ON THE USE OF NATURAL REFERENCES

N. Capitaine*, B. Guinot**, J. Souchay*

* Observatoire de Paris, F-75014 Paris
**Bureau International des Poids et Mesures, F-92310 Sèvres

ABSTRACT. The catalogues of positions of radio-sources obtained by VLBI, their link with precise and dense star catalogues (HIPPARCOS) and the atomic time open an era where "natural" references in space and time will be quasi-ideal. Are our traditional concepts and usages adapted to this new situation ?

CRITERIA FOR THE DEFINITION OF REFERENCES IN SPACE AND TIME

The realization of references in space (reference frame) and time (time scale) implies three steps

- a basic assumption,
- a conceptual definition of reference systems,
- the realization according to this definition.

An example is shown by figure 1. To each step corresponds a criterion for a good choice.

(a) The basic assumption consists in believing that a class of phenomena is convenient for a specific purpose, for instance, to give the simplest form to the dynamical theories. For reasonable choices, the criteria for the basic assumption are less important than the following ones.

(b) The conceptual definition should be such as the theory-dependence be minimum. This leads to the idea that natural phenomena should provide directly the reference. When analysing the differences between observed and predicted motions, the ideal is that no doubt can arise concerning a theory implied in the conception and realization of the references.

(c) The realization in conformity with the conceptual definition should be such as the uncertainties of all types of measures should be due to the measured quantity or to the instrumentation, the uncertainties of the reference itself being negligible.

HOW FORTUNATE WILL BE THE ASTRONOMERS IN THE 1990's

For the first time in modern astronomy (Guinot, 1984) criteria (b) and

J.-P. Swings (ed.), Highlights of Astronomy, 97–100.

(c) will be satisfied simultaneously, both for space references and time scales. Figure 1 displays the situation as already attained for time and as recommended for space by the MERIT/COTES Working Groups (Wilkins and Mueller, 1985). It would be a pity not to take this opportunity to reconsider some practices in fundamental astronomy and to investigate on possible clarifications.

QUESTIONS AND SUGGESTIONS

(a) Relation between the reference system, the equator and the equinox.

Shall we continue to align from time to time the reference system to the best estimation of the equator and of the equinox at some date ? Our opinion is that no intentional rotations of the reference system should be made. If the reference frame has to be improved in order to give a better representation of the angular distances between the sources, it should be made without net rotation. For evident reasons, the initial orientation may be selected so that the reference system be as close as possible to the FK5 reference system for standard epoch J2000.0 But later on, improved models for the motion of the pole of rotation and of the pole of ecliptic should include possible shifts.

(b) Precession and nutation

Shall we continue to use the classical precessional quantities ? Since all the informations on precession and also nutation are contained in the motion of the pole of rotation P and of the pole of ecliptic, is it not simpler to provide the series for the motion of these two poles in the Conventional Celestial Reference System CCRS ? We see some advantages in the use of these coordinates of the poles.

(c) Reference point on the equator

Is the equinox the best reference ? The use of the equinox has a practical advantage: the mean equinox provides immediately the orientation of the nutation, aberration, parallaxes ellipses. But the equinox has the drawback of introducing on the equator an element which depends on an other phenomenon than the rotation of the Earth: it is an hybride concept. We have advocated the use of a non-rotating origin (Guinot, 1979) kinematically defined by the condition that the system attached to the true equator has no rotation around the moving polar axis (see Annex).

(d) Ephemerides

What is the meaning of the headings "time", "coordinates" of the geocentric ephemerides ? Subtle distinctions have been recently made between the various time scales used in the ephemerides, while no such problem was raised about the meaning of the space reference, probably because it was too poorly realized.

CONCLUSION

It might happen that, after centuries of optimization, the concepts and the definitions in fundamental astronomy have reached a point where no improvements are possible.
However, in a recent past, we have sometimes recognized that this optimization was effective on computational procedures at the cost of obscuring the principles (E-terms of aberration for instance).
We believe that it would be worthwhile to reexamin, without prejudgement, the concepts and definitions of fundamental astronomy, taking into account the new situation where we will have quasi-ideal realized references, both in space and for time.

REFERENCES

Guinot, B., 1979, Time and the Earth's Rotation, 7-18, D.Reidel Pub. Co.
Guinot, B., 1986, Concepts of reference systems, IAU Symp. No. 109, p. 1.
Wilkins, G.A. and Mueller, I.I., 1985, Joint Summary Report on the IAU/UGGI Working Groups MERIT and COTES.

Fig. 1.- The steps of the realization of reference frames (an example)

	SPACE	TIME
Basic assumption	The directions of the most remote bodies of the universe are fixed	Frequencies associated to atomic transitions do not vary
Conceptual definition	The CCRS is defined by a set of designated extragalactic sources, theories and constants, so that there is no net rotation between the reference frame and the set of radiosources	The atomic time is based on a continuous count of the periods associated to a selected atomic transition
Realization	Reference frame defined by the positions and motions of designated radiosources	Time scale TAI based on the hyperfine transition of the ground state of cesium 133
	Choice of the angular origin	Choice of the origin
	Choice of the angle unit (one revolution)	Choice of the time interval unit (the SI second)

https://doi.org/10.1017/S1539299600006286 Published online by Cambridge University Press

ANNEX. The non-rotating origin (NRO)

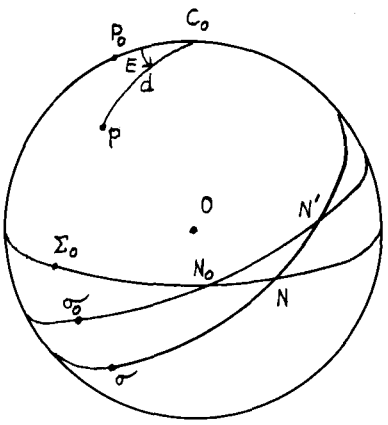

fig. A1

Let us consider the Conventional Celestial Reference System (CCRS), with the fundamental great circle of pole C_0 and the reference point Σ_0 on this circle (fig. A1). P_0 and P are the positions of the pole of rotation at dates t_0 and t. The NRO, σ, is defined by the condition that, when P moves, the triad attached to OP, Oσ has no rotation at any instant around OP. The quantity s is defined by

$$s \equiv (\sigma N - \Sigma_0 N) - (\sigma_0 N_0 - \Sigma_0 N_0)$$

the N being the nodes shown on the figure. Using the polar coordinates of P : $d \equiv C_0P$ and E, polar angle reckoned from an arbitrary origin,

$$s = \int_{t_0}^{t} (\cos d - 1)\, \dot{E}\, dt.$$

Let us assume that P_0 coincides with C_0 (the general case will be treated in an article in preparation), s contains

- a term due to the precession of the order of 0.036" t^3, t in centuries.
- a linear term due to components of the luni-solar nutation: - 0.0039" t.
- small cross terms nutation x precession, nutation x nutation (analogous terms appear in the derivation of the true equinox from the mean equinox), which are periodic or quasi-periodic (the amplitude varying with time). The maximum amplitude of these terms is 0.0447" after a century.

Due to its smallness, s is practically insensitive to the improvements which can be brought to the model of the motion of P.
The hour angle of σ reckoned from the origin of the terrestrial longitudes represents strictly the rotation of the Earth in space. UT1 could be defined as being proportional to this hour angle; the numerical coefficients of the definition are practically independent of the model of the motion of P.

https://doi.org/10.1017/S1539299600006286 Published online by Cambridge University Press