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THE TIME COORDINATE USED IN THE VARIABLE-STAR COMMUNITY

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The variable-star community does not use a correct physical time coordinate for recording observations and for deriving light-curve elements. Below I describe the problem and propose a solution. IAU Commissions 27 and 42 should take a decision on the subject.

Up to now, all observations, as well as light-curve elements, are published in terms of "JD". The conventional Julian Date, JD, is linked to the Universal Time, UT, which is not a physical time coordinate. Depending on whether you precisely refer to UT1 or UTC, its run is either wavy or has irregular jumps of a full second. Universal Time is not a physical time coordinate because it is defined by the varying rotation rate of the Earth.

The preferred physical time coordinate for astronomy, as recommended by IAU Division I, is Terrestrial Time, TT. Technically, TT is simply defined as TT = TAI + 32.184 sec, where TAI is the International Atomic Time. Physically, TT is the continuation of Ephemeris Time, ET, into the era of TAI. For more details and explanations see Seidelmann & Fukushima (1992) and references therein. The representation of TT and ET in terms of day numbers is called Julian Ephemeris Date, JED.

The mean trend between TT (or ET) and UT is about 0.6 sec/yr for the interval from 1920 to 2000 (over which most of the presently used light-curve elements have been determined), amounting to almost a minute over a century, see Fig. 1.

Now, two problems arise. First, a period defined in terms of UT is not the same as one defined in terms of TT (TAI, ET). The two differ by roughly 2×10^{-8} over the twentieth century. Since some published periods are given to 10 decimal digits, this difference can be highly significant. In other words: A "JD-based" period is not given in days of 86400 seconds, but in days about 2 milliseconds longer.

Second, a variable star with perfectly constant period will show an $O - C$ diagram with humps and bumps with a full amplitude of about 15 sec. The mean trend between TT (or ET) and UT was about 0.9 sec/yr (or 3×10^{-8}) between 1965 and 1985, and it was practically zero between 1920 and 1940, see Fig. 1. In other words: Relative period changes of the order of a few times 10^{-8} are induced by a UT-based time coordinate.

All this is pretty small numbers, and for the majority of all variable-star observations it is well below the observing precision. But there are cases like HW Vir where it is highly significant already. And these cases will tremendously grow in numbers in the near future. In addition, the gradual slowing of the earth's rotation will soon induce a mean decrease of all variable-star periods over time. This will be detectable for a whole group (e.g. the

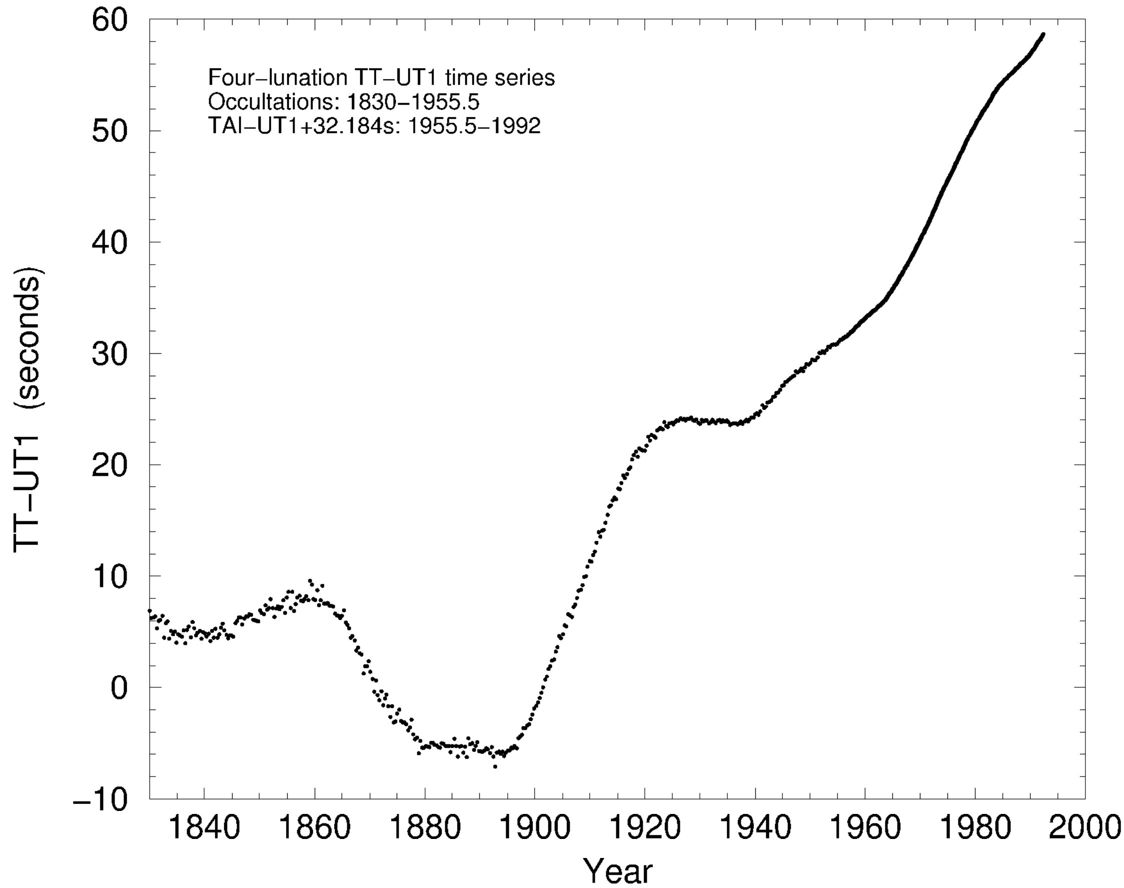

Figure 1. The difference TT − UT1 (or ET − UT1) in the period 1830–1992. The values 1830–1955.5 were derived from lunar occultations, after 1955.5 directly from UT1 − TAI. The UTC scale follows the UT1 curve within 0.9 sec, with 1-sec jumps introduced whenever needed. This graph is a copy of Fig. 5 in Jordi et al. (1994), where a more complete description is given.

RR Lyrae stars) long before it will become obvious for individual stars, and may lead to incorrect astrophysical interpretations.

All that mentioned above is not really new, and the research communities observing pulsars or the solar system, for instance, are fully aware of it. The general variable-star community should — like these others have done long ago — turn to correct physical time units as soon as possible. It is now too late to organize a Joint Discussion for the forthcoming IAU General Assembly, but perhaps a resolution can be taken on the business meeting of either or both commissions at Manchester.

The fairly obvious solution to the problem would be as follows: In the future, all light-curve elements and $O-C$ diagrams must be determined and published in terms of TT, represented in the form of JED. As for raw observations, publication in terms of UTC, represented in the form of JD, is still acceptable, but publication in terms of TT/JED should be preferred. The usage of the TT time coordinate must in any case be indicated by the symbol "JED" instead of "JD".

The convention proposed here is both clear and unambiguous, as well as very easy to use. The transformation from JD to JED is simply

$$\mathrm{JED} = \mathrm{JD} + (32.184 + n_{\mathrm{leap}})/86400,$$

where n_{leap} is the cumulated number of leap seconds applicable at date JD. This number is tabulated in astronomical almanacs. Forthcoming leap seconds are announced in the IAU Circulars regularly. For observational epochs before 1972 (when leap seconds had not been fully in use yet) the values of $\Delta\mathrm{T} = \mathrm{ET} - \mathrm{UT}$, as tabulated in the astronomical almanacs, can directly be used for the transformation. The light-curve elements of an eclipsing variable in the new convention would have the form

$$\mathrm{JED\ (Min\ I)} = 2\,456\,456.4564 + 0.456456456 \times E.$$

As a cautionary remark it should perhaps be noted that the proposed convention, along with the usual procedure of barycentric correction, makes the physical interpretation of variable-star timings correct to the level of about 0.1 sec. Below that level, more disturbing effects become significant which require more conventions and more complex reduction procedures. By far the biggest effect is the topocentric light-time correction (up to 20 msec). All others, e.g. the relativistic corrections due to the non-flat metric along the light path through the solar system and to the varying gravitation potential at the geoid are well below 1 msec.

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