

Part 8. Catalogues

OVERVIEW OF THE TYCHO CATALOGUE

E. HØG¹, C. FABRICIUS¹, V.V. MAKAROV¹,
D. EGRET², J.L. HALBWACHS², G.BÄSSGEN³,
V. GROßMANN³, K. WAGNER³, A. WICENEC³,
U. BASTIAN⁴ AND P. SCHWEKENDIEK⁴

¹*Copenhagen University Observatory, Denmark*

²*Observatoire de Strasbourg, France*

³*Astronomisches Institut der Universität Tübingen, Germany*

⁴*Astronomisches Rechen-Institut, Germany*

1. Overview of the Tycho Catalogue

The final Tycho Catalogue (ESA 1997b) has been derived from 37 months of observations with the star mapper of the astrometric satellite Hipparcos. The Hipparcos Catalogue (ESA 1997a) with about 120,000 stars is the result of the main Hipparcos mission and has, *e.g.*, been described by Kovalevsky *et al.* (1995). Both catalogues will be published in 1997.

The Tycho Catalogue provides astrometry (positions, parallaxes and proper motions) and two-colour photometry (in B_T and V_T) for more than one million stars brighter than $V_T = 11.5$ mag. The median precision (standard error) is 25 mas in position and 0.10 mag in the $B_T - V_T$ colour index. These values apply at the median magnitude $V_T = 10.5$ mag for stars of median colour index $B_T - V_T \simeq 0.7$ mag. The Tycho Catalogue contains 1,052,031 entries (stars) observed by Tycho, supplemented by 6301 entries from the Hipparcos Catalogue that were not observed by Tycho. The Tycho Catalogue contains roughly 40,000 stars brighter than $V_T = 9$ mag which are not contained in the Hipparcos Catalogue. For these stars the median precision is 7 mas in position, parallax and annual proper motion and 0.019 mag in $B_T - V_T$. Double stars with separations larger than 2 arcsec and with moderate magnitude difference are usually resolved.

The Tycho Catalogue, and its photometric annex, referred to as the Tycho Epoch Photometry Annex, is strictly an observational catalogue. It contains data derived exclusively from the Hipparcos satellite's star mapper observations, with the exception of certain cross-identifications.

V_T	<6.0	6–7.0	7–8.0	8–9.0	9–10.0	10–11.0	>11.0	All	<9.0
Median V_T	5.38	6.63	7.62	8.62	9.61	10.58	11.19	10.47	8.33
N (TYC)	4553	9550	27,750	78,029	211,107	515,029	205,934	1,052,031	119,882
N (not HIP)	4	55	3485	36,511	182,773	506,720	205,275	934,901	40,055
Median standard errors in astrometry (mas):									
Position	1.8	2.6	4.0	6.7	12.9	27.2	39.2	24.6	5.6
Parallax	2.5	3.6	5.3	8.6	16.4	34.3	49.6	31.2	7.2
P.M./yr	2.3	3.3	5.0	8.3	16.0	33.5	48.6	30.2	7.0
Median standard errors in astrometry (mas):									
B_T	0.003	0.006	0.010	0.018	0.036	0.084	0.128	0.074	0.014
V_T	0.003	0.005	0.008	0.014	0.027	0.064	0.122	0.057	0.012
$B_T - V_T$	0.005	0.008	0.014	0.024	0.049	0.117	0.200	0.104	0.019
$B - V$	0.004	0.007	0.012	0.020	0.041	0.098	0.171	0.087	0.017

TABLE 1. This table gives the number of stars in TYC and the number of TYC stars not included in HIP, along with the corresponding median standard errors for stars within the given intervals of V_T magnitude (the column ‘All’ also including entries for which V_T is not available). Systematic errors in astrometry are less than 1 mas and 1 mas/yr, although the external standard errors (the true accuracies) may be 50 per cent larger than the quoted standard errors for faint stars. In photometry, systematic errors may reach the level of the quoted standard errors for faint stars. The photometry for about 20,000 stars is considered to be uncertain, for example when the standard errors are larger than 0.3 mag.

The reduced data comprise two parts. The main catalogue (the Tycho Catalogue, or TYC) contains the astrometric and summary photometric data for each star. The Tycho Epoch Photometry Annex contains summary photometric data for all stars, along with ‘epoch photometry’ (photometry at each epoch of observation) for a subset of stars observed with sufficiently high signal-to-noise ratio. In structure, the Tycho Catalogue and the Tycho Epoch Photometry Annex resemble the corresponding machine-readable parts of the Hipparcos Catalogue (HIP) and the associated Hipparcos Epoch Photometry Annex.

Solar system objects observed as part of the Tycho experiment are contained within a general annex of solar system observations by the Hipparcos satellite.

1.1. COMPLETENESS OF THE TYCHO CATALOGUE

Some Hipparcos Catalogue stars were not observable by the star mapper. The dynamic range of the star mapper detector resulted in non-linearity at the brightest magnitudes (Sirius was not observable). The faintest Hippar-

cos Catalogue stars fell below the detection threshold of the star mapper detectors. Stars in very dense clusters and other dense fields could not be observed by Tycho, thus leaving the resulting Tycho Catalogue incomplete in such regions.

All 6301 single star entries and double and multiple star components contained within the Hipparcos Catalogue but not observed by Tycho have nevertheless been included in the Tycho Catalogue for completeness, and assigned a corresponding TYC number. In these cases a truncated astrometric and photometric descriptor taken from the Hipparcos Catalogue has been included in the Tycho Catalogue. The position of the entry taken from the Hipparcos Catalogue is also included in order to assist cross-identification between the catalogues.

2. Tycho Photometry

Tycho photometry was obtained in two colour bands, B_T and V_T , closely corresponding to B and V in the Johnson UBV system. The Tycho colour index, written $B_T - V_T$ or $(B - V)_T$, is not explicitly given, but may be simply derived from the difference of the published magnitudes. Approximate values of the Johnson V magnitude and colour index $B - V$ are also provided, derived by a suitable transformation. Because it is a strict observable, and unaffected by the uncertainties inherent in such a transformation, the Tycho colour index rather than the derived Johnson colour index is recommended for use whenever appropriate.

A simple linear transformation from the Tycho B_T, V_T magnitudes to B, V magnitudes in the Johnson photometric system is:

$$\begin{aligned} V &\simeq V_T - 0.090 (B_T - V_T) \\ B - V &\simeq 0.850 (B_T - V_T) \end{aligned}$$

In the interval $-0.2 < B_T - V_T < 1.8$ mag the systematic errors of this simple transformation do not exceed 0.015 mag for V and 0.05 mag for $B - V$ for unreddened main-sequence stars.

3. Reference Stars

A distinct flag indicates whether the Tycho Catalogue entry is considered as a 'recommended' astrometric reference star. This classification of the entry requires, *e.g.*, non-duplicity and good astrometric quality, resulting in 886,000 stars being flagged as astrometric reference stars.

Most of the Tycho Catalogue magnitudes have a sufficient accuracy for calibration of magnitudes derived from photographic survey plates in colour bands near to B or V . A selection of non-double and non-variable

stars having a standard error < 0.1 mag results in about 520,000 Tycho photometric reference stars suitable for such a purpose.

4. Concluding Remarks

The Tycho Catalogue constitutes an astrometric reference system with twice as many stars as PPM which is the best system up to now with high star density, cf. Table 2 by Høg (1995). The 30 mas standard error of positions for TYC at the epoch 1990 is ten times smaller than that of PPM and the systematic errors are 100 times smaller. The accuracy is maintained for one or two decades from 1990 if PPM proper motions are used or, even better, if proper motions are derived for all Tycho stars by means of positions from the Astrographic Catalogue, reduced to the Hipparcos reference system, as proposed by Röser & Høg (1993) and discussed by Röser, Schilbach & Hirte (1995).

As a photometric reference catalogue in two colour bands the TYC is about an order of magnitude larger though less accurate than the collection of all ground-based photometric data with UBV photometry for about 100,000 stars by Mermilliod & Mermilliod (1994).

References

- ESA, 1997a, The Hipparcos Catalogue, ESA SP-1200
 ESA, 1997b, The Tycho Catalogue, ESA SP-1200
 Høg E. 1995, in: E. Høg and P.K. Seidelmann (eds.), *Astronomical and Astrophysical Objectives of Sub-Milliarcsecond Optical Astrometry*, 317, Kluwer Academic Publ.
 Kovalevsky J., Lindegren L., Froeschle M., van Leeuwen F., Perryman M.A.C., Falin J.L., Mignard F., Penston M.J., Petersen C.S., Bernacca P.L., Bucciarelli B., Donati F., Hering R., Høg E., Lattanzi M.G., van der Marel H., Schrijver H., Walter H.G. 1995, *Astron. Astrophys.* 304, 34
 Mermilliod J.-C. & Mermilliod M, 1994, *Catalogue of Mean UBV Data on Stars*, Springer Verlag, New York, Berlin, Heidelberg, 1994.
 Röser, S., Høg, E., 1993, 'Tycho Reference Catalogue: A Catalogue of Positions and Proper Motions of one Million Stars.' In: *Workshop on Databases for Galactic Structure*. Ed.: A.G. Davis Philip, B. Hauck and A.R. Upgren. Van Vleck Observatory Contr. No.13, 137. L. Davis Press, Schenectady, N.Y.
 Röser S., Schilbach E. & Hirte S., 1995, ESA SP-379, 143