Guide to the Tycho-2 Catalogue

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A reference catalogue of 2.5 million stars
with positions, proper motions, B_T and V_T magnitudes
derived from observations made with the ESA Hipparcos satellite
in combination with the Astrographic Catalogue
and 143 other ground-based star catalogues

2000

1 Introduction

The Tycho-2 Catalogue gives positions, proper motions, and B_T and V_T magnitudes for 2.5 million stars across the entire sky, with a density ranging from 25 stars deg^{-2} at the Galactic poles to 150 stars deg^{-2} in the Galactic plane. The detailed variation is shown in Fig.1. The catalogue supersedes in most applications the Tycho-1 Catalogue (ESA 1997), the TRC (Kuzmin et al. 1999) and the ACT (Urban et al. 1998) catalogues.

The positions and magnitudes of the Tycho-2 Catalogue were derived in a new reduction of the Tycho data from the ESA Hipparcos satellite. The proper motions given for nearly all the Tycho-2 stars were obtained by a new analysis of 144 ground-based astrometric catalogues, including the Astrographic Catalogue, bringing the positions in these catalogues firmly on the Hipparcos system.

The Tycho-2 Catalogue and its construction are described in two papers (Høg et al. 2000a, 2000b). These papers are placed on the CD-ROM as submitted to the journal, with permission from the editors. The present document is intended as a short guide to the user of the catalogue. In addition, it also presents some details of the proper motion determination which could not be conveniently included in the above mentioned papers.

The catalogue with documentation is published on a CD-ROM by Høg et al. (2000c). The catalogue can also be retrieved from CDS through anonymous ftp, and can be queried using the VizieR service : (`http://vizier.u-strasbg.fr/cgi-bin/VizieR?-source=Tycho-2`). It is also available from the Aladin interactive sky atlas : (`http://aladin.u-strasbg.fr/`) or through the ESO skycat tool : (`http://archive.eso.org/skycat/servers/ASTROM`).

Information on the Tycho-2 Catalogue will be placed on its www site : (`http://www.astro.ku.dk/~erik/Tycho-2`), e.g. documentation, software and possible corrections to the catalogue.

Details of the Hipparcos mission catalogues, and on-line search facilities, can be found at the ESA Hipparcos www site : (`http://astro.estec.esa.nl/Hipparcos`).

2 The data files

The following catalogue files are contained in the data directory of the Tycho-2 CD-ROM. Each record is terminated with a \r\n (i.e. CR,LF), giving a physical record length which is two characters longer than the logical record length indicated below. In the file description we have adopted the Hipparcos convention: $\sigma_{\alpha*} \equiv \sigma_\alpha \cos\delta$ and $\mu_{\alpha*} \equiv \mu_\alpha \cos\delta$.

Table 1: The data files

File name	Rec. length	Records	Explanations
catalog.dat	206	2 539 913	The Tycho-2 main catalogue
suppl_1.dat	122	17 588	The Tycho-2 supplement-1
suppl_2.dat	122	1146	The Tycho-2 supplement-2
index.dat	42	9538	Index to Tycho-2 and supplement-1

The fields in a record are separated by a vertical bar, |. In this connection the TYC identifier (TYC1, TYC2 and TYC3) constitutes one field and the pair of a HIP number with a CCDM identifier is also considered one field. In the format descriptions, the vertical bars are indicated as "1X". If a numerical field may be blank, this is indicated by a question mark following the range specification in the Explanations column, e.g. "[ ]?".

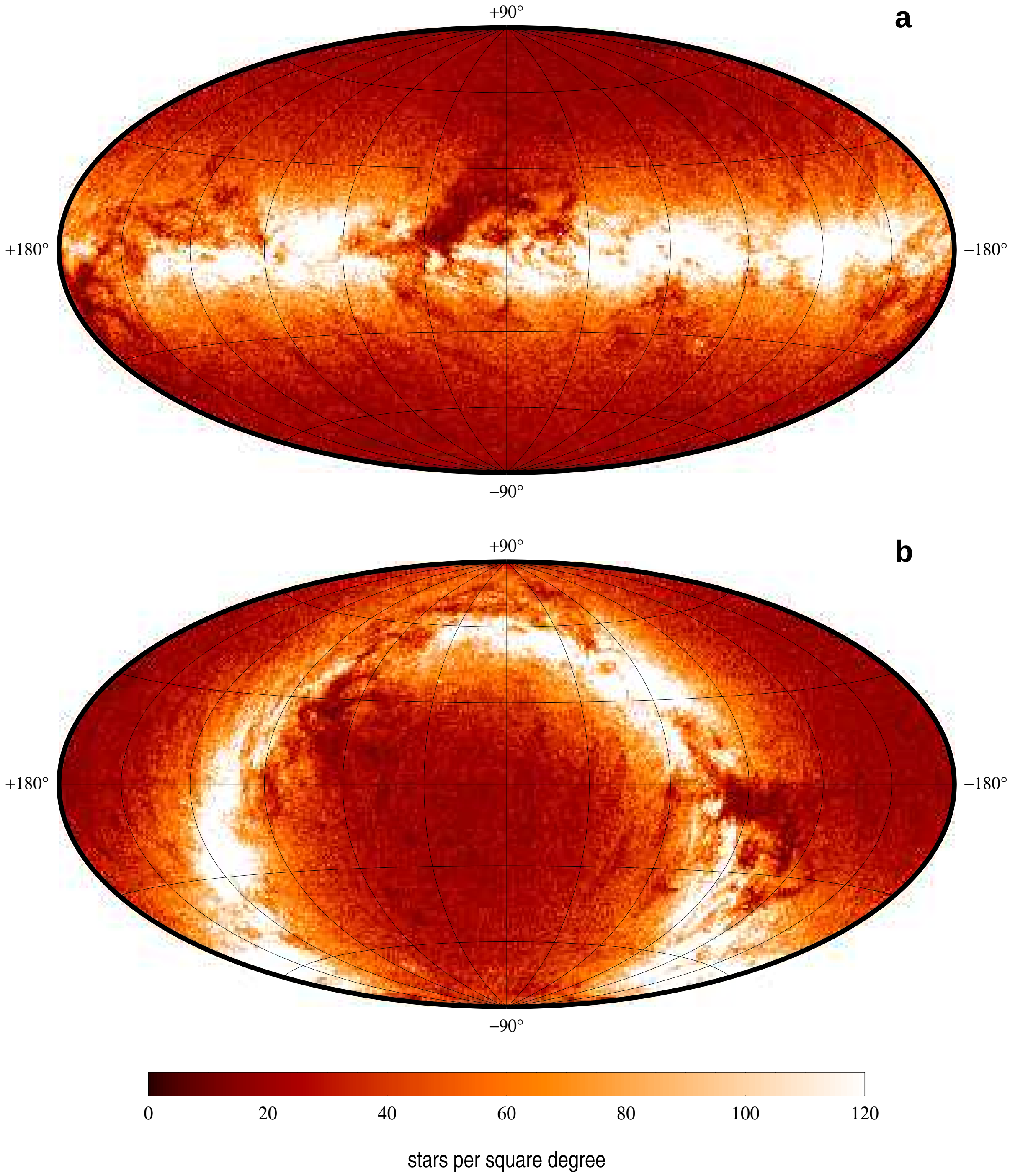

Figure 1: The density of Tycho-2 stars on the sky shown in galactic coordinates (panel a) and in equatorial coordinates (panel b). Some of the dark features reveal low star density due to nearby Galactic dust clouds, while other reveal variations in the limiting magnitude caused by the scanning pattern of the satellite. The densest areas have more than 350 stars deg^{-2}, while the thinnest have close to zero. The average density varies from 25 stars deg^{-2} at $b = \pm 90°$ and 50 stars deg^{-2} at $b = \pm 30°$ to 150 stars deg^{-2} at $b = 0°$

Table 2: Byte-by-byte description of the file catalog.dat

Bytes	Format	Units	Label	Explanations
1- 4	I4.4	—	TYC1	$[1, 9537]$+= TYC1 from TYC or GSC
6- 10	I5.5	—	TYC2	$[1, 12121]$ TYC2 from TYC or GSC
12- 13	I1,1X	—	TYC3	$[1, 3]$ TYC3 from TYC
14- 15	A1,1X	—	pflag	[PX] mean position flag [a]
16- 28	F12.8,1X	deg	mRAdeg	[ ]? α, mean position, ICRS, at epoch J2000
29- 41	F12.8,1X	deg	mDEdeg	[ ]? δ, mean position, ICRS, at epoch J2000
42- 49	F7.1,1X	mas/yr	pmRA*	$[-4418.0, 6544.2]$? $\mu_{\alpha*}$, ICRS, at epoch J2000.0
50- 57	F7.1,1X	mas/yr	pmDE	$[-5774.3, 10277.3]$? μ_{δ}, ICRS, at epoch J2000.0
58- 61	I3,1X	mas	e_mRA*	$[3, 183]$? $\sigma_{\alpha*}$ (model-based) at mean epoch
62- 65	I3,1X	mas	e_mDE	$[1, 184]$? σ_{δ} (model-based) at mean epoch
66- 70	F4.1,1X	mas/yr	e_pmRA*	$[0.2, 11.5]$? $\sigma_{\mu_{\alpha*}}$ (model-based)
71- 75	F4.1,1X	mas/yr	e_pmDE	$[0.2, 10.3]$? $\sigma_{\mu_{\delta}}$ (model-based)
76- 83	F7.2,1X	yr	mepRA	$[1915.95, 1992.53]$? mean epoch of α
84- 91	F7.2,1X	yr	mepDE	$[1911.94, 1992.01]$? mean epoch of δ
92- 94	I2,1X	—	Num	$[2, 36]$? Number of positions used
95- 98	F3.1,1X	—	g_mRA	$[0.0, 9.9]$? Goodness of fit for mean α [b]
99-102	F3.1,1X	—	g_mDE	$[0.0, 9.9]$? Goodness of fit for mean δ [b]
103-106	F3.1,1X	—	g_pmRA	$[0.0, 9.9]$? Goodness of fit for $\mu_{\alpha*}$ [b]
107-110	F3.1,1X	—	g_pmDE	$[0.0, 9.9]$? Goodness of fit for μ_{δ} [b]
111-117	F6.3,1X	mag	BT	$[2.183, 16.581]$? Tycho-2 B_T magnitude [c]
118-123	F5.3,1X	mag	e_BT	$[0.014, 1.977]$? σ_{B_T}
124-130	F6.3,1X	mag	VT	$[1.905, 15.193]$? Tycho-2 V_T magnitude [c]
131-136	F5.3,1X	mag	e_VT	$[0.009, 1.468]$? σ_{V_T}
137-140	I3,1X	—	prox	$[3, 999]$ proximity indicator [d]
141-142	A1,1X	—	TYC	[T] Tycho-1 star flag
143-148	I6	—	HIP	$[1, 120404]$? Hipparcos number
149-152	A3,1X	—	CCDM	CCDM component identifier for HIP stars
153-165	F12.8,1X	deg	RAdeg	α, observed Tycho-2 position, ICRS
166-178	F12.8,1X	deg	DEdeg	δ, observed Tycho-2 position, ICRS
179-183	F4.2,1X	a	epRA	$[0.81, 2.13]$ epoch-1990 of RAdeg
184-188	F4.2,1X	a	epDE	$[0.72, 2.36]$ epoch-1990 of DEdeg
189-194	F5.1,1X	mas	e_RA*	$\sigma_{\alpha*}$ (model-based), observed position
195-200	F5.1,1X	mas	e_DE	σ_{δ} (model-based), observed position
201-202	A1,1X	—	posflg	[DP] type of Tycho-2 solution [e]
203-206	F4.1	—	corr	correlation, $\rho^{\delta}_{\alpha*}$, observed position

[a] The mean position flag:
- ␣ = normal mean position and proper motion
- 'P' = the mean position, proper motion etc refer to the B_T photo-centre of two Tycho-2 entries
- 'X' = no mean position, no proper motion

[b] This goodness of fit is the ratio of the scatter-based and the model-based error. It is only defined when $Num > 2$. Values exceeding 9.9 are truncated to 9.9

[c] Blank when no magnitude is available. Either B_T or V_T is always given.

[d] Distance in units of 100 mas to the nearest entry in the Tycho-2 main catalogue or supplement-1, computed for the epoch 1991.25. A value of 999 (i.e. 99.9 arcsec) is given if the distance exceeds 99.9 arcsec

[e] ␣ = normal treatment, 'D' = double star treatment, 'P' = photo-centre treatment

2.1 The main catalogue file

The Tycho-2 Catalogue uses a similar star numbering system as the GSC (Jenkner et al. 1990). The system is consistent with Tycho-1. The TYC identifier is constructed from the GSC region number (TYC1), the running number within the region (TYC2) and a component identifier (TYC3) which is normally 1. Some non-GSC running numbers were constructed for the first Tycho Catalogue and for Tycho-2. The recommended star designation contains a hyphen between the TYC numbers, e.g. TYC 1–13–1.

Two positions are given for each star, the *mean position* at epoch 2000.0 and the *observed position* at the epoch of Tycho observations (around 1991.5). The mean position is a weighted mean for all the catalogues contributing to the proper motion determination, including Tycho-2. This mean has then been brought from the mean epoch to epoch 2000.0 by the computed proper motion. For four percent of the stars only the Tycho-2 position was available and neither proper motion nor mean position could be determined. For close double stars, the ground-based photographic positions referred to the photo-centre of the system and a common proper motion and mean position has been determined and identical values are given here for the two components, likely being of lower quality than for single stars. The observed position is the position derived from the Tycho observations alone and is given for all stars.

Transformation of the mean position from the catalogue epoch $T_0 = 2000.0$ to an arbitrary epoch $T = T_0 + t$ may be done rigorously as described, e.g., in the Hipparcos and Tycho Catalogues (ESA 1997) Vol. 1, Sect. 1.2.8. A simpler transformation may be used if the proper motion and the epoch difference, t, are small and if the star is not too close to one of the celestial poles:

$$\alpha_t = \alpha + \mu_{\alpha*} t / \cos\delta \quad (1)$$

$$\delta_t = \delta + \mu_\delta t \quad (2)$$

where $\alpha, \delta, \mu_{\alpha*}$ and μ_δ are given in bytes 16–57.

The standard errors of the position components are computed from the values in bytes 58–75 and the mean epochs, T_α, T_δ, in bytes 76–91:

$$\sigma_{\alpha*_t} = (\sigma^2_{\alpha*} + (T - T_\alpha)^2 \sigma^2_{\mu_{\alpha*}})^{0.5} \quad (3)$$

$$\sigma_{\delta_t} = (\sigma^2_\delta + (T - T_\delta)^2 \sigma^2_{\mu_\delta})^{0.5} \quad (4)$$

The Tycho photometry gives a blue and a visual magnitude, B_T and V_T, for nearly all the stars. For every star at least one of the magnitudes is given. The faintest magnitudes (fainter than $B_T \approx 13$ and $V_T \approx 12$) are not to be trusted and the very faintest may simply mean that the star was too faint for detection in that passband. The Tycho magnitudes are not identical to the Johnson magnitudes, but an approximate Johnson photometry for unreddened main sequence stars may be obtained as:

$$V = V_T - 0.090(B_T - V_T) \quad (5)$$

and

$$B - V = 0.850(B_T - V_T). \quad (6)$$

The transformation depends in reality on the detailed spectrum of the star, especially on luminosity class and reddening, and it is recommended to work with the B_T and V_T magnitudes directly. Consult Sections 1.3 and 2.2 of Vol. 1 of the Hipparcos and Tycho Catalogues for details.

The stars in common between Tycho-2 and the first Tycho Catalogue, Tycho-1, are flagged in the following manner: If there is a Tycho-1 star within 0.8 arcsec of a Tycho-2 star; or if there is a Tycho-1 star marked with a '9' in the Tycho-1 astrometric quality field (indicating good photometry but poor astrometry) within 2.4 arcsec of a Tycho-2 star. In the case of single stars, the identifier (TYC1, TYC2, and TYC3 in the format) is the same for both catalogues. For Tycho-1 "single" stars resolved in Tycho-2 as a close pair, both component are flagged as a Tycho-1 star. In this case the identifier from Tycho-1 is assigned to the brightest (V_T) component. Hipparcos stars which were not detected in the first Tycho data analysis, i.e. those stars marked with and 'H' in the source field of Tycho-1, are not flagged as Tycho-1 stars.

The CCDM component identifiers are given for double or multiple Hipparcos stars believed to contribute to the Tycho-2 entry in question. For photo-centre solutions, all components within 0.8 arcsec contribute. For double star solutions any unresolved component within 0.8 arcsec contributes. For single star solutions, the predicted signal from close stars was normally subtracted in the analysis of the photon counts and such stars therefore do not contribute to the solution. When more than one component contributes to a Tycho-2 entry, the CCDM identifier lists the components in alphabetical order irrespective of their magnitudes.

In Tycho-2, three different methods were used in the data analysis: the *normal* single star treatment, the *double star* treatment and the *photo-centre* treatment. In the normal treatment, the signal from close stars was subtracted when possible. In the double star treatment, two stars were found and both are normally included as separate Tycho-2 entries, but sometimes one of them may have been rejected. In the photo-centre treatment, the signal from close stars was not subtracted. This special treatment was applied to known or suspected doubles which were not successfully (or reliably) resolved in the Tycho-2 double star processing.

The observed Tycho-2 position is derived from a series of one dimensional observations, taken in a number of different orientations. In general, the observed right ascension and declination are therefore correlated quantities. The relevant correlation coefficient is given for each star. It is needed for computing the errors of separation and position angle for double stars and for similar tasks.

2.2 The supplement files

In the Tycho-2 data analysis many fairly bright Hipparcos and Tycho-1 stars had to be abandoned, including all stars brighter than $B_T = 2.1$ or $V_T = 1.9$. For the convenience of the user, we supply lists of all Hipparcos and Tycho-1 stars which are not included in Tycho-2. The first supplement contains 17 588 good quality stars while the second supplement contains 1146 Tycho-1 stars which are either false or heavily disturbed by brighter stars. Stars with astrometric quality flag of '9' from Tycho-1 were excluded from both supplements. It is noted that the supplements are the only places where HIP or Tycho-1 data are found in the catalogue.

2.3 The index file

The catalogue is sorted according to the GSC region numbers. Each of the 9537 GSC regions is an area on the sky of at most $3.75^\circ \times 3.75^\circ$. In order to facilitate looking up all stars in some field, we provide an index file. The line i of the index file gives the *record number* in Tycho-2 of the first star in GSC region i. Line $i + 1$ gives the *record number* + 1 of the last star in GSC region i. For Supplement-1, some regions are empty and line i and line $i + 1$ give the same *record number*.

We also give the range of right ascension and declination for the stars in each region. We have made sure that minimum values are always rounded down and maximum values up. For many applications it may be more convenient to use the mean value and the half width of the right ascension and declination intervals.

Table 3: Byte-by-byte description of the files: suppl_1.dat and suppl_2.dat

Bytes	Format	Units	Label	Explanations
1- 4	I4.4	—	TYC1	[2,9529]+= TYC1 from TYC
6- 10	I5.5	—	TYC2	[1,12112] TYC2 from TYC
12- 13	I1,1X	—	TYC3	[1,4] TYC3 from TYC
14- 15	A1,1X	—	flag	[HT] data from Hipparcos or Tycho-1 [a]
16- 28	F12.8,1X	deg	RAdeg	α, ICRS, at epoch J1991.25
29- 41	F12.8,1X	deg	DEdeg	δ, ICRS, at epoch J1991.25
42- 49	F7.1,1X	mas/yr	pmRA*	[ ]? $\mu_{\alpha*}$, ICRS, at epoch J1991.25
50- 57	F7.1,1X	mas/yr	pmDE	[ ]? μ_{δ}, ICRS, at epoch J1991.25
58- 63	F5.1,1X	mas	e_RA*	$\sigma_{\alpha*}$
64- 69	F5.1,1X	mas	e_DE	σ_{δ}
70- 75	F5.1,1X	mas/yr	e_pmRA*	[ ]? $\sigma_{\mu_{\alpha*}}$
76- 81	F5.1,1X	mas/yr	e_pmDE	[ ]? $\sigma_{\mu_{\delta}}$
82- 83	A1,1X	—	mflag	[BVH] magnitude flag [b]
84- 90	F6.3,1X	mag	BT	[ ]? Tycho-1 B_T magnitude
91- 96	F5.3,1X	mag	e_BT	[ ]? s.e. of B_T
97-103	F6.3,1X	mag	VT	[ ]? Tycho-1 V_T or Hp magnitude
104-109	F5.3,1X	mag	e_VT	[ ]? s.e. of V_T
110-113	I3,1X	—	prox	[1,999] proximity indicator [c]
114-115	A1,1X	—	TYC	[T] Tycho-1 star flag
116-121	I6	—	HIP	[1,120404]? Hipparcos number
122-122	A1	—	CCDM	CCDM component identifier for HIP stars

[a] 'H': Hipparcos data including proper motion, 'T': Tycho-1 data, no proper motion is given

[b] ␣ = both B_T and V_T, 'B' = only B_T, 'V' = only V_T, 'H' = Hp is given instead of V_T, and B_T is blank

[c] Distance in units of 100 mas to nearest Tycho-2 main or Supplement-1 entry. (Computed for the epoch 1991.25). A value of 999 (i.e. 99.9 arcsec) is given if the distance exceeds 99.9 arcsec.

Table 4: Byte-by-byte description of the file index.dat

Bytes	Format	Units	Label	Explanations
1- 8	I7,1X	—	rec_t2	+ Tycho-2 rec. of 1st star in region
9-15	I6,1X	—	rec_s1	+= Suppl-1 rec of 1st star in region
16-22	F6.2,1X	deg	RAmin	[−0.01,] smallest RA in region
23-29	F6.2,1X	deg	RAmax	[,360.00] largest RA in region
30-36	F6.2,1X	deg	DEmin	smallest Dec in this region
37-42	F6.2	deg	DEmax	largest Dec in this region

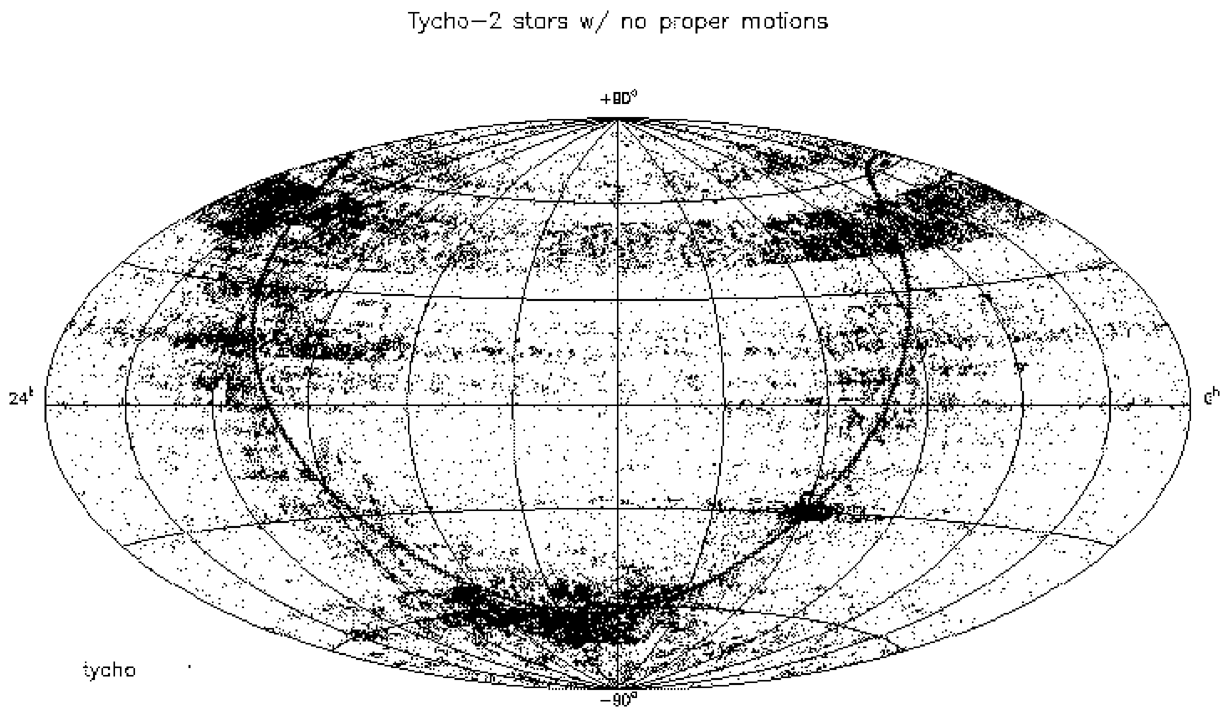

Figure 2: The 100 000 stars without proper motion. The location of the Galactic plane is shown with a thick line.

A Proper motions

The proper motions in Tycho-2 were computed by combining Tycho-2 positions with those from ground-based catalogues using methods described in Section 8 of Høg et al. (2000b). The following contains details on:
– A.1: Removing a catalogue postion
– A.2: The catalogues and position weights
– A.3: Stars without proper motion

A.1 Removing a ground-based catalogue position from the computation

Catalogue positions should be removed from determining mean positions and proper motions due to a variety of circumstances. The main reasons are the positions may be very poor, may contain typographical errors, or may be for a different star. The following three criteria were used to remove catalogue positions in the computation of the Tycho-2 mean positions and proper motions. Under no circumstances was a star allowed to have more than 3 catalogue positions removed. Under no circumstances was the Tycho-2 catalogue position removed. Standard errors of proper motion were computed by two different methods. The *model method* uses assumed positional errors of each of the catalogue positions. The *scatter method* uses a goodness of fit of the catalogue positions to the computed proper motion. Details on each method can be found elsewhere (Høg et al. 2000b).

1) Following the computation of a preliminary proper motion, if the σ_μ of either coordinate (using the *scatter method*) exceeded 30 mas/year, then the proper motion error was deemed "extreme". In this case, it is likely that at least one of the catalogue positions is of another star or may contain a typographical error. For stars with four or more catalogue positions, the one farthest from the Tycho-2 position was removed. For stars with only 3 catalogue positions, the farthest one from the Tycho-2 position was removed only if it was 5 or more times farther than the other non-Tycho-2 position. This last test was imposed to avoid the problem of computing an erroneous proper motion from two catalogue positions of a non-Tycho-2 star with that of a nearby Tycho-2 star. This is the only case when a star with 3 or fewer catalogue positions is allowed to have one discarded. Only one catalogue position was allowed to be removed for any star using this "extreme" criterion.

2) Following the computation of a preliminary proper motion, new residuals for each catalogue position coordinate were computed. If any exceeded 3.5 times its *a priori* estimate and was larger than 400 mas, then the one catalogue position with the largest residual was removed and the computation of the proper motion was repeated. The Tycho-2 catalogue position residual was not used in this test. Additionally, this test was made only if 4 or more catalogue positions were available.

3) Following the computation of a preliminary proper motion, the σ_μ using both the *scatter method* and the *model method* were compared. If the scatter method error exceeded 3.0 times that of the model method in either coordinate, then the catalogue position with the largest residual was removed and the computation of the proper motion was repeated. Only one catalogue position was allowed to be removed for any star using this criterion, and this was only performed if 4 or more catalogue positions were available.

A.2 The catalogue and position weights

There is quite a disparity of positional accuracies between different catalogues, therefore weighting of the positions was necessary when computing the mean position and proper motion. Weights of each catalogue position were computed as the inverse of an estimate of the standard error. This standard error was estimated differently depending on the information known about each catalogue.

For a handful of catalogues with which the authors are intimately familiar, the standard errors used in weighting were taken directly from the catalogue. This was the case for the Tycho-2 positions, the CPC2, and the Twin Astrograph Catalog (TAC). Due to a chance alignment of observations going into the CPC2 or the TAC, it is possible some of the published errors are too low. For this reason, the minimum standard error for a CPC2 and a TAC position is 45 mas in either coordinate.

For the Astrographic Catalogue data, the standard errors used in weighting are based on the mean standard error as a function of magnitudes, the declination zones, and number of observations. For each of the 22 zones of the AC, mean errors per observation were computed for all stars appearing on 2 or more plates. These were based on their positional consistency between the overlapping plates. These mean errors were then binned based on the stars' magnitudes; those brighter than 8.0 were treated together, those between 8.0 and 13.0 were binned in 0.5 magnitude intervals, and those fainter than 13.0 were treated together. The mean standard error of each interval was then computed. Since these are of *individual* observations, one must divide by $\sqrt{N}$ to determine the standard error of a catalogue position, where N is the number of observations of this star. These mean standard errors per observation generally range from 180 to 460 mas, with the vast majority falling between 230 and 300 mas.

For the remaining catalogues, weights are computed as described in Section 8.2 of Høg et al. (2000b). For some catalogues, the number of observations used in computing the position varies significantly from star to star. Therefore if the number of observations are known, the standard error used in computing the weights are divided by $\sqrt{N}$. These catalogues are marked with a 'Y' under the heading $\sigma/\sqrt{N}$ in Table 5.

Table 5 is a list of the catalogues used in computing the Tycho-2 proper motions. The name of each catalogue, instrument type (transit circle, astrograph, or satellite), standard errors in mas ($\sigma_{\alpha*}, \sigma_\delta$ for either position or single observation) and number of positions of Tycho-2 stars in the catalogue, Num, are given. For comparative purposes, the standard errors of a typical catalogue position from each catalogue, $\sigma_{cat_{\alpha*}}$, σ_{cat_δ}, are also provided.

A.3 Stars without proper motion

Figure 2 shows the sky distribution of the almost 100 000 stars where no proper motion could be determined. These are mainly situated in specific zones of the Astrographic Catalogue, where the limiting magnitude was rather bright, or in areas of the Galactic plane.

References

[1] ESA 1997, The Hipparcos and Tycho Catalogues, ESA SP-1200, Volumes 1-17

[2] Høg E., Fabricius C., Makarov V.V., Urban S.E., Corbin T.E., Wycoff G.L., Bastian U., Schwekendiek P., Wicenec A. 2000a, The Tycho-2 Catalogue of the 2.5 Million Brightest Stars, A&A, submitted

[3] Høg E., Fabricius C., Makarov V.V., Bastian U., Schwekendiek P., Wicenec A., Urban S.E., Corbin T.E., Wycoff G.L. 2000b, Construction and verification of the Tycho-2 Catalogue, A&A, submitted

[4] Høg E., Fabricius C., Makarov V.V., Urban S.E., Corbin T.E., Wycoff G.L., Bastian U., Schwekendiek P., Wicenec A. 2000c, The Tycho-2 Catalogue on CD-ROM, including Guide to Tycho-2, Copenhagen University Observatory

[5] Jenkner H., Lasker B.M., Sturch C.R., McLean B.J., Shara M.M., Russell J.L. 1990, AJ 99, 2081

[6] Kuzmin A., Høg E., Bastian U., Fabricius C., Kuimov K., Lindegren L., Makarov V.V., Röser S. 1999, A&AS 136, 491

[7] Urban S.E., Corbin T.E., Wycoff G.L. 1998, AJ 115, 2161

Table 5: Catalogues used in computing Tycho-2 proper motions

Name	type	$\sigma_{\alpha*}$	σ_δ	$\sigma/\sqrt{N}$	$\sigma_{cat_{\alpha*}}$	σ_{cat_δ}	Num
ABBADIA 00 +16/+24	T.C.	990	810	Y	440	360	13930
ABBADIA 00 -2/+4	T.C.	950	930	Y	420	420	13310
ABBADIA 00 -3/-9	T.C.	980	850	Y	490	430	7200
AGK2 BERGEDORF	Ast.	210	200	N	210	200	107510
AGK2 BONN	Ast.	260	260	N	260	260	58420
AGK2A	T.C.	170	220	N	170	220	13590
AGK3	Ast.	200	190	N	200	190	165760
AGK3R	T.C.	80	110	N	80	110	21440
ALBANY -2/+1 1900	T.C.	840	840	Y	590	590	2750
ALBANY -20/-40 00	T.C.	840	1160	Y	480	670	8000
ALBANY 10	T.C.	290	280	N	290	280	19600
ALGER AG 1900	T.C.	1160	960	Y	820	680	9390
A.C.	Ast.						5509800
BERGEDORF 1-25	T.C.	430	540	Y	300	380	4700
BERLIN 10 79/90	T.C.	500	620	Y	350	440	1790
BERLIN 1920	T.C.	560	660	Y	400	470	8460
BONN 00	T.C.	370	330	N	370	330	10440
BONN 00 +40/+50	T.C.	510	460	Y	290	270	2010
BONN 20	T.C.	530	500	Y	240	220	1780
BORD 00-2	T.C.	1040	730	Y	740	520	6580
BORD 00-2 RE-OBN	T.C.	400	380	Y	280	270	1360
BORD 50 +11/+18	T.C.	110	150	N	110	150	2020
BUCHAREST -11/+11	T.C.	380	490	Y	190	250	3920
CAMC Series	T.C.	180	240	Y	70	100	125780
CAPE -40/-52 1900	T.C.	740	670	Y	370	340	8350
CAPE 1-25	T.C.	470	460	Y	150	140	4330
CAPE 1-50	T.C.	370	370	Y	130	130	4820
CAPE 17 -30/-35	Ast.	390	410	N	390	410	12400
CAPE 18 -35/-40	Ast.	320	350	N	320	350	11410
CAPE 19 -52/-56	Ast.	300	320	N	300	320	8650
CAPE 1ST FUND 1900	T.C.	590	560	Y	120	110	1140
CAPE 2-25	T.C.	470	450	Y	210	200	11450
CAPE 2-50	T.C.	470	590	Y	170	210	6960
CAPE 20 -56/-60	Ast.	210	190	N	210	190	7240
CAPE 20 -60/-64	Ast.	200	200	N	200	200	6740

Table 5: Catalogues used in computing Tycho-2 proper motions, continued

Name	type	$\sigma_{\alpha*}$	σ_{δ}	$\sigma/\sqrt{N}$	$\sigma_{cat_{\alpha*}}$	$\sigma_{cat_{\delta}}$	Num
CAPE 21 -64/-68	Ast.	180	190	N	180	190	5010
CAPE 21 -68/-72	Ast.	190	200	N	190	200	4180
CAPE 21 -72/-76	Ast.	210	210	N	210	210	3420
CAPE 21 -76/-80	Ast.	190	200	N	190	200	2570
CAPE 22 -80/-89	Ast.	180	230	N	180	230	2480
CAPE 2ND FUND 1900	T.C.	530	460	Y	130	120	1720
CAPE 3-25	T.C.	470	420	Y	240	210	6440
CAPE G.C. 1900	T.C.	670	600	Y	300	270	4220
CAPE ST 50 -30/-35	T.C.	740	670	Y	370	340	1660
CAPE ST 50 -35/-40	T.C.	530	510	Y	270	260	1860
CAPE ST 50 -52/-56	T.C.	720	610	Y	360	310	1000
CAPE ST 50 -56/-60	T.C.	330	340	Y	170	170	1210
CAPE ST 50 -60/-64	T.C.	300	340	Y	150	170	1070
CAPE ST 50 -64/-68	T.C.	370	400	Y	190	200	1010
CAPE ST 50 -68/-72	T.C.	380	380	Y	190	190	820
CAPE ST 50 -72/-76	T.C.	370	420	Y	190	210	640
CAPE ST 50 -76/-82	T.C.	330	370	Y	170	190	510
CAPE ST 50 -82/-90	T.C.	230	330	Y	120	170	390
CORDOBA 6429 ST 00	T.C.	720	720	Y	510	510	5950
CORDOBA D 1950	T.C.	590	630	Y	420	450	15550
CORDOBA E 1950	T.C.	620	950	Y	310	480	1580
CPC2	Ast.						240500
FOKAT	Ast.	220	240	Y	110	120	180390
GREENWICH 1-50	T.C.	500	490	Y	190	190	6020
GREENWICH 1910	T.C.	430	320	N	430	320	12120
GREENWICH 2-25	T.C.	450	470	Y	200	210	10360
GREENWICH 9Y2	T.C.	950	850	Y	390	350	9640
HEIDELBERG ZOD 50	T.C.	380	450	Y	170	200	2740
KONIGSBERG 25	T.C.	180	200	Y	130	140	110
KONIGSBERG 25-II	T.C.	480	430	Y	240	220	520
LA PLATA 3710 S 50	T.C.	710	660	Y	500	470	3460
LA PLATA A 1925	T.C.	810	790	Y	570	560	7070
LA PLATA B 1925	T.C.	810	680	Y	470	390	6480
LA PLATA C 1925	T.C.	800	700	Y	460	400	4160
LA PLATA D 1925	T.C.	1000	870	Y	500	440	4360
LA PLATA E 1925	T.C.	910	860	Y	530	500	2380
LA PLATA EROS 1930	T.C.	500	390	N	500	390	470

Table 5: Catalogues used in computing Tycho-2 proper motions, continued

Name	type	$\sigma_{\alpha*}$	σ_δ	$\sigma/\sqrt{N}$	$\sigma_{cat_{\alpha*}}$	σ_{cat_δ}	Num
LA PLATA F 1935	T.C.	490	520	Y	280	300	4690
LA PLATA GC 1950	T.C.	560	590	Y	320	340	6520
LEIDEN 25 XV/1	T.C.	460	580	Y	270	330	1500
LEIDEN 25 XV/2	T.C.	460	660	Y	270	380	1060
LEIDEN 25 XV/4	T.C.	2310	2070	Y	260	270	1170
LICK 17 HARVD AG	T.C.	250	350	N	250	350	1050
LICK 28 20/30	T.C.	220	200	N	220	200	1180
LICK ZODIACAL 1900	T.C.	420	340	Y	300	240	3090
LUND 50 FAINT AG	T.C.	710	750	Y	410	430	6010
LUND AG 25 35/40	T.C.	660	700	Y	470	490	11230
MADISON 1910	T.C.	440	470	Y	250	270	2620
MELB 2ND GC 1880	T.C.	1380	860	Y	360	330	1050
MELB 3RD GC 1890	T.C.	1510	1120	Y	500	500	2710
MUNICH A 1900	T.C.	680	750	Y	150	180	1040
MUNICH B 1900	T.C.	730	680	Y	160	160	650
NICE 10 +5/+15	T.C.	560	610	Y	230	250	960
NICE 25 -5/+5		170	240	N	170	240	1020
NICOLAEV -5/-20 50	T.C.	310	370	Y	160	190	2600
PARIS 1900	T.C.	1300	850	Y	650	430	10390
PARIS ASTR +17/+25	Ast.	290	320	N	290	320	6840
PERTH 83	T.C.	210	410	Y	70	150	11880
PERTH VOL 2 1900	T.C.	720	710	Y	420	410	1570
PERTH VOL 3 1900	T.C.	900	970	Y	520	560	1750
PERTH VOL 4 1900	T.C.	840	800	Y	480	460	1970
PERTH VOL 5 1900	T.C.	910	800	Y	530	460	1970
PERTH VOL 6 1900	T.C.	760	780	Y	440	450	1920
PFKSZ 50	T.C.	60	60	N	60	60	580
PULKOVO 10 39/44	T.C.	300	290	N	300	290	3270
PULKOVO 1900	T.C.	1270	910	Y	640	460	8490
SAN LUIS 1910	T.C.	720	660	Y	320	300	14720
SCHWACHER STERNE	T.C.	110	150	N	110	150	3350
SIDNEY 1499 IMD 25	T.C.	780	770	Y	350	340	1460
SRS	T.C.	270	370	Y	70	90	20410
STRASBOURG AG 1900	T.C.	1010	910	Y	580	530	7950
SYDNEY -48/-54	Ast.	160	140	N	160	140	16810
SYDNEY -51/-63.5	Ast.	80	80	N	80	80	25280

Table 5: Catalogues used in computing Tycho-2 proper motions, continued

Name	type	$\sigma_{\alpha *}$	σ_{δ}	$\sigma/\sqrt{N}$	$\sigma_{cat_{\alpha *}}$	$\sigma_{cat_{\delta}}$	Num
TOKYO PMC 86-89	T.C.	460	540	Y	190	220	12350
TOULOUSE 00 3-B	T.C.	460	380	N	460	380	1820
TOULOUSE 3	T.C.	680	570	Y	300	250	9340
TYCHO-2	Sat.						2431940
WASH 00 9-IN	T.C.	590	540	Y	190	180	4200
WASH 1-J00	T.C.	200	240	Y	60	80	6890
WASH 2-50	T.C.	260	380	Y	90	130	4930
WASH 2-J00	T.C.	270	320	Y	70	90	43940
WASH 20	T.C.	640	540	Y	260	220	10200
WASH 25 ZOD 6-IN	T.C.	350	410	Y	160	180	3420
WASH 3-50	T.C.	290	380	Y	100	130	5690
WASH 33 -10/-20	T.C.	560	440	Y	280	220	1240
WASH 40 9-IN	T.C.	370	450	Y	120	150	5110
WASH AG 1900	T.C.	1220	980	Y	860	690	8370
WASH TAC	Ast.						660030
WIEN AG 1900	T.C.	810	810	Y	570	570	8210
YALE 11 -10/-14	Ast.	360	360	N	360	360	7650
YALE 12/1 -14/-18	Ast.	320	260	N	320	260	8270
YALE 12/2 -18/-20	Ast.	280	250	N	280	250	4420
YALE 13/1 -20/-22	Ast.	290	250	N	290	250	4090
YALE 13/2 -27/-30	Ast.	340	350	N	340	350	8530
YALE 14 -22/-27	Ast.	310	280	N	310	280	13100
YALE 16 -6/-10	Ast.	240	240	N	240	240	8140
YALE 17 -2/-6	Ast.	250	230	N	250	230	7990
YALE 18 +15/+20	Ast.	200	210	N	200	210	8960
YALE 19,22/2 +9/15	Ast.	210	190	N	210	190	10640
YALE 20 +1/+5	Ast.	200	190	N	200	190	7890
YALE 21 +1/-2	Ast.	230	230	N	230	230	5560
YALE 22/1 +5/+9	Ast.	200	210	N	200	210	8730
YALE 24,25 +20/+30	Ast.	190	150	N	190	150	18350
YALE 26/1 +85/+90	Ast.	160	170	N	160	170	940
YALE 26/2,27 50/60	Ast.	120	140	N	120	140	15790
YALE 28 -30/-35	Ast.	290	320	N	290	320	12410
YALE 29 -35/-40	Ast.	280	290	N	280	290	11410
YALE 30 -40/-50	Ast.	200	200	N	200	200	16420
YALE 31 -70/-90	Ast.	190	220	N	190	220	14440
YALE 32 -60/-70	Ast.	300	310	N	300	310	13730