J2000.0

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1.INTRODUCTION.

It was recommended in a resolution of the International Astronomical Union that as of Jan. 1, 1984, a new astronomical reference frame would be adopted (IAU 1976). This reference frame has been designated as the FK5 reference frame of J2000.0. The problem of the interim realization of this reference frame pending completion of work on the compilation of the FK5 catalog at the Astronomisches Rechen-institut has been addressed by a number of authors, see, e.g., Kaplan(1981), Standish(1983), Aoki et al.(1983), and Lederle and Schwan(1984). Their discussions are primarily concerned with the steps which must be taken to transform FK4 catalog positions and proper motions referred to the equator, equinox and epoch of B1950.0 to J2000.0. The primary emphasis of the following discussion is on the transformation of catalogs other than the FK4 to the J2000.0 equinox. There are a few remarks concerning the FK4 catalog.

2.TRANSFORMATION FROM B1950.0 to J2000.0.

2.1 The Elliptic Terms in Aberration.

Equations for the corrections to the mean right ascensions and declinations, respectively, referred to the moving equinox at B11950.0 are

$$d\_Alpha = [0".07Cos(Alpha)-0".34Sin(Alpha)]Sec(Delta)/15$$
$$d\_Delta =[-0".34Cos(Alpha)-0".07Sin(Alpha)]Sin(Delta)+0".03Cos(Delta)$$

The elliptic terms in aberration have coefficients as large as 0.3 arcsec. In the past, these terms were purposely ignored, except for circumpolar stars, because they change so slowly as a function of time. Most of the elliptic terms in aberration change by a few milliarcseconds per century, except for circumpolar stars, where for the proper motion in right ascension, a term containing a product of the tangent of the declination with the secant of the declination can become very large for a star very near to a pole. This problem was recognized by the compilers of the FK3 and FK4 catalogs. For stars within 10° of the poles, the

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effects of the elliptic terms in aberration were removed from the positions before transformation to another equinox, and then the effects of the elliptic terms in aberration appropriate to the new equinox were re-introduced into the mean positions.

2.2 Precession/Proper Motion.

Fricke(1967,1971) has shown that Newcomb's value of general precession at 1900.0 requires a correction of +1".10 per tropical century for the luni-solar component. An additional correction of -0".029 to the planetary precession is given by Lieske et al.(1977) based on changes in the system of planetary masses. These corrections result in a net correction to Newcomb's value of general precession at 1900.0 of +1".127 per tropical century.

2.3 Change of Unit of Time from Tropical to Julian Centuries.

The definition of the length of the tropical year (see the Explanatory Supplement, p 69ff.) depends on Newcomb's expression for the geometric mean longitude of the Sun, referred to the mean equinox of date. As such, the unit of time is dependent on a theory of the motion of the Sun, which contains a term in the square of the time interval from 1900 to the date of interest with a coefficient of 1".089. This implies that after one Julian century has elapsed, the century measured in tropical units will be shorter by about 0^{s}.27 than it was in 1900. By adopting the Julian century as the unit of time, problems associated with a unit of time dependent on a theory of the solar motion can be avoided.

2.4 Zero Point Adjustment to the Right Ascensions and the Proper Motions in Right Ascension of the FK4 Catalog.

In an extensive study of the equinox and equator of the FK4 system based on a wide variety of observations including transit circle observations of the Sun and other solar system objects, lunar occultations, and an analysis of the FK4 proper motions, Fricke(1982) determined that at 1950.0, the right ascensions of the FK4 catalog must have 0^{s}.035 added to them. Fricke also found that the proper motion system in right ascension requires a correction described as non-precessional in nature, of 0.085 s/cy which must be added to the right ascension proper motions. The non-precessional nature of this correction implies that it is a constant which has the curious property of being applicable to the right ascension proper motions at any equinox without any right ascension- or declination-dependent change in the magnitude of the correction. This behaviour is most unlike the correction to the precession which propagates into the proper motions in such a way as to leave the annual variations in both coordinates essentially unchanged.

3. THE PRINCIPAL STELLAR REFERENCE FRAMES

The compiled catalogs of star positions and proper motions most likely to be of interest to anyone who requires the realization of a stellar

reference frame constructed according to fundamental principles are the FK4/FK3, the N30, and the GC. In realizing the benefits of the IAU recommended changes, the only catalog to which all of the considerations in section 2 apply is the FK4 catalog. The zero point adjustment to the right ascensions and their proper motions properly applies only to the FK4 catalog. It can be made to apply to the N30 and GC catalogs if they are first reduced into the system of the FK4, but this would be objectionable if it is desired only to transform the systems of the N30 and GC catalogs to the J2000.0 basis. The other IAU-recommended improvements discussed in section 2 are not related specifically to the FK4 catalog and may be included in a transformation of the N30 and GC catalogs to the J2000.0 basis without introducing characteristics of the FK4 catalog system.

4. THE SECONDARY STELLAR REFERENCE FRAMES

Secondary catalogs which represent the system of the FK4 reference frame in the fainter magnitude range (from about 6.5 to 9.5 visual magnitude) and with higher density (about one star per square degree) at their mean epochs of observation are the AGK3R and the (soon to be completed) SRS catalogs and the compiled catalogs of positions and proper motions based on the work of Corbin(1974,1978). Among the secondary catalogs, one must also mention the AGK3 photographic catalog of positions and proper motions for approximately 190,000 stars in the northern hemisphere, based on the AGK3R, and for the southern hemisphere, the Second Cape Photographic Catalog (CPC2) of about 200,000 stars, which will be based on the SRS reference frame when it becomes available. All of these secondary catalog systems have been referred to the system of the FK4 catalog.

A tertiary catalog commonly used because of its large size is the SAO catalog. An effort was made by the compilers to refer positions and proper motions of the SAO catalog to the system of the FK4. This effort has been less successful than for the secondary catalogs because of the notoriously difficult problem of effecting a transfer from one catalog system to another by analytical means as compared to an observational approach.

5. OBSERVATIONAL CATALOGS

The observational catalogs to which we especially refer are those based on radio interferometric techniques and fundamentally observed transit circle positions, or catalogs like them. In other words, they are catalogs of positions produced by the use of a technique which confers unique, systematic and independent qualities on them which it is important to preserve under transformation to some other equinox. With such catalogs, it is not likely that the FK4 transformation is wanted.

6. THE PROBLEM OF THE EQUINOX AND EPOCH OF TRANSFORMATION TO J2000.0

Early authors on the subject of the transformation of the FK4 catalog from the B1950.0 equator and equinox to the J2000.0 basis preferred to introduce the changes referred to in section 2 either at B1950.0, or at J2000.0. Aoki et al.(1983) proposed that the changes should be

introduced at the equinox and epoch of 1984 Jan. 1, 0 h, with the very strong argument that this would preserve the relationship between UT1 and GMST described in Aoki et al.(1982). What should be the guiding principle in the selection of an equinox and epoch at which to introduce the changes? The most notable consequence of changing the equinox and epoch at which the transformation is effected, is to introduce systematic right ascension and declination dependent differences in positions and proper motions at the milliarcsecond level. Such differences are probably unimportant to the transformation of all but the catalogs based on interferometric observational techniques. With this in mind, the following question may be asked: To achieve minimum distortion of a very high quality reference frame upon transformation of the positions from the equinox of B1950.0 to the equinox of J2000.0, what is the best equinox and epoch at which to apply the changes? While it may not be obvious that there is a best equinox and epoch at which to apply the changes in the case of a catalog such as the FK4, it is clear that from the observers' point of view, the best time to apply the changes is at the epoch of observation when the reduction from apparent to mean place is applied. Indeed, if observers had had the improved IAU 1976 constants available to them at the time their observations were being made, then their reductions would already be referred to the IAU 1976 conventional values. This suggests that the best equinox and epoch (best in the sense of minimizing distortions of the coordinate reference frame due to the transformation process itself) at which to introduce the changes would be in the instantaneous mean frame and equinox of the mean epoch of observation. In this way, catalog positions and proper motions would receive treatment closely approximating the treatment which the observational material would have received had the improved IAU 1976 constants been available at the time of observation. I hope participants in this first Joint Discussion will find the time to consider this problem.

7. REFERENCES

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