DIFFERENCE BETWEEN DYNAMIC AND STELLAR REFERENCE FRAMES: RESULTS BASED ON ASTROMETRIC OBSERVATIONS OF MARTIAN SATELLITES

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ABSTRACT. The possibility of using precise astrometric observations of Martian satellites in 1988 for improving the mutual orientation of the dynamic and stellar reference frames is discussed. The results obtained lead to the conclusion that the stellar reference frame is rotated about the X axis of the dynamic one. However, the value of this rotation (~2$''$.5) proves to be unrealistically large and repetitions of precise observations of Martian satellites are needed in the future for verifying this result.

During the period from July up to November 1988 Sternberg Astronomical Institute (SAI) astronomers made a large series of photographic measurements of Martian satellites coordinates (rms error is 0$''$.12) at the Mt. Maidanak obsevatory.

These data [1] are presented not as the satellite coordinates relative to Mars or another satellite but as the absolute measurements of the right ascention and declination in the SRS catalog reference frame which is an expansion of the FK4. Attempts to use this kind of measurements of Phobos and Deimos for improving its orbital parameters display systematic differences (up to 0$''$.4) in the measurements with their calculated values. These differences cannot be removed by correction of satellite orbital parameters without contradiction with another observations. But in the case of "Phobos – Deimos" relative coordinates, the measurements are in full correspondence with the theory [2] of Martian satellites motion worked out in the Mission Control Centre (MCC).

These are the possible explanations of the phenomenon:

1. *Systematic errors of observation.* The satellite coordinates were first determined relative to distant stars fixed on plates. Star positions were then connected to the SRS catalog reference frame. As a result the systematic observation error is evaluated to be less then 0$''$.1" to 0$''$.15.

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2. *Errors in Earth and Mars ephemerides.* In our calculations we used the American DE118 and/or DE200 ephemerides and/or Soviet ephemerides [3]. These ephemerides are mainly based on precise radar measurements of Mercury, Venus and Mars — so relative distances between those planets are well determined. The errors in the position of Mars relative to Earth are evaluated to be not more than 10-15 km. Equal angular errors are less than 0''.05.

3. *The difference between the dynamic and stellar coordinate systems as a whole.* Connection of those systems was based on optical planetary observations which have 0''.5 to 1''.0 errors. Only as a result of the 1988 observations did it become possible to use high-precision Martian satellites measurements for this purpose.

The authors have investigated a conclusion that one should be able to give if one accepts the 3rd explanation of the phenomenon. The obtained results are based on two separately derived theories of satellite motion and various planet ephemerides. In MCC an analytical theory of the 2nd order of Martian satellites motion [2] based on all known ground-based and space observation of satellites in 1877–1989 and high-precision radio-tracking of the spacecraft "Phobos-2" in the vicinity of Phobos was used.

The calculation precision of the satellite ephemerides on the theory base is evaluated as (1-σ) 2-3 km for Phobos and 6-9 km for Deimos. An analytical theory of Phobos motion [4] was developed in SAI. The features of this theory are utilization of solving the general problem of two static centres for an intermediate satellite orbit and the determination of all perturbations from gravity factors with required precision. DE118 and/or soviet ephemerides in MCC and DE200 in SAI were used to represent the planet coordinates.

The table shows values of rotation angles of the stellar reference frame relative to the axes of DE118 and/or DE200 one obtains on the basis of different measurements files. The results obtained with use of soviet ephemerides are very close to those which were obtained in the case of using DE118.

Table 1. Rotations of the stellar reference frame relative to axes of the dynamical one

Rotation (right)	Observations involved, method, planet ephemerides			
	Phobos, MCC, DE118	Phobos, SAI, DE200	Deimos, MCC, DE118	Phobos+Deimos MCC, DE118
Wx	−2''.40 ± 0''.33	−2''.14 ± 0''.27	−2''.70 ± 0''.33	−2''.56 ± 0''.24
Wy	+0''.04 ± 0''.05	+0''.04 ± 0''.06	+0''.01 ± 0''.05	+0''.02 ± 0''.05
Wz	−0''.10 ± 0''.03	+0''.56 ± 0''.06	−0''.09 ± 0''.03	−0''.10 ± 0''.03

The Wz values in the MCC and SAI alternatives differ significantly because of utilization of different planet ephemerides. The DE118 reference frame differs from the DE200 one mainly by precession and additional rotation around the Z-axis at 0''.53 angle.

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As soon the results that are given in the table contradict with optical observations of Mars, the existence of systematic errors in photographic stellar catalogs may be assumed.

The orientation of the stellar reference frame relative to the dynamic one may be well determinated on the basis of precice Mars satellite observations in the future.

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Discussion

STANDISH: There is no way for the plane of the Martian orbit to be mis-aligned by 2.5 arcsec in the ephemerides. This is two orders of magnitude too much. You have tilted the orbit of Mars by that large amount in order to fit a small time-span of residuals that are only about 0.4 arcsec. From the type of astrometry that you have done, 0.4 arcsec is not an unreasonable error to expect. Additional observations, especially ones that are in other parts of the orbit, would be most informative.

KUDRYAVTSEV: We agree with you that the obtained value of ~2.5 arcsec for the discrepancy between a stellar reference frame and a dynamical one is too large. Nevertheless, the results which we discussed give a reason for the conclusion that a small rotation of a stellar reference frame about the X-axis of a dynamic one really exists. We consider, as mentioned in our report, that the repetition of photographic observations of Martian satellites in the near future would be very desirable. The task of connecting different celestial coordinate systems is important for space missions.

KISSELEV: How large was the working field of the telescope? I think that there may be a mistake caused by a two-step reduction.

KUDRYAVTSEV: There were two telescopes: one was an astrograph AFR (5°x 5°) and the other was Zeiss-1000 (40' x 40'). As for the second question, we agree with you that a mistake in reduction is possible.

BRONNIKOVA: Why have you used the FK4 system?

KUDRYAVTSEV: The observations were reduced in that system.

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