EARTH ROTATION IN THE EROLD FRAMEWORK

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I - INTRODUCTION

The project EROLD (Earth Rotation from Lunar Distances) was conceived in 1974, in the COSPAR framework, with the goal of demonstrating that the lunar distances technique might be an efficient candidate in a new-generation service for the determination of Earth orientation.

Two years later, it was decided that the computations of the observational residuals and partial derivatives, as well as the analyses themselves, would be done at C.E.R.G.A. on a regular basis, for all the participating stations. Indeed, it was recognized to be important that all the observations be reduced in an homogeneous process. The target chosen for this program was that of Apollo XV which is the easiest to observe. Unfortunately, the operations could not start quickly due to a lack of observations and each station was encouraged to press the completion of the equipment, but many problems slowed the integration of these stations. Still now, only McDonald Observatory transmits observations regularly, and Orroral is operating, but with scattered results; presently this latter station is in course of modifications for improvement of accuracy.

Finally, after some attempts by a few groups including ourselves, we published the first series of results for Universal Time, in the Annual Report of BIH for 1978. Since then, the results are published (Calame and Guinot, 1979, Calame 1980, Calame, 1981).

II - BASIC EQUATION - METHOD OF RESOLUTION

To determine the Earth rotation in a "quick turn-around" context, concerned with near real-time determinability, it is necessary to adopt a relatively simple reduction mode, which is not too difficult to implement.

For that, we first compute the observational residuals and partial derivatives with an accurate mathematical model, whose basis was

O. Calame (ed.), High-Precision Earth Rotation and Earth-Moon Dynamics, 41–51.

reported by Calame (1979) but with many additions and improvements. Among the characteristics of this model, one may mention that the orbital motion of the Moon is represented by the ephemeris ECT18 (Calame, these proceedings), the lunar librations are computed from the Migus analytical model (Migus, 1977) for the second-order and third-order effects of lunar potential field, while semi-analytical terms are adopted for the planetary perturbations; for the Earth tide phenomena, an optimized model was established from the Cartwright series (1970), by Valein (1979), assuming the Earth to be an elastic body; the effects of ocean loading were not introduced, but do not seem to be very important. Concerning the Earth orientation, the basic values of UT1 and polar motion were computed from the BIH Circular D smoothed values, by linear interpolation, with addition of the tidal variations in UT1 according to Woolard's series (Woolard, 1959) and of the terms of diurnal nutations to the pole coordinates (McClure, 1973).

In a second step, the residuals (O-C) in time delay are processed to determine the Earth rotation parameters and a few global parameters to take account for uncertainties of the model, such that the general condition equation is as follows :

$$\begin{aligned} \frac{D}{2\mathfrak{D}}\,(O-C) = {} & w \cos\delta \sin H \,\Delta(UT^*) \\ & + \cos\delta \cos H \left[z\,\Delta\phi - w\left(\frac{\Delta r}{r} + \frac{\Delta\mathfrak{D}}{\mathfrak{D}}\right)\right] \\ & + \sin\delta \left[-w\,\Delta\phi - z\left(\frac{\Delta r}{r} + \frac{\Delta\mathfrak{D}}{\mathfrak{D}}\right)\right] \\ & + \left(w \cos H \sin\delta - z \sin\delta \right) \Delta\delta \\ & + \frac{r}{\mathfrak{D}}\,\Delta r + \Delta\mathfrak{D} \end{aligned} \tag{1}$$

with : $w = r\cos\phi$

$z = r\sin\phi$

$UT^* = (UT1 - UTC) - \lambda - \alpha$

where :

$\mathfrak{D}$, α, δ are the geocentric distance, right-ascension and declination of the reflector, referred to the true equatorial system of date;

r, λ, ϕ are the geocentric distance, longitude (reckoned positive westward) and latitude of the station, referred to the instantaneous equatorial frame;

H is the geocentric hour-angle of the reflector.

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In these equations, five unknowns appear, representing the uncertainties on UT*, r, ϕ, $\mathfrak{D}$, δ. The solution is computed by the least-square method. Thus, we have analyzed the McDonald ranging data acquired from 1971 to April 1981 (Shelus, 1976-81) on the Apollo XV reflector (Fig.1). Each solution is extended on time intervals not exceeding about 5 days, in which the variations of the unknowns can be considered as negligible. Furthermore, a few results could be obtained for 1979-1980 from combinations of observations from both McDonald and Orroral stations.

In a parallel way, another type of solution was performed with 3 unknowns representing, in the equation(1), a constant and the factors of sinH, cosH. In this case, the time intervals for the observations participating to the solution are limited to about one day, because of the possible variations in the unknown represented by the constant. The results are generally less good and more scattered than with five unknowns, because the span in hour angle of the available data is often too short.

More recently some attempts were done with 6 unknowns to take account of a possible variation of UT1 on the time intervals of the solutions. The results do not change significantly the value for the weighted middle of the interval, and the drift is badly determined.

Obviously, the determination of the Earth rotation suffers still by the lack of data and particularly of observation stations well-distributed on the Earth surface. This is essentially critical for the pole position determination, since with only one station, such as McDonald, it is possible to estimate only variations of its distance to the equator, or of its latitude.

III - COMPARISONS

To attempt to judge about the validity of the results and study the influence of the model and method, we have done some comparisons in both an internal and external way.

1/ Influence of the lunar orbital ephemeris : The parameter ΔUT^*, which is really determined for the Universal Time by this method, is defined in the equation (1), that is to say :

$$\Delta UT^* = \Delta\ (UT1 - UTC) - \Delta\lambda - \Delta\alpha$$

In the present context, we are only interested by the variations in the time of the Universal Time so that $\Delta\lambda$ represents only a correction of the reference system and has to be considered only at the time of combination with other techniques to define a reference frame. On the other hand, $\Delta\alpha$ represents an algebric sum of uncertainties in the orbital motion of the Moon, the lunar librations and more generally the geocentric motion of the considered reflector.

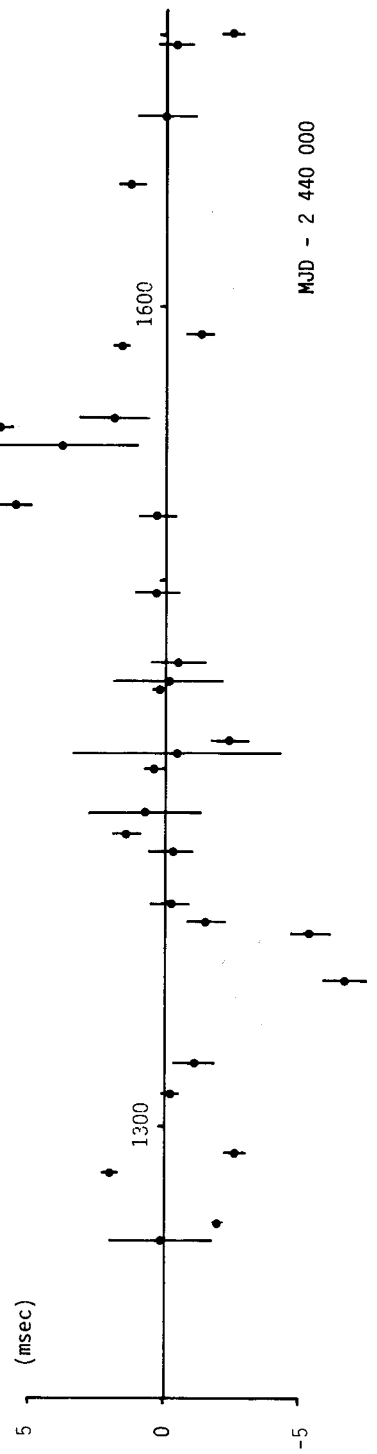

FIGURE 1 - UT1 (ECT18) - UT1 (BIH)
(1979 SYSTEM)

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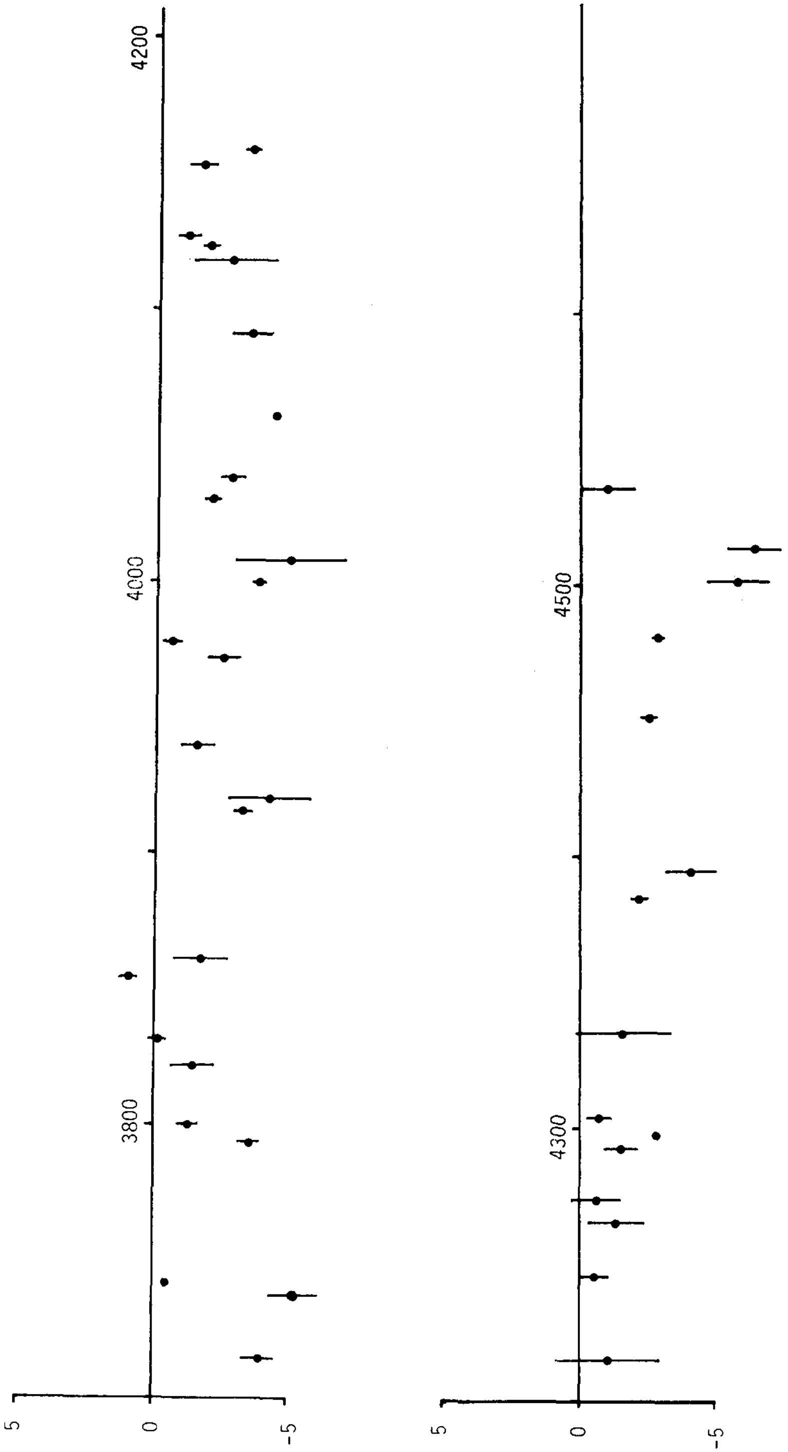

FIGURE 1 (continued)

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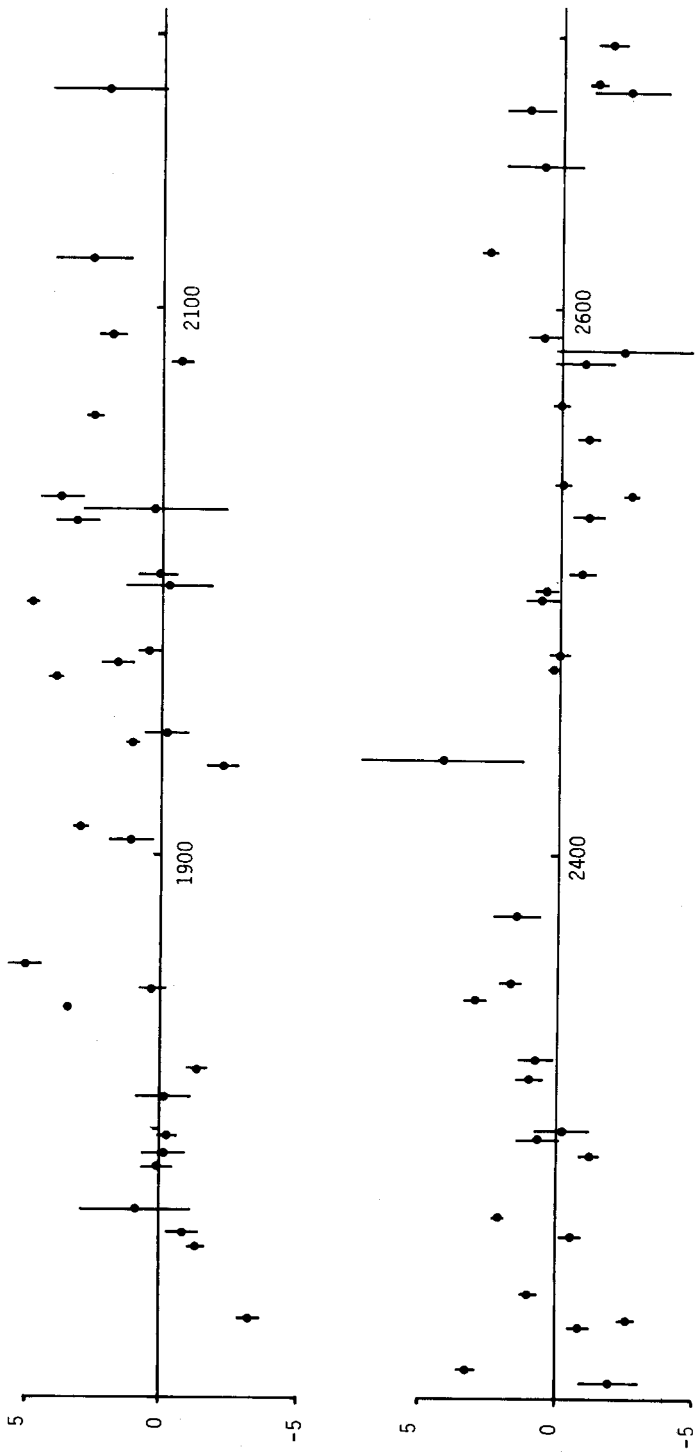

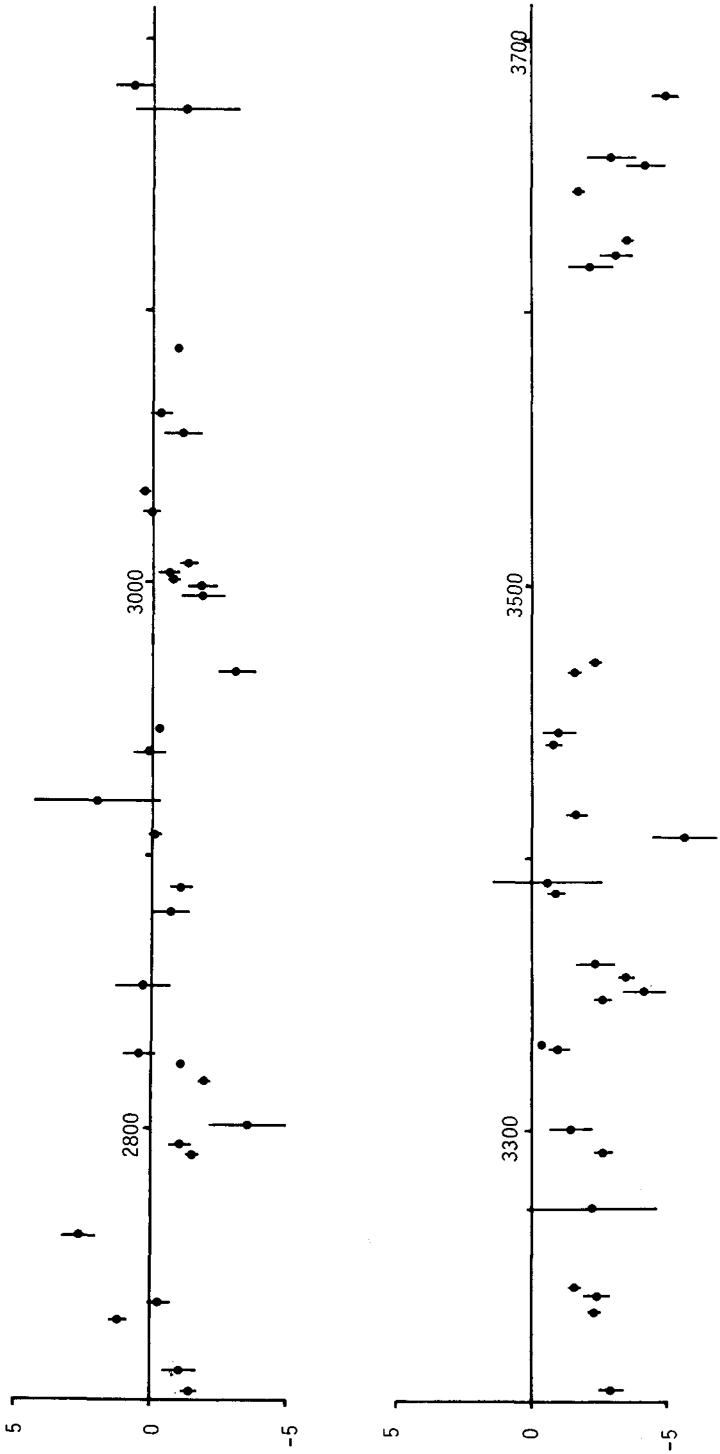

FIGURE 1 (continued)

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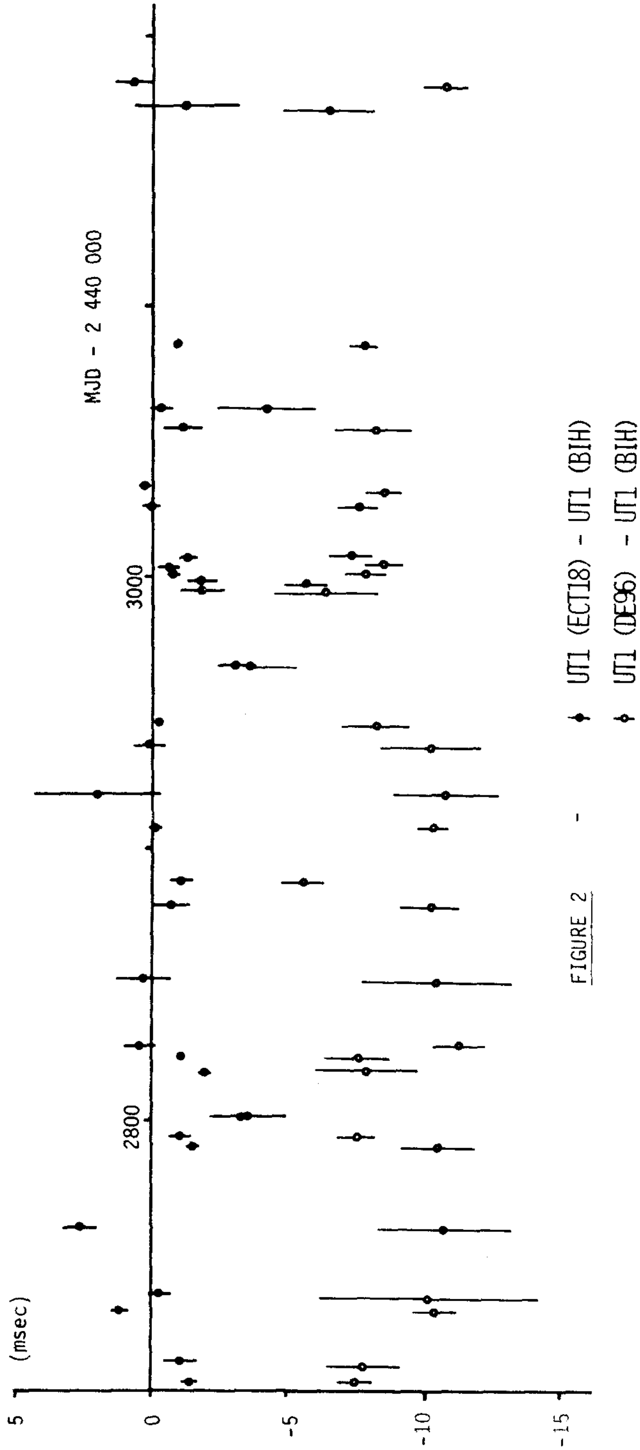
(msec)
MJD - 2 440 000
2800
3000
5
0
-5
-10
-15
UT1 (ECT18) - UT1 (BIH)
UT1 (DE96) - UT1 (BIH)

FIGURE 2

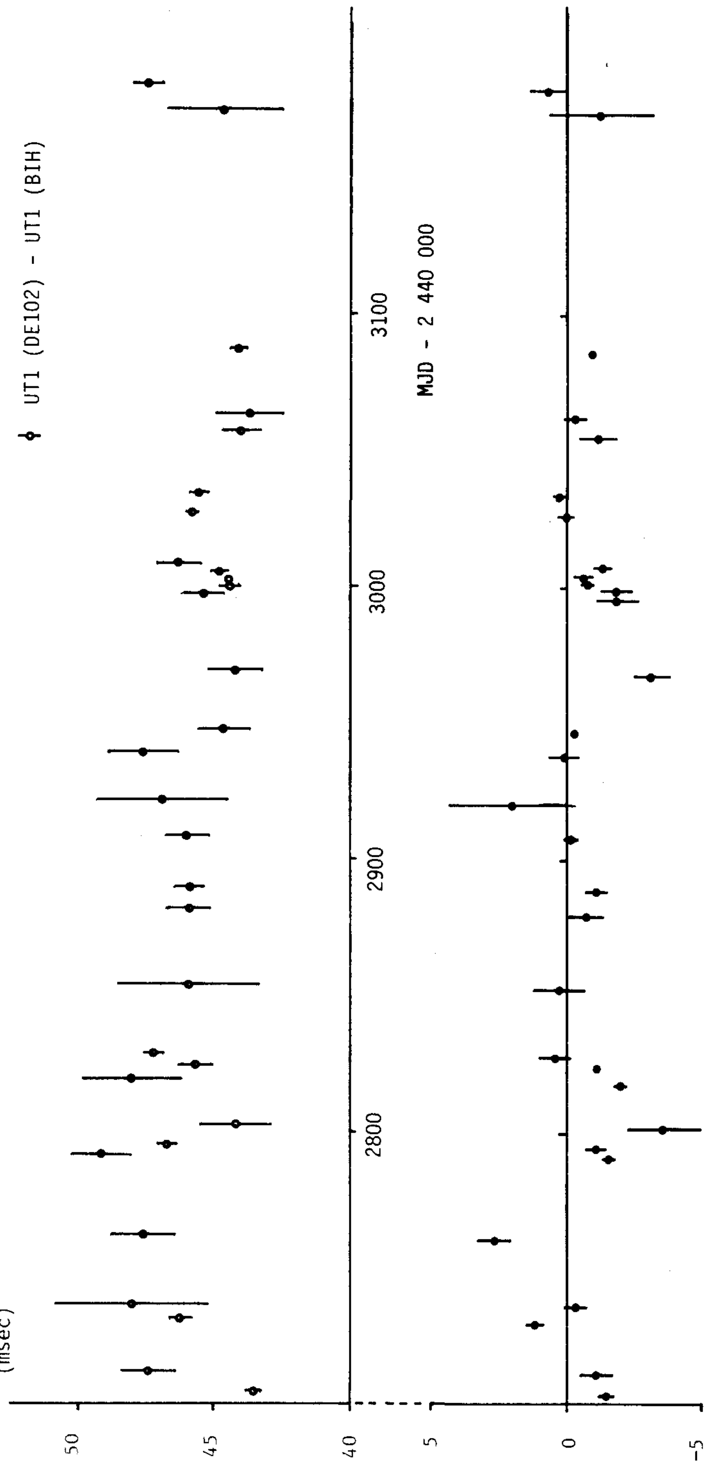

FIGURE 3 - UT1 (ECT18) - UT1 (BIH)
UT1 (DE102) - UT1 (BIH)

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Thus, among the various available lunar ephemerides, we have performed some comparisons on the Earth rotation corresponding results, in particular with the JPL ephemerides DE96/LE44 and DE102/LE51. A sample of the differences is given in the figures 2 and 3. On the span of 8 years, the r.m.s. residuals of UT* from ECT18, DE96 and DE102 are 0.82 ms, 2.0 ms and 0.83 ms, respectively. Also, the fluctuations with the time are often quite different in the three cases.

2/ Comparison with other methods : Two other methods of resolution have been used for the UT determinations from the lunar laser data (Langley et al. 1982; Fliegel et al. 1982). It is to note that such methods are badly adapted for the quick turn-around context in which we are concerned, but the accuracy may be better. Anyhow the present results, from the ECT18 ephemeris, seem to be compatible with those from the other methods; however, it is not very easy to perform such comparisons, in particular because the applied various corrections are not the same in all cases.

These studies on the Earth rotation from the lunar laser data are in continuation for improvement of the results, but the major improvement will be probably supplied by the increasing of the number of observations and stations.

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DISCUSSION

Feissel : *Do you see any long-period effects in the differences of UT1 results using DE96 and ECT18 ?*

Calame : There is detectable average drift, but it is difficult to say whether it is significantly attributable to any long-period terms.

King : *Your figure showing Universal Time results from either your own ephemeris (ETC18) or the JPL ephemeris DE96 illustates clearly the importance of the ephemeris to one's results.*

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