The Prime Meridian of the Planet Mercury

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1. Introduction

The prime meridian of Mercury is defined by the impact crater Hun Kal (twenty in the Mayan mathematical system). The angle between the prime meridian and the intersection point of the planet's equator and the equator of the International Celestial Reference Frame (ICRF)[1] at epoch J2000.0 is the prime meridian constant, W_0. The value of W_0 should ensure that the center of the crater Hun Kal is at planetographic longitude 20°W or planetocentric longitude 340°E.

An early value of W_0 was calculated by *Davies and Batson* [1975] from a control point network derived from Mariner 10 images. A value of $W_0 = 329.71°$ (184.74° with respect to the equinox B1950, epoch J1950) was adopted by the International Astronomical Union (IAU) Working Group on Cartographic Coordinates and Rotational Elements of the Planets and Satellites (WGCCRE) [*Davies et al.*, 1980]. The value was refined by *Davies et al.* [1995] to $W_0 = 329.69°$ on the basis of a new control network computation that included a determination of the focal lengths of the Mariner 10 cameras. More recently the prime meridian constant was further refined by an improved control net to $W_0 = 329.548°$ from Mariner 10 images [*Robinson et al.*, 1999]. In 2007, longitudinal librations of Mercury were observed [*Margot et al.*, 2007] and led to a redefinition of the W_0 value, as the libration angle is not 0.0 at J2000.0. The new value $W_0 = 329.5469°$ was adopted by the IAU in 2009 [*Archinal et al.*, 2011].

Observations by the MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) spacecraft during orbital operations suggest a rotation rate of Mercury somewhat higher than the resonant value [*Mazarico et al.*, 2014; *Stark et al.*, 2015a], a situation that demands a correction to the prime meridian value. Furthermore, calculations by *Stark et al.* [2015b] revealed that the resonant mean spin rate of Mercury, i.e., the spin rate that is precisely a factor of 1.5 greater than the mean motion[2], differs from the value often quoted as the resonant mean spin rate and adopted for Mercury by the IAU since 1980. The spin rates derived from MESSENGER data [*Mazarico et al.*, 2014; *Stark et al.*, 2015a] are significantly different from both the current IAU spin rate and the resonant spin rate of *Stark et al.* [2015b].

A possible explanation for the higher observed rotation rate is that the planet undergoes long-period librations with a period of about 12 years [*Stark et al.*, 2015a]. On short time scales, e.g., the duration of orbital operations by the MESSENGER spacecraft, the long-period librations correspond to an apparent increase in the rotation rate of the planet. If long-period librations

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[1] The ICRF is the reference frame of the International Celestial Reference System and is itself epochless. There is a small (well under 0.1 arcsecond) rotation between the ICRF and the mean dynamical frame of J2000.0 [*Archinal et al.*, 2011].

[2] The precession of the argument of pericenter is also considered in the calculation of the resonant mean spin rate.

indeed dominate the observations, then the rotation rate should be to be set to the resonant mean rotation rate [*Stark et al.,* 2015b] and long-period librations should be included in the rotation model (see supplementary online material of *Stark et al.* [2015a]).

Given the latest value for the spin rate, a new value for W_0 is required. Such a new value in turn requires observations of the location of Hun Kal with respect to the inertial frame, i.e., the ICRF. Topography measurements have been acquired by the Mercury Laser Altimeter (MLA) and the Mercury Dual Imaging System (MDIS). As of 2014, MDIS had acquired about 12 images as resolutions less than 1 km in which the crater Hun Kal is identifiable. However, errors in the attitude of the imaging system as well as the calibration of the imaging system result in uncertainties in the coordinates of the image pixels when projected onto the spherical grid of Mercury (orthorectification). The nearest MLA observation (data up to April 2014) to Hun Kal is located at 0.455°S, 338.536°E, i.e., more than 60 km from the crater. Since no MLA profiles cross Hun Kal, an update to the W_0 value is not easily obtained from MLA data alone.

2. Definition of the prime meridian constant W_0 of Mercury from MDIS images

MDIS images available up to April 2014 that include Hun Kal were orthorectified using the rotation rate of W_1 = 6.1385025°/day [*Archinal et al.*, 2011]. The location of the center of Hun Kal was then determined visually by reading the coordinates of a crosshair. From the image resolution and the visibility conditions of the crater, a positioning error was assigned. Figure 1 shows the coordinates of Hun Kal so obtained. With the IAU rotational model [*Archinal et al.*, 2011], the crater was found to be offset by approximately 0.09° (3.9 km) from –20°E. The latitude of Hun Kal was found to be at 0.4631°S. Least-squares fits to the data with updated rotation rates yield the following values for W_0 with an uncertainty of 0.0037°:

- Retaining the IAU rotation rate of W_1 = 6.1385025°/day [*Archinal et al.*, 2011] leads to an updated value of W_0 = 329.6369°.
- When the rotation rate W_1 = (6.13851804 ± 0.00000094)°/day [*Stark et al.*, 2015a] is adopted, the value for W_0 is 329.5648°.
- For the resonant rotation rate W_1 = 6.1385068°/day [*Stark et al.*, 2015b] and with the introduction of additional long-period librations, the prime meridian constant is W_0= 329.6268° and long-period librations must be included in the rotation model (see supplementary online material of *Stark et al.* [2015a]).
- *Mazarico et al.* [2014] calculated a rotation period of 58.646146 ± 0.000011 days, which is equivalent to a rotation rate of (6.13851079 ± 0.0000012)°/day. The corresponding W_0 value should then be W_0 = 329.5988°.

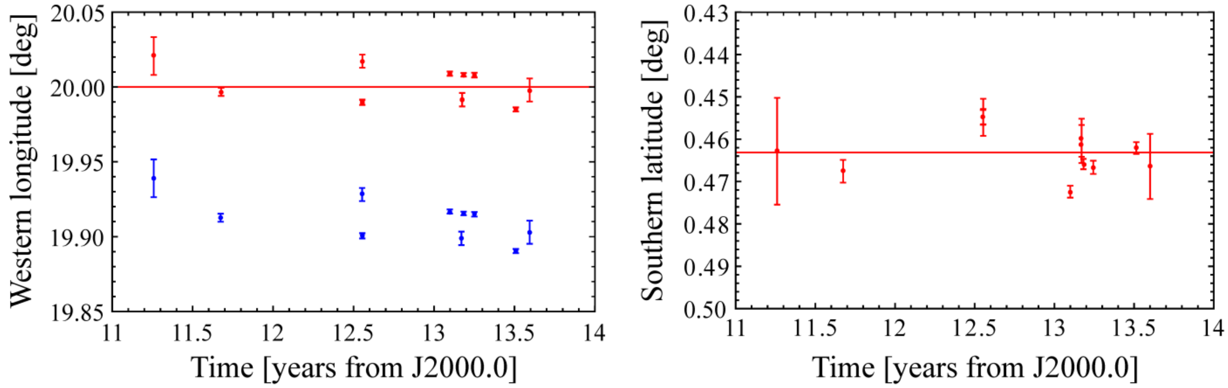

Figure 1. Measured longitude (left) and latitude (right) of the center of the crater Hun Kal in 12 MDIS images acquired from orbit about Mercury. The longitudes obtained with the current IAU rotation model [*Archinal et al*., 2011] are shown in blue, and the adjusted longitudes (with the rotation rate of *Stark et al.* [2015a] and updated W_0 value) are shown in red.

Appendix

List of MDIS images used in this analysis:

1	EN1005053163M
2	EN1002521325M
3	EN1015451668M
4	EN1007130467M
5	EN0223616660M
6	EN0251340756M

7	EN0251369558M
8	EN1004678315M
9	EN1004678277M
10	EN1018134317M
11	EN0251369585M
12	EN0210498522M

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