Earth mean equator and equinox of 1950.0, are

$$\alpha = (317.340^\circ \pm 0.003^\circ) - 0.10106^\circ T$$

$$\text{and } \delta = (52.711^\circ \pm 0.002^\circ) - 0.05706^\circ T$$

where T is measured in Julian centuries from 0 hours, January 1, 1950 (Julian Day 2433282.5). The secular variations in α and δ are obtained from the Lowell (1914) predicted precession of -708 arc s per Julian century. An assumed uncertainty of $\pm$ 50 arc s per century in this value of the precession constant is the primary contributor to the quoted uncertainties in α and δ at the 1950 epoch. The uncertainties in the instantaneous coordinates of the pole at any epoch within the Viking time frame are approximately $\pm$ 0.001 deg.

The recommended value for the sidereal rotation rate of Mars, determined as the average rate for essentially two full Martian years, is 350.891985 $\pm$ 5 x 10^{-6} deg per day. This corresponds to a sidereal rotation period of 24h 37m 22.6631s $\pm$ 0.0013s. By convention, the sidereal rotation is referred to the vernal equinox of Mars, which is assumed to precess at the rate mentioned earlier. The Viking-derived value for the rotation period is in very close agreement with the recently modified value of 24h 37m 22.662s $\pm$ 0.002s obtained by de Vaucouleurs (1980) from albedo station data for the past 300 years, suggesting that these improved results are definitive.

SEASONAL VARIATION IN THE MARS ROTATION RATE

The rather significant seasonal variation in atmospheric pressure measured at the Viking landing sites, due to alternate deposit and release of carbon dioxide at the polar caps, suggests that this effect could lead to a detectable variation in the rotation rate. The magnitude of such an effect can be estimated by a simple model which assumes conservation of angular momentum about the polar axis and relates changes in atmospheric pressure to changes in the polar moment of inertia. A combination of simple expressions leads to the relation $\Delta\omega = -(5/3)\omega\ \Delta M/M$ where ω is the rotation rate, ΔM is the change in mass of a spherical shell representing the well-mixed Martian atmosphere (3.9 x 10^{18}g per mbar change in surface pressure), and M is the mass of Mars (6.4 x 10^{26}g). Using smoothed lander 1 pressure data from Hess et al. (1980), with periodic extrapolation beyond the first Martian year, the predicted seasonal variation in the Mars rotation rate, $\Delta\omega$, is shown in Figure 1.

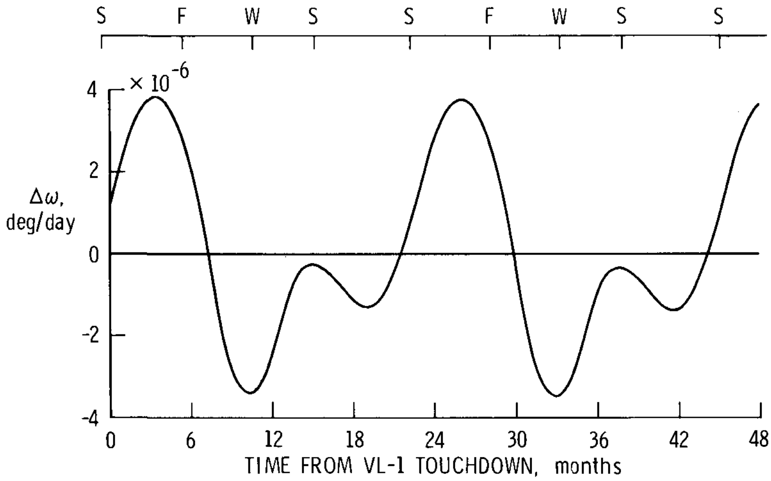

Fig. 1. Predicted Variation in the Mars Rotation Rate.

This model for the rotation rate variation, together with its integrated effect representing displacement, has been incorporated in the data analysis program, with the normalized amplitude as an additional solution parameter. Preliminary estimates for the amplitude are 0.4 that of Figure 1, giving an indication of the existence of a small seasonal variation in the rotation rate but at a lower level than predicted with the limited considerations of the simple model. This experimental result tends to support the analytical work of Philip (1979). Definitive confirmation of this effect would be of considerable interest in geophysical and atmospheric studies of Mars.

THE PRECESSION CONSTANT FOR MARS

With a sufficiently long data span it should be possible to determine the precession constant μ for Mars from the motion of the spin axis, even though the yearly motion is quite small. Figure 2 shows values obtained for μ from solutions with various data spans. The values of μ obtained for data spans longer than three years are just within the limits of the assumed uncertainty and, although not definitive, exhibit an encouraging trend. With additional tracking data from lander 1, which is expected to continue operating for some years, a definitive determination of μ can be anticipated. Such a determination, in turn, could have important applications to the polar moment of inertia of Mars and to analyses of its interior structure.

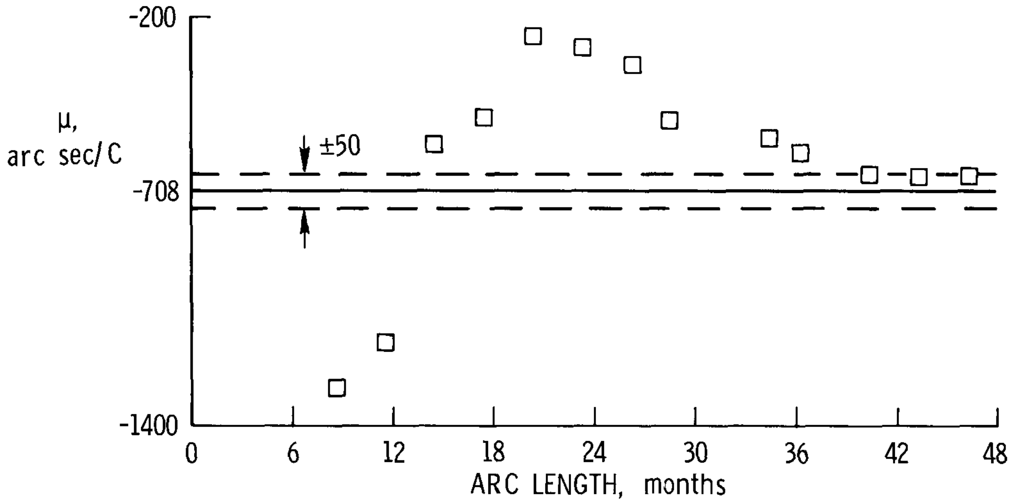

Fig. 2. Results of Solutions for the Mars Precession Constant.

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