ACT Reference Catalog

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Catalog of Positions and Proper Motions Derived from the Combination of the AC 2000 Catalog and the Positions in the Tycho Catalogue. Positions and proper motions are on the Hipparcos System (J2000.0) for the Epoch J2000.0.

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1 Introduction

The ACT Reference Catalog contains 988,758 star positions and proper motions covering the entire sky for the epoch and equinox J2000.0. The proper motions are from new reductions of the Astrographic Catalogue (AC 2000; Urban et al., 1997) combined with the positions in the Tycho Catalogue (ESA 1997). Additional photometric and cross referencing data from Tycho are included. This document briefly describes these two data sets, and the catalog resulting from their combination.

2 The AC 2000

The AC 2000 is a positional catalog recently compiled at The U.S. Naval Observatory using the plate measures contained in the Astrographic Catalogue (AC). The AC was an international program designed to photograph and measure the positions of all stars brighter than magnitude 11.0. Since observing and measuring the 22,000 plates needed to cover the sky was too labor intensive for any one observatory to undertake, the task was spread among several observatories, each photographing and measuring stars between two parallels of declination. In total, 20 observatories participated in the data gathering and the sky was sectioned into 22 zones. By the conclusion of the project, positions of 4.6 million stars had been measured, many as faint as 13th magnitude. These positions have an extremely early epoch; the average epoch of an AC plate is 1907.

To compile the AC 2000, each of the 22 zones making up the Astrographic Catalogue was reduced independently using the Astrographic Catalog Reference Stars (ACRS; Corbin & Urban 1988, Corbin & Urban 1990). The plates of each zone were analyzed for tilt, radial and tangential distortions, coma, magnitude equation and non-symmetric field distortions. Following this analysis, reductions of each plate were made to transform the image measures to equatorial coordinates. Following these reductions, the data were placed on the Hipparcos system and the magnitudes were converted to be close to those of the Tycho B data. The resulting data were then combined into the final catalog. Detailed information on the reduction methodology and input data can be found in the INTRO.TEX file on the CD-ROM containing the AC 2000.

Although positional accuracies contained in the AC 2000 vary from zone to zone and star to star, most are between 150 and 300 mas at the mean epochs of observations. The average epoch for an AC plate is 1907 (although this too can vary quite a bit). The early epochs and good accuracies make the positions in the AC 2000 extremely valuable for determining proper motions when combined with modern observations.

3 The Tycho Catalogue

The Hipparcos satellite was a European Space Agency (ESA) funded, astrometric instrument launched in 1989 and operated until 1993. The primary mission was the determination of accurate positions, proper motions and parallaxes of 118,218 stars. The results of these observations form the Hipparcos Catalogue (ESA 1997). The accuracies of the Hipparcos astrometric parameters are roughly 1 mas for position, 1 mas/year for proper motion, and 1 mas for parallax.

Early in the planning stage for Hipparcos, the mission was expanded to include data from the satellite's star mapper. The results of the star mapper's observations are contained in the Tycho Catalogue (ESA 1997) of 1,058,332 objects. The accuracies of the Tycho positions and proper motions are roughly 30 mas for position and 30 mas/year for proper motion. In addition to the positional information, the Tycho Catalogue contains two-color photometry for the vast majority of its objects. The precisions of the Tycho photometric data are generally well under 0.1 magnitude. A thorough introduction of the Hipparcos and Tycho missions can be found in the above reference.

4 The ACT Reference Catalog

It was recognized many years ago that the data contained in the Astrographic Catalogue could be combined with modern epoch observations to compute or dramatically improve proper motions (Eichhorn 1974) especially with a catalog such as Tycho (Urban 1993). Tycho is a perfect catalog to combine with the AC 2000 since the Tycho positions make it the most accurate catalog of comparable size at its epoch of observation, but its proper motions degrade it to a sub-standard reference catalog in less than 10 years. The proper motions of the Tycho stars can be improved from about 30 mas/year to about 3 mas/year by recomputing them using the AC 2000 data (Urban 1997). This combination of AC 2000 and Tycho, called ACT Reference Catalog, degrades much more slowly and is a valuable astronomical dataset for applications spanning many decades.

Matching Tycho and AC 2000

In order to make the ACT Reference Catalog high quality, it was decided that some problematic "stars" would not be used. Positions indicated in the Tycho Catalogue as coming from close multiple stars or those of extremely low astrometric quality were discarded (No stars with 'D', 'R' or 'S' in the MultFlag field or stars with '9' in the Q field were used).

To match the two data sets, the Tycho entries were brought to the AC 2000 epochs by the application of the published Tycho proper motions. An area with a radius of 15 arcsec around each Tycho star was searched. If there was a one-to-one match, that is one AC 2000 entry and one Tycho entry in the search area, then the two are identified as the same star. If there was not a one-to-one match, for example one Tycho entry and two AC 2000 entries, then a ratio of the distances between the Tycho and the closest AC 2000 star and the Tycho and the farther AC 2000 star was computed. If the value of the ratio was 0.2 or less, then the Tycho and the closer AC 2000 star were identified as the same. Otherwise, the matching was considered ambiguous and no cross identification was made. For the Tycho stars not matched at this point, another search was made but without application of any proper motions. A search area with a radius of 20 arcsec was used. Again, a ratio test of .2 was applied for all non-singular matches. For the Tycho stars still not matched, a search in the New Luyten's Two Tenths Catalog (Luyten 1979, Luyten and Hughes 1980) was made. Luyten's proper motions were then applied to the Tycho stars to bring them to the epoch of the AC 2000 positions. A search area with a radius of 15 arcsec around each Tycho star was used. Once again, if more than one star fell within the search area, a ratio test was used to determine which observations were really the same star.

Computation of proper motions

Once the identifications between the AC 2000 and Tycho were made, the proper motions were computed using the differences in position and epoch. To bring these proper motions from the mean epoch to J2000.0, the application of standard formulae were used. In the computation of the foreshortening terms, the radial velocities were taken from the Hipparcos Input Catalogue (Turon et al. 1991) and the parallaxes were taken from the Hipparcos Catalogue.

Computation of standard errors of proper motion

The computation of the standard error in proper motions is straightforward, since only two position proper motions are involved. The formula used is

$$\sigma_\mu = \frac{\sqrt{\sigma_{\mathrm{AC}}^2 + \sigma_{\mathrm{T}}^2}}{EP_{\mathrm{T}} - EP_{\mathrm{AC}}} \tag{1}$$

where σ_{AC} and σ_{T} are the standard deviations of the AC 2000 and Tycho positions respectively. Note that σ_{AC} was computed by the scatter in positions of the individual images making up the mean position. In order not to under estimate σ_μ for stars stars with very small values of σ_{AC}, a lower limit of 80 mas has been placed on this value.

5 Description of ACT Reference Catalog

Right ascension

The right ascension for each star as computed from its Tycho position (epoch 1991.25) and ACT proper motion, in units of hours, minutes and seconds of time, referred to the Hipparcos system (J2000.0) at epoch J2000.0.

Declination

The declination for each star as computed from its Tycho position (epoch 1991.25) and ACT proper motion, in units of degrees, minutes and seconds of arc, referred to the Hipparcos system (J2000.0) at epoch J2000.0.

Proper motion, right ascension

The proper motion for each star as computed from the combination of the Tycho and AC 2000 positions, referred to the Hipparcos system (J2000.0) at epoch J2000.0, in units of seconds of time/year.

Proper motion, declination

The proper motion for each star as computed from the combination of the Tycho and AC 2000 positions, referred to the Hipparcos system (J2000.0) at epoch J2000.0, in units of seconds of arc/year.

Standard errors of equatorial coordinates

The standard errors in right ascension and declination at epoch 1991.25, in units of mas. This is T14 and T15 in the Tycho Catalogue.

Standard errors of proper motion

The standard errors in proper motion computed as described in section "Computation of standard errors of proper motion" in this document, in units of mas/year.

BT Magnitude

The Tycho Blue magnitudes. This is T32 in the Tycho Catalogue.

VT Magnitude

The Tycho Visual magnitudes. This is T34 in the Tycho Catalogue.

B-V

The color index Johnson B-V. This is T37 in the Tycho Catalogue.

Flags

Flags are provided to give additional data to users. All are from the Tycho Catalogue. A brief meaning is given below; for a more detailed description, consult SP-1200 Volume 1.

- Astrometry Flag (T10 in Tycho)
  - blank: a recommended astrometric reference star
  - "X": a dubious astrometric reference star in Tycho

- Quality flag (T40 in Tycho)
  - 1 through 5: very high to medium quality; probably single stars
  - 6: perhaps non-single
  - 7: low astrometric quality
  - 8: perhaps non-stellar
  - blank: unassigned, observed by Hipparcos, not Tycho

- Known variability flag (T47 in Tycho)
  - "G": Star in General Catalogue of Variable Stars, 4th Edition
  - "N": Star in New Catalogue of Suspected Variable Stars

- Variability from Tycho (T48 in Tycho)
  - "U": Apparent variability in Tycho data; may be due to duplicity
  - "V": strong evidence of variability in the Tycho data
  - "W": variability suspected in the Tycho data

- Duplicity from Tycho (T49 in Tycho)
  - "Y": Investigation of duplicity made, no indication of duplicity
  - "Z": No investigation of duplicity was performed

Cross identifications

Cross identifications between Tycho, AC 2000, the Bonner, Cordoba and Cape Durchmusterungs, the Henry Draper Catalog, and Hipparcos Catalogue are provided. The identifications of the Durchmusterungs, Henry Draper, and Hipparcos numbers are from the Tycho Catalogue.

References

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[4] ESA, 1997, The Hipparcos and Tycho Catalogues, SP-1200

[5] Luyten, W.J., 1979, 1980, New Luyten Catalogue of Stars with Proper Motions Larger than Two Tenths of an Arcsecond (Minneapolis: University of Minnesota)

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[10] Urban, S.E., Corbin, T.E., Wycoff, G.L., Martin, J.C., Jackson E.S., Hall, D.M, and Zacharias, M.I., 1997, The AC 2000: The Astrographic Catalogue on the Hipparcos System, in preparation.

Table 1: Byte-by-byte description of ACT Reference Catalog using format requested by the CDS.

Bytes	Format	Units	Label	Explanations
1- 2	I2	h	RAh	Right Ascension, Eq. and Epoch J2000.0 (hours)
4- 5	I2	min	RAm	Right Ascension, Eq. and Epoch J2000.0 (minutes)
7-13	F7.4	s	RAs	Right Ascension, Eq. and Epoch J2000.0 (seconds)
15	A1	—	DE-	Declination, Eq. and Epoch J2000.0 (sign)
16-17	I2	deg	DEd	Declination, Eq. and Epoch J2000.0 (degrees)
19-20	I2	arcmin	DEm	Declination, Eq. and Epoch J2000.0 (minutes)
22-27	F6.3	arcsec	DEs	Declination, Eq. and Epoch J2000.0 (seconds)
29-35	F7.5	s/yr	pmRA	Proper Motion in RA, at J2000.0 (sec of time/yr)
37-43	F7.4	arcsec/yr	pmDE	Proper Motion in Dec, at J2000.0 (arcsec/yr)
45-49	F5.1	mas	e_RAs	?Stand. dev. of RA at 1991.25 (T14 in Tycho)
51-55	F5.1	mas	e_DEs	?Stand. dev. of Dec at 1991.25 (T15 in Tycho)
56-61	F6.2	mas/yr	e_pmRA	?Stand. dev. of Proper motion (RA), in mas/yr
62-67	F6.2	mas/yr	e_pmDE	?Stand. dev. of Proper motion (RA), in mas/yr
69-74	F6.3	mag	B(mag)	Blue magnitude from Tycho (T32)
76-81	F6.3	mag	V(mag)	Visual magnitude from Tycho (T34)
83-88	F6.3	mag	B-V	Johnson B-V from Tycho (T37)
90-90	A1	—	Flag1	Astrometric Quality flag (T10)
91-91	A1	—	Flag2	Quality flag (T40)
92-92	A1	—	Flag3	Known variability flag (T47)
93-93	A1	—	Flag4	Variability from Tycho (T48)
94-94	A1	—	Flag5	Duplicity from Tycho (T49)
96-107	A12	—	TYCHO	Tycho ID, embedded zeros for blanks
109-115	I7	—	AC2000	AC 2000 Number
117-125	A9	—	BD	BD identifier (T54)
127-135	A9	—	CD	CD identifier (T55)
137-145	A9	—	CPD	CPD identifier (T56)
147-152	I6	—	HD	Henry Draper Number (T53)
154-159	I6	—	HIP	Hipparcos number (T31)