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Phobos astrometric observations in support of the Mars Express Phobos flyby experiment on December 29, 2013

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Abstract

Here, we report on Phobos astrometric observations and orbit modeling using images obtained during Mars Express Phobos approaches between May 2013 and February 2014, performed in support of the MEX Phobos gravity and radio science experiment on December 29, 2013.

1. Introduction

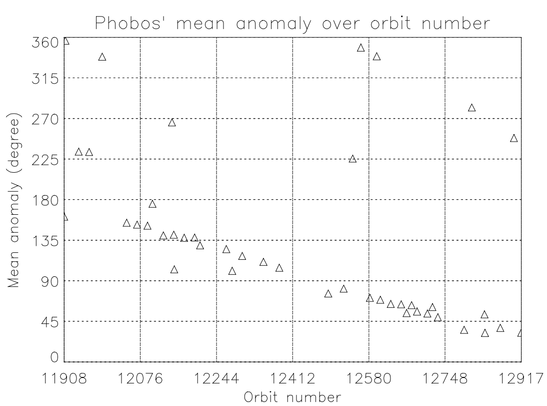

Figure 1: Phobos mean anomaly over MEX orbit #

On December 29, 2013 the MEX S/C carried out the closest Phobos flyby ever, only 45 km above the moon's surface. The flyby experiment was designed for radio science observations and studies of Phobos' gravity field parameters [1,7].

As knowledge of the Phobos flyby distance is crucial for the modeling of the radio science data, accurate ephemerides of Phobos are needed. Unfortunately, during the particular flyby dedicated to radio science, simultaneous imaging was not possible. Therefore, after May 2013, 38 MEX Phobos flybys have been scheduled before and after the critical flyby with distances ranging from 350 to 14,000 km to verify or correct the nominal Phobos orbit data.

2. Image sequences

During each approach the SRC camera is directed to a fixed point on the celestial sphere while Phobos is crossing the camera's field-of-view. Usually, a sequence of eight images is taken, of which the first and the last one are long-time exposures to detect the faint light of background stars. The exposure times of the images in-between are adjusted to the bright Phobos surface.

3. Methods

Given the position of the S/C and the approximate pointing of the camera, we can describe the direction to the satellite's center-of-figure (COF) in equatorial coordinates in the International Celestial Reference Frame (ICRF) [2]. The European Space Operations Centre (ESOC) provides the MEX orbit and attitude in the form of SPICE kernels. While the positional data is reconstructed from tracking data and believed to be accurate, the information on orientation is predicted only and needs to be verified [5].

3.1 Pointing verification

The pointing is verified by comparing predicted and observed positions of catalogue stars. Pointing corrections in line and sample are derived for every star image. For images showing Phobos only, the corrections are interpolated assuming a linear pointing drift [8]. However, continuous star observations enable more accurate pointing data. For long-time exposures the limiting star magnitude of the SRC is about 9.0.

Besides usual star observations, image sequences of Phobos and Pleiades (12279, 12563, 12598), Phobos, Jupiter and the Galilean satellites (12151) as well as Phobos and the Earth-Moon system (12545) were available for pointing verification.

Table 1: MEX and Phobos mutual events

Orbit	Time	Distance	MA_{Phobos}
12151	2013-07-23T03:15	6,528	102.6
12279	2013-08-29T11:04	6,000	101.1
12545	2013-11-14T18:36	12,726	225.5
12563	2013-11-19T23:45	13,901	348.6
12598	2013-11-30T04:33	13,624	338.9

3.2 COF measurements

Image positions of Phobos are determined by fitting predicted to observed limb points, where the limb is the visible boundary of the moon's illuminated portions and dark space [4]. Limb points are predicted based on models of the satellite's orbit, rotation, and shape [9]. Limb points in the image are detected by fitting predicted limb curves to the observed limb using least-squares methods.

The errors are estimated as square root of sum of squares of the error in S/C position, camera pointing and COF measurement [2].

$$\sigma = \sqrt{\sigma_{pos}^2 + \sigma_{pnt}^2 + \sigma_{cof}^2} \qquad (1)$$

Thus, 340 Phobos positional observations have been made, which achieve relative accuracies between 226 and 707 m.

4. Summary & Conclusions

To derive global parameters of the Phobos gravity field from data generated during the MEX close flyby on December 29, 2013 we need to know the moon's position with high accuracy [1,7]. Therefore, a large number of astrometric observations have been reduced from images taken from May 2013 to February 2014.

Our observations are being used to model Phobos orbit with unprecedented accuracy, taken into account the most recent physical parameters describing the Mars dynamic environment [3]. Besides, the observations will be used to improve the MEX S/C orbit during observation times [8]. Any progress will be reported at the meeting.

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