INTRODUCTION

This booklet provides examples for the reduction of 64 mean star places to apparent places for the year 2025. In view of the high accuracy of the mean positions and proper motions in the FK6 and in the HIPPARCOS catalogue we have increased the number of significant digits in the tabulated apparent places by one compared with the volumes before 2000. Since no "short period terms" are included in the apparent places following 2005 there exists no interpolation to intermediate dates based on the printed version. The internet version listing "daily" apparent places should be used for an approximate interpolation.

In this booklet we present apparent places for only a few fundamental stars as examples. The intermediate and apparent places for a large number of fundamental stars are provided by the Astronomisches Rechen-Institut at the URL:

http://www.ari.uni-heidelberg.de/ariapfs

We tabulate the intermediate and apparent places for *daily* upper culminations at Greenwich. Those entries that would have been published according to the conventions of the printed volumes are marked by an asterisk in the online version. It may be noted here that we can easily use the program for transits over other meridians just by subtracting the longitude of an observer from the Greenwich sidereal date of the transit.

At its 23rd General Assembly in 1997, the International Astronomical Union decided (*Trans. IAU* **23B** 39, 1999) to adopt an International Celestial Reference System (ICRS). The ICRS is realized at optical wavelengths by stars in the Hipparcos Catalogue, in particular by those having reliable proper motions. This subset - comprising more than 80 per cent of the stars of the Hipparcos Catalogue - constitutes the Hipparcos Celestial Reference Frame (HCRF).

The new highly accurate IERS-observing technique (VLBI) has recommended to adopt a new zero point for the equatorial system. Guinot's non-rotating origin (Guinot, B., 1979, In: McCarthy, D.D., Pilkington, J.D. (eds.), Time and the Earth's Rotation. D. Reidel Publ. Co., p. 7) was adopted for substituting the classical equinox. This origin is stable in such a way that there are merely motions of the new zero point in right angles to the instantaneous equator. With this new definition the rotation of the Earth is given directly as the difference between the non-rotating origin and the terrestrial origin. This difference is directly proportional to UT1 and no precession-nutation terms are included.

In addition to the CIO-based procedure we also give the apparent places using the classical equinox as the origin in right ascension; this older method may still be used in many applications. No differences in declination occur since the equator remains unchanged.

Precession and nutation reductions agree with IAU2000/2006 precession-nutation in accordance with IAU 2006 Resolution B1 (see e.g. Capitaine & Wallace, A&A 450, 855 (2006)).

DE430/LE430 ephemerides (ftp://ssd.jpl.nasa.gov/pub/eph/planets/README.txt) are used for GAVO.

Introduction

From VLBI observations it has been found that there exists a “celestial pole offset” between a CIO-based and a J2000 right ascension that has to be applied before making use of the precession-nutation terms. This bias is described more explicitly in Feissel, M., Mignard, F. (A&A 331, L33 (1998)) and in Hilton, J.L., Hohenkerk, C.Y. (A&A 413, 765 (2004)). It is, however, included already in the SOFA subroutines, and no changes to the input files were applied.

The input data are the HIPPARCOS and the FK6 catalogue. The parallaxes used are those from the HIPPARCOS catalogues, and the radial velocities are taken from the machine readable version of the FK6.

In our work on the FK6 we have shown that the HIPPARCOS proper motions are “instantaneous motions” that may differ in many cases significantly from the mean (centre of mass) motion. With the combination of the HIPPARCOS data and the FK5 catalogue (reduced to the HIPPARCOS system) we have derived proper motions in the FK6 which describe much better the mean motion. As part of our reduction process we have also obtained additional information on possible double stars as well as on stars that can be regarded with high probability as single star candidates. Single star candidates are best suited to maintain the International Reference System, and from the year 2000 onwards we only give apparent places for the single star candidates (except Polaris, see p. 7-8). For comparison we provide the differences between the given SI-solution with respect to the HIPPARCOS data and to the long-term prediction (LTP) in the FK6. This table is given on pages 34-35.

Apparent Places of 10-Day Stars (Pages 11-25)

Examples for the apparent places of the stars with declinations between ±81° are given for every tenth upper transit at Greenwich on pages 11-25. The choice of the data is fixed by the moment for which the integral part of the Greenwich sidereal date is divisible by 10. In this booklet we give the equinox-based right ascension, which has a much larger difference from date to date than those determined with the CIO-based method. The CIO-based method is given additionally in the internet version.

The column U.T. gives the approximate time of transit for the first star on the page; it is rounded to the nearest tenth of a day. For transits over other meridians the column U.T. can be regarded as the “local” mean solar date for that transit. For transits of other stars on that page the right ascension difference of the star from the first star should be taken into account.

The right ascension and declination are referred to the true equator and equinox, or non-rotating origin in the CIO-based method. Since the equator does not change merely the right ascensions are affected and the declinations remain unchanged.

From 1984 onwards (see Preface to APFS 1984) the mean positions of the stars in the FK6 or the HIPPARCOS catalogue are freed from the term of elliptic aberration (E-terms), which depends on the eccentricity of the Earth’s orbit. This term is now included in the reduction to the apparent place.

The hours and minutes of right ascension and the degrees and minutes of declination given at the head of the columns are adjusted so that the seconds never change sign, though this may involve their exceeding 60.

Immediately below the tabulated right ascension and declination we provide:

(I) the mean place for the middle of the year.
(II) sec δ and tan δ corresponding to the mean place.
(III) the day upon which the star transits twice in upper culmination.

In the volumes prior to 2006, examples were given for interpolating the apparent place for other meridians, including in particular the short period terms of nutation. In the present booklet we do not to give any interpolation and the user should enter his or her subroutine using the appropriate time. An approximate transit could also be obtained from the daily positions given in the internet version.

Apparent Places of Circumpolar Stars (Pages 26-33)

Examples for the apparent places of circumpolar stars with declinations exceeding $\pm 81°$ are given for every upper transit at Greenwich on pages 26-33. Polaris (HIPPARCOS No. 11767, FK6 No. 907) is not included in the FK6 Part I, because it is a binary. The apparent places given on pages 26 and 27 are based on the retrograde orbit derived by Wielen et al. (A&A **360**, 399, (2000)). Each two facing pages are devoted to a star. In the left hand column only the day of the month is given without the fraction of the day. The right ascension and declination are referred to the true equator and equinox (and additionally the non-rotating origin in the Internet version), short period terms of nutation are included. Three decimals of a second are only given for the right ascensions. On the one day during the year when there are two upper transits at Greenwich both are shown.

The values of sec δ and tan δ are given for every month and refer to the apparent place on the 16^{th} day of the month. The footnotes, repeated on each page, give the mean right ascension and declination in the middle of the year and the date of double lower transit.

Reduction to the HIPPARCOS catalogue
Reduction to the FK6 (Long-term prediction)
(Pages 34-35)

The FK6 is the result of combining the FK5 with the HIPPARCOS observations. Various solutions have been derived in the FK6, adopting different models for the star's kinematic behaviour, which leads to different weighting schemes in the least squares solutions. Two of these solutions are briefly mentioned here. For details please refer to the FK6.

The apparent places given in this booklet and in the internet version are based on the so-called single-star solution (abbreviated as SI) of the FK6 assuming that the star can be treated as a single star. Stars with no indication of a binary nature are best suited to maintain the International Celestial Reference System (ICRS). We have therefore restricted the stellar sample in this booklet mainly to such candidates, which are called "astrometrically excellent stars of the highest rank (***)" in the FK6. A few non-excellent stars are also included because of their brightness, their large foreshortening effects or their special importance (Polaris, a binary not included in the FK6, Part 1). Starting in 2006 we added ten other excellent stars, including two circumpolar stars.

In the FK6 long-term prediction (LTP) we admit a possible (but still undetected) binary nature of a star. In this case HIPPARCOS observed, more or less, an instantaneous proper motion, depending on the star's observational period. Combining the HIPPARCOS observations with highly-weighted FK5 data yields an FK6 proper motion that describes much better the star's position for epochs differing significantly from the HIPPARCOS epoch, about 1991.25. Examples can be found in the table on pages 34-35.

The table on pages 34-35 provides the differences of the FK6 single-star solution (SI) with the HIPPARCOS data on one hand, and with the long-term prediction in the FK6 (LTP) on the other hand. The data in the table hold for the middle of the year. Columns one and two list the FK6 and HIPPARCOS number, column three gives the difference in right ascension between the HIPPARCOS data and the single-star solution of the FK6 in units of 0.0001 seconds of time, column four is the proper motion difference in 0.0001 seconds of time per year, and columns five and six list the corresponding differences in declination in 0.001 arcsec and 0.001 arcsec/year, respectively. The differences between the long-term predicition and the single-star solutions in the FK6 are given similarly in the columns seven through ten. Polaris (FK6 No. 907) is a binary and needs a special treatment. The small table at the end of page 35 provides the data to reduce the apparent place of Polaris from the FK6 (p. 26-27) to the HIPPARCOS catalogue.

These data permit, for any date in the year, the computation of the corrections that have to be added to the tabulated apparent places in order to get the positions based on the HIPPARCOS catalogue or on the long-term prediction in the FK6 from the SI position.

Table UT–ST (Pages 36-39)
Sidereal Time at 0$^{\mathrm{h}}$ U.T.

On these pages are given in order of 0$^{\mathrm{h}}$ U.T. on each day of the year:

(I) the apparent (or true) sidereal time to $0\overset{\mathrm{s}}{.}001$
(II) the mean (or uniform) sidereal time, given as seconds and decimals only, the hours and minutes being the same as in the first column
(III) difference Apparent – Mean (app–mean) in units of $0\overset{\mathrm{s}}{.}001$

In the APFS volumes preceding 1960, the equation of equinoxes was designated as the nutation in right ascension.

Conversion of Mean Solar Time to Sidereal Time
Conversion of Sidereal Time to Mean Solar Time

The following relations derived from the expressions between mean solar time and mean sidereal time as given in *Trans. I.A.U.* **18B,** 72 (1983) are used. Both relations can be used in the following two examples.

$$1 \text{ mean solar day} = 24^{\mathrm{h}}03^{\mathrm{m}}56\overset{\mathrm{s}}{.}55536\,79 \quad \text{in mean sidereal time} \quad (1a)$$
$$1 \text{ mean sidereal day} = 23^{\mathrm{h}}56^{\mathrm{m}}04\overset{\mathrm{s}}{.}09053\,08 \quad \text{in mean solar time} \quad (1b)$$

The time dependence of these relations has been ignored, since it is of no practical importance in the present development.

In using the above relations for passing from mean solar time to apparent sidereal time and vice versa, we also must use the apparent sidereal time at 0$^{\mathrm{h}}$ taken from the last table on page 36-39. It must be remembered that a correction should be applied for the change of the equation of equinoxes between 0^h and the given U.T.

Thus the local apparent sidereal time at Heidelberg (Longitude = $0^h34^m53^s.190$) at U.T. $7^h\,21^m\,36^s.572$ on 2025 January 26 is obtained as:

Mean solar interval at 0^h		7^h	21^m	$36^s.572$
Correction to mean solar time to given sidereal time } (relation (1a))	+		1	12.445
	+			0.100
Apparent sidereal time at 0^h (Table p. 36)		8	22	09.848
Change in the equation of equinoxes from 0^h to 7^h (Table p. 36)	+			0.003
Sum = Greenwich apparent sidereal time		15	44	58.968
Longitude Heidelberg	+	0	34	53.190
Sum = Heidelberg apparent sidereal time		16	19	52.158

Similarly the U.T. on 2025, January 26 corresponding to an apparent sidereal time at Heidelberg of $16^h19^m52^s.158$ is obtained as:

Heidelberg apparent sidereal time		16^h	19^m	$52^s.158$
Longitude Heidelberg	–	0	34	53.190
Difference = Greenwich apparent sidereal time		15	44	58.968
Apparent sidereal time at 0^h (Table p. 36)		8	22	09.848
Sidereal interval		7	22	49.120
Correction to sidereal time to given mean solar time } (relation (1b))	–		1	12.445
	–			0.100
Change in the equation of equinoxes from 7^h to 0^h (Table p. 36)	–			0.003
Sum = required U.T.		7	21	36.572

Apparent places for different longitudes

Suppose the apparent position needs to be obtained for a star at upper transit in Heidelberg ($\lambda = +0^h\ 34^m53^s.190$, i.e. the star culminates 0.581 hours or 0.0242 days earlier than in Greenwich). We would use the apparent place subroutine for this, using as input date the Heidelberg transit which is 0.581 hours (or 0.0242 days) earlier than the corresponding transit in Greenwich. This information can be directly included in the subroutine.

For example the apparent position of 94 Piscium (FK6 No. 1039) may be required at upper transit in Heidelberg for 13th May 2025. We include the longitude of Heidelberg into the subroutine and we find an apparent position of

$\alpha = \ 1^h\,28^m\,02^s.8313$ (EQUINOX-based)

$\alpha = \ 1^h\,26^m\,44^s.8231$ (CIO-based)

$\delta = 19^\circ\,22'\ 11''.054$ (CIO-based = EQUINOX-based)

Diurnal Aberration

The diurnal aberration must be added to the right ascension for upper transits. Alternatively, it can be subtracted from the time of transit. In the case of lower transits the sign of the correction has to be reversed. With declination δ and latitude ϕ the given correction is

$$\text{Diurnal Aberration} = 0\overset{\text{s}}{.}0213 \cos\phi \sec\delta$$

A remark concerning the history of the APFS at ARI

Many staff members have contributed to the APFS since the first volume for 1960 was published. We would like to mention in particular F. Gondolatsch, T. Lederle, H. Schwan and H. Lenhardt in addition to the former directors W. Fricke and R. Wielen.