

17. VERIFICATION OF THE TYCHO CATALOGUE: STELLAR CONTENT

In this chapter, the stellar content of the Tycho Catalogue is analyzed. Comparisons are made with major reference catalogues: the Hipparcos main catalogue, the Catalogue of Positions and Proper Motions (PPM), the Guide Star Catalog, etc. It is shown that the Tycho Catalogue can be considered a nearly complete star survey up to a magnitude limit of $V_T = 10.5$ mag. Missing stars are listed, and cross-identifications are discussed.

17.1. Introduction

In general terms, the Tycho Catalogue can be described as a survey of stars brighter than 11.0 mag. In practice, this means that the Tycho Catalogue contains about 99.9 per cent of the stars brighter than $V = 10.0$ mag, and a large fraction of the stars in the range 10.0 to 11.5 mag. The completeness ratio drops, at the faint end, from more than 90 per cent at $V = 10.5$ mag, to roughly 65 per cent at 11.0 mag and 10 per cent at 11.5 mag (see Figure 17.1). Among the 120 000 stars brighter than 9.0 mag in the Catalogue of Positions and Proper Motions (PPM), about 120 are missing in the Tycho Catalogue, i.e. 0.10 per cent. In this chapter the limits and characteristics of the survey are examined in more detail.

17.2. Completeness of the Tycho Catalogue at the Bright End

A few very bright stars, e.g. Sirius, were not observable by the star mapper. The dynamic range of the star mapper detector resulted in a non-linearity at the brightest magnitudes. Stars in very dense clusters and other dense fields could not be observed by Tycho, thus leaving the Tycho Catalogue incomplete in such regions. However, stars contained in the Hipparcos Catalogue and not observed by the Tycho star mapper have been added, for completeness, in the Tycho Catalogue and flagged accordingly. As a consequence, one can expect to have a complete catalogue at the bright end. There are some exceptions, setting aside the photometric variability, and the specific case of very close binaries. For instance, during the preparation of the Millennium Star Atlas the exercised eyes of Sky & Telescope experts discovered a missing star near Alcyone. Of a triangle of three stars near Alcyone, one is missing from the Tycho Catalogue: SAO 76188 (HD 23608). This star was also actually missing from the Guide Star

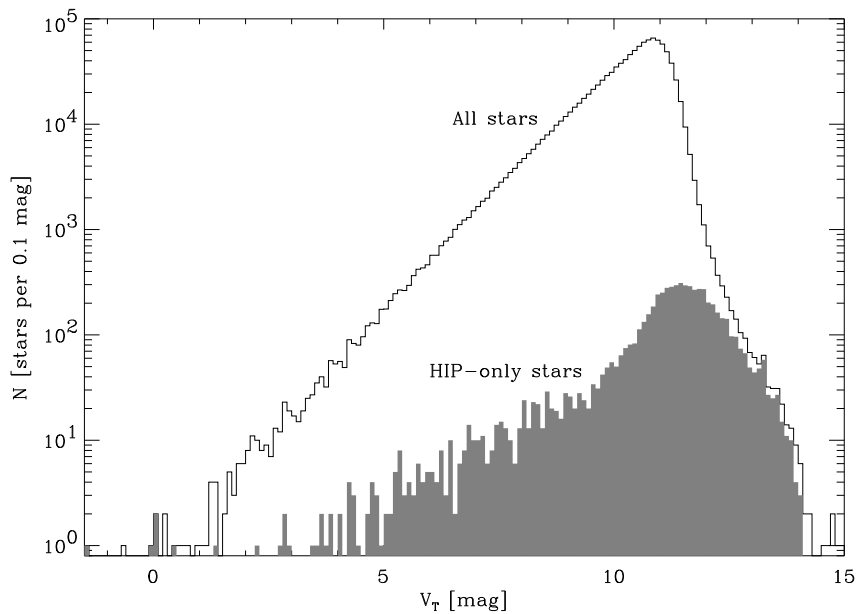


Figure 17.1 Histogram of Tycho stars as a function of V_T magnitude. For 1 per cent of the stars another magnitude had to be used.

Catalog Version 1.0 but had been introduced into the Tycho Input Catalogue (and later on into Version 1.1 of the Guide Star Catalog) from the SIMBAD/INCA Data Bases. Although present in the Tycho Input Catalogue Revision (TICR), this star failed to be included in the final Tycho Catalogue, due to an insufficient number of transits not affected by parasites (see Section 7.2). The Hipparcos Catalogue does not contain the star, which would otherwise have been included as a ‘HIP-only’ entry.

A reasonably complete list of such bright missing stars can be derived from comparisons with ground-based catalogues. Stars in the Catalogue of Positions and Proper Motions (PPM), including the Bright Star Supplement, of magnitude 9.0 or brighter were sought in the Tycho Catalogue. Among a total of 143 490 stars, no Tycho Catalogue star was found within 3.0 arcsec in 137 cases. A closer examination showed that at least 117 stars are not in the Tycho Catalogue. These stars are listed in Table 17.1. In 103 cases there is not even a Tycho Catalogue star within 30 arcsec of the PPM position. In the 14 remaining cases there is a Tycho star at some distance, but it is very unlikely to be the PPM star. One of the missing stars, PPM 122593, is in fact HIP 31067. It has no astrometric solution in the Hipparcos main catalogue, but the result of a new astrometric solution is given in the notes.

Out of the 137 PPM stars, 20 are not clearly missing in the Tycho Catalogue. There is rather an inconsistency. Except for PPM 215592, all 20 stars seem to be in the Hipparcos Catalogue. These 20 stars are listed in Table 17.2. In 14 cases the PPM entry gives the position of the photocentre of Tycho double stars with separations 6.6–10 arcsec. The remaining six cases require individual remarks. PPM 323067 is flagged in the Catalogue of Positions and Proper Motions as ‘double’ and as a ‘problem case’. In SAO, in the Hipparcos Input Catalogue and on the Digitized Sky Survey it is much fainter than 9.0 mag, more like 10.5 mag. The other five PPM stars are at distances 3.1–3.8 arcsec from a Tycho star. They are all double stars with separations 5–16 arcsec and both components are in the Tycho Catalogue, but with different positions from the PPM Catalogue. The relative positions (position angle and separation) of these stars in the

CCDM are in good agreement with the Tycho positions. Therefore, the inconsistencies are probably due to errors in the PPM Catalogue. PPM 331230 is even a high proper motion star and part of an orbiting pair. It should finally be noted that the bright supplement to the PPM Catalogue (PPM numbers 400nnn) gives only approximate positions. It is concluded that among the stars of the PPM Catalogue brighter than 9 mag, only 117 are missing in the Tycho Catalogue, providing a completeness of 99.9 per cent.

Status of Bright Stars Absent from the Tycho Catalogue

The status has been checked of stars brighter than 9.0, present in the Hubble Space Telescope Guide Star Catalog (GSC), and therefore in the Tycho Input Catalogue (TIC), but which are not in the Tycho Catalogue. There are 2028 such stars in the northern sky ($V \leq 9.0$ mag), i.e. 1.5 per cent of the Tycho Input Catalogue in this magnitude range. There are 4635 such stars in the southern sky ($B \leq 9.0$ mag; no V available). As explained below, most of these 'stars' are false Guide Star Catalog entries.

Such stars have been checked in two sample areas of 6° radius, one in the South and one in the North, using the Centre de Données astronomiques data bases: SIMBAD and ALADIN. In the South, from a test on 31 objects, 70 per cent are galaxies or nebulae and 30 per cent are redundancies. For the galaxies and nebulae the 'stellar' magnitude given by the Guide Star Catalog was too bright because these are extended objects. The redundancies occur when the same bright star appears on two plates with a position difference slightly too large for automatic identification. In the North, from a test on 15 objects, 50 per cent are redundancies, 25 per cent are galaxies/nebulae or false stars, most often flagged in the Guide Star Catalog with 'nonstar' class and 25 per cent are double systems. For these doubles the median position given by the Guide Star Catalog has not been confirmed by Tycho. Therefore the Tycho Catalogue obtained 'new' entries, carrying a new identification number.

All these features of the Guide Star Catalog were already known, and some of them have been corrected in later versions of the Guide Star Catalog. The comparison with the Tycho Catalogue provided useful tools for wiping out these defects from the Guide Star Catalog.

Does the Tycho Catalogue Include False Bright Stars?

We have considered all Tycho Catalogue entries with $V_T \leq 7.0$ mag and no Hipparcos Catalogue (HIP) identifier, as potential candidates for being 'false stars'. There are only 59 such entries:

- for one star (TYC 5619-1257-1 = HIP 78727) the Hipparcos Catalogue cross-identification was omitted in the Tycho Catalogue because of missing Hipparcos astrometry;
- 23 stars are components of a double or multiple system: the Hipparcos Catalogue number was assigned to (one of) the other component(s) of the system, but not to this one. An example is TYC 1800-2201-1 = HD 23629; HIP 17702 is assigned to HD 23630;

Table 17.1. Bright stars from the Catalogue of Positions and Proper Motions (PPM) which are missing in the Tycho Catalogue (117 cases).

PPM	m	RA Dec h m deg	pm " yr ⁻¹	HD	SAO	Other Name	Simbad type stat	Comments
A neighbouring star is present in the Tycho Catalogue within 30 arcsec; 14 cases:								
14174	8.0	03 16 +60	0.00	20053	23908		*i2	4049-1502-1 at 7.1 arcsec
187290	9.0	04 45 -03	0.01		131463		*	
122176	9.0	06 15 +10	0.01	43231	95453		*i2	735-863-1 at 5.4 arcsec
96101	8.7	06 31 +21	0.01	45900			*i2	1340-1326-1 at 8.1 arcsec
251060	8.3	06 49 -24	0.03	49892	172384		*i2	
253068	8.2	07 44 -24	0.83				?	Sim-
191001	8.6	08 07 -03	0.04	67324	135523		*	
222919	7.0	10 24 -18	0.02	90255	155965		V*	PN NGC 3242
400169	7.2	12 06 +68	0.00				D/M	ADS 8419 DS
359380	8.6	12 23 -62	0.02	107862	251882		*i2	
400197	7.4	14 50 -67	0.01			AV Cir	Cep	
294473	8.9	15 57 -31	0.01		207167		*i2	
322113	8.7	16 44 -42	0.06	150674	227139		*i2	
234740	8.4	18 34 -14	0.01	171333	161630		*i2	
No Tycho star within 30 arcsec; 103 cases:								
182211	7.3	00 24 -09	0.00	1987	128740	S Cet	Mira	
701131	8.4	01 06 -01	0.01	6592		Z Cet	Mira	
367685	8.5	02 29 -70	0.03	15919			*	
367701	8.3	02 32 -70	0.02	16242	255896		*	
353126	8.1	02 46 -68	0.01	17646			*	
212820	8.9	03 23 -10	0.01	21040	148931		*i2	
92883	8.9	03 47 +24	0.04	23608	76188		*i2	Cl: Pleiades
186599	8.9	04 09 -09	0.04	26316	130990		*	
186800	8.9	04 19 -02	0.04	27450	131117		*i2	
214263	8.7	04 23 -14	0.02	27913	149601		*	
187096	8.9	04 34 -02	0.02		131327		*	
280771	8.9	04 51 -34	0.08		195366		*	
187717	8.6	05 06 -09	0.01	33009	131781		*	
187853	8.9	05 15 -07	0.01				IRS	
47921	8.3	05 16 +46	0.06		40184		*i2	
248729	8.5	05 18 -25	0.02	34691	170292		*	
248800	8.7	05 21 -24	0.01	35164	170354		*i2	
354812	9.0	05 31 -61	0.01	37049	249301		*	
702316	9.0	05 35 -05	0.00			V1230 Ori	*iCl	Cl: NGC 1977
216476	7.1	05 56 -11	0.05	40120	150958		*	
216908	8.5	06 15 -11	0.02	43345	151269		*	
217036	8.6	06 20 -10	0.01	44258	151371		*	
189105	8.6	06 22 -04	0.01	44678	133186		*	
335155	9.0	06 24 -52	0.01		234486		*	
335172	8.5	06 25 -52	0.03	45634	234497		*	
335182	8.9	06 26 -52	0.06		234507		*	
122593	7.6	06 31 +16	0.05	45951	95765		*i2	
122609	8.5	06 31 +17	0.02	258878	95781	OW Gem	V*	
217355	8.6	06 33 -11	0.04	46564	151640		*	
217462	9.0	06 38 -13	0.02	47437	151732		*	
217467	8.8	06 38 -13	0.06	47496			*i2	

Table 17.1. (Continued).

PPM	m	RA Dec h m deg	pm " yr ⁻¹	HD	SAO	Other Name	Simbad type stat	Comments
251001	8.5	06 47 -20	0.02	49372	172328		*iCl	Cl: NGC 2287
283329	8.2	06 57 -31	0.02	51824	197403		*	
151884	9.0	07 04 +01	0.01	53391	114885		*	
151890	8.1	07 05 +00	0.01	53451	114891		2/M	
190469	9.0	07 37 -08	0.01	61177	134908		*i2	
703729	8.7	07 39 -00	0.01				?	Sim- IRAS 07369-0025??
714833	9.0	08 02 -13	0.01	66245		DX Pup	SRP	
312671	9.0	08 09 -47	0.00		219512		*	
784704	9.0	08 21 -76	0.03	71793		R Cha	Mira	
254377	8.7	08 22 -22	0.03	70712	175701		*	
220070	8.6	08 24 -11	0.01	70973	154216		*	
31719	8.5	08 31 +54	0.03	71677	26882		*	
220932	8.8	09 00 -17	0.01				?	Sim-
221044	8.8	09 05 -14	0.01	78031	154897		*	
192098	8.9	09 10 -08	0.03	78953	136643		*	
178057	9.0	10 01 -00	0.08	86842	137292		*	
315052	9.0	10 09 -43	0.00	88172	221806		*	
357865	8.6	10 14 -69	0.01				*	CPD-69 1182
288139	8.7	10 48 -31	0.02		201771		*	
288154	8.8	10 49 -30	0.02	93769	201783		*	
193935	8.6	10 55 -06	0.03	94636	94636		*	
194314	8.7	11 17 -07	0.07	98104	138108		*i2	
400161	3.8	11 18 +31	0.73	98230J		ξ UMa	V* *i2	
225140	8.8	11 56 -14	0.02	103696	156998		*	
260462	9.0	12 32 -25	0.10	109107	180874		*	
260514	8.9	12 34 -27	0.05	109393	180916		*	
226058	8.9	12 35 -18	0.01			U Crv	Mira	
360021	8.9	13 18 -67	0.01				*	
291948	8.2	13 53 -35	0.00	120987E	204956		*i2	
779714	8.3	13 54 -60	0.02	121022			*	
780093	9.0	14 37 -61	0.01				?	Sim-
229250	8.2	14 45 -18	0.02	129943	158786		*	
320305	7.7	15 10 -41	0.02	134267	225503		*i2	
293749	8.7	15 21 -36	0.04		206551		*	
294637	8.8	16 05 -31	0.02	144074	207312		*	
322370	7.9	16 54 -41	0.00	152314	227400		V*	Cl: NGC 6231
232686	9.0	17 09 -12	0.02				*	BD-12 4677
80006	8.5	17 11 +33	0.01	155591	65852		*	
296915	9.0	17 52 -34	0.01	320764	209380		*iCl	Cl: NGC 6475
749152	7.8	17 53 -34	0.01	162630			Sp2	
749154	9.0	17 53 -34	0.01				?	Sim- Cl: NGC 6475
749156	8.4	17 53 -34	0.01	162656			Sp2	Cl: NGC 6475
296958	6.5	17 53 -34	0.01	162678	209425		*iCl	Cl: NGC 6475
749167	8.6	17 54 -34	0.01				?	Sim- Cl NGC 6475 region
749169	8.9	17 54 -34	0.01	320859			*iCl	Cl: NGC 6475
296971	7.7	17 54 -34	0.01	162781	209435		*iCl	Cl: NGC 6475
297080	8.2	17 58 -36	0.06	163651	209543		*i2	

Table 17.1. (Continued).

PPM	m	RA Dec h m deg	pm " yr ⁻¹	HD	SAO	Other Name	Simbad type stat	Comments
297133	8.5	18 01 -30	0.02	164199	209601		*i2	
267782	7.5	18 03 -24	0.01	164816	186207		*iCl	Cl: NGC 6530
267805	8.9	18 04 -24	0.04	164948	186226		*iCl	Cl: NGC 6530
233999	8.6	18 05 -11	0.01	165148	161051		*	
268081	8.6	18 13 -28	0.01	166855	186494		*i2	
325276	9.0	19 37 -46	0.01	184558	184558		*	
764510	8.8	19 44 -41	0.01	186087		TV Sgr	Mira	
83501	8.5	19 45 +35	0.00		68812		*i2	
325713	8.9	20 00 -41	0.02	189119	229972		*	
237205	9.0	20 17 -12	0.01		163421		*i2	
348543	8.9	20 26 -56	0.02		246577		*	
86047	5.2	21 06 +38	5.26	201091	70919	V1803 Cyg	V* *i2	
238481	9.0	21 10 -16	0.01	358906	164193	Z Cap	Mira	
272333	8.9	21 19 -21	0.04	202841	190226		*	
301543	8.6	21 33 -30	0.03	204987	213085		*	
301657	8.9	21 39 -33	0.02	205890	213169		*	
301662	9.0	21 39 -33	0.01		213174		*	
205591	8.8	21 46 -06	0.01	207091	145655		*i2	
205592	8.4	21 46 -06	0.02	207092	145656		*i2	
273214	9.0	21 59 -25	0.10	208850	190801		*	
375228	9.0	22 03 -74	0.00	208833	257994		*	
722964	8.6	22 05 -13	0.05				?	Sim-
722977	8.6	22 07 -13	0.03				?	Sim-
327932	9.0	22 08 -44	0.04		230995		*	
329803	8.7	23 56 -49	0.00	224269	248066	R Phe	Mira	

Abbreviations used in the tables

Alg	Eclipsing binary of Algol type
Cep	Classical Cepheid variable Star
D/M	Double or multiple star
HPM	High proper-motion Star
IRS	Infra-Red source
Mira	Variable Star of Mira Cet type
PN	Planetary Nebula
Sim-	Object was not present in Simbad
Sp2	Spectroscopic binary
SRP	Semi-regular pulsating Star
V*	Variable Star
*	Star
*i2	Star in double system
*iCl	Star in Cluster
?	No Simbad classification is available

Table 17.2. Bright stars from the Catalogue of Positions and Proper Motions (PPM) which are inconsistent with the Tycho Catalogue (20 cases).

PPM	m	RA Dec	pm	HD	SAO	Other	Simbad	Comments
		h m deg	" yr ⁻¹			Name	type stat	
Stars present in the Tycho Catalogue or error in the PPM Catalogue; 6 cases:								
331230	5.3	01 39 -56	0.34	10360			HPM *i2	8478-1394-2 at 3.8 arcsec
129400	7.3	12 51 +19	0.20	111845	100307		*i2	1452-906-1 at 3.1 arcsec
400211	7.2	15 55 -02	0.11				?	5023-464-1 at 3.6 arcsec
323067	6.3	17 31 -46	0.03		228073		*i2	faint star ?
236293	6.7	19 39 -16	0.07	185344	162853		*i2	6303-2842-1 at 3.3 arcsec
63460	8.2	22 49 +40	0.08	216122	52401		*i2	3218-1759-1 at 3.3 arcsec
PPM gives the photocentre position of two Tycho stars; 14 cases:								
244506	6.4	01 59 -22	0.09	12180	167451	AA Cet	V* *i2	6430-2303-1 at 3.7 arcsec
215592	8.6	05 19 -10	0.06	34750	150333		*i2	5335-1378-1 at 4.5 arcsec
309786	6.2	05 31 -42	0.04	36648	217374		*i2	7604-684-1 at 3.4 arcsec
283868	5.9	07 22 -35	0.07	58038	197907		*i2	7116-2739-1 at 3.4 arcsec
284007	5.4	07 28 -31	0.05	59499J			D/M	7104-3987-1 at 4.2 arcsec
286548	5.1	09 30 -31	0.07	82383J		ζ^1 Ant	D/M	7158-2544-1 at 4.0 arcsec
286658	7.1	09 36 -31	0.04	83231	200538		*i2	7167-716-1 at 3.5 arcsec
259116	5.8	11 32 -29	0.12	100287	179968	17 Crt A	*i2	6663-1171-1 at 3.2 arcsec
400179	7.5	12 45 -75	0.04				*i2	9413-2768-1 at 3.8 arcsec
294448	5.4	15 56 -33	0.09	142629	207144	ξ^1 Lup	*i2	7337-1460-1 at 4.2 arcsec
294532	8.1	16 00 -36	0.06	143215	207220		*i2	7341-1239-1 at 3.2 arcsec
294737	5.6	16 09 -32	0.04	144927	207396		*i2	7334-2610-1 at 3.8 arcsec
400246	7.3	18 43 -52	0.00	172494B			*i2	8758-2848-1 at 3.3 arcsec
374833	7.1	20 58 -70	0.04	199005	257869	KZ Pav	Alg *i2	9325-1020-2 at 3.1 arcsec

- 4 stars are (according to SIMBAD/INCA Data Bases) fainter than the formal survey limit, and thus they were not included in the Hipparcos Catalogue. An example is: TYC 736-1489-1 = HD 45047; $V_T = 6.9$ mag, but $V(\text{SIMBAD}) = 7.5$ mag;
- 30 stars, a little brighter than the limit of the survey, were not, for various reasons, selected in the Hipparcos Input Catalogue. An example is TYC 1472-1427-1 = HD 124953; $V_T = 6.0$ mag; $V(\text{SIMBAD}) = 6.0$ mag;
- 1 false star (with appropriate flags, including astrometric quality, $Q = 9$) was found at 26 arcsec from a very bright star and at the exact location of a much fainter Tycho Input Catalogue entry. This object is TYC 6842-1291-1; $V_T = 6.4$ mag.

In a second step, stars in the range 7.0 to 8.0 mag were also considered, which are neither in the Hipparcos Catalogue nor in the HD Catalogue. As HD is expected to be complete at least to 8.0 mag, this criterion was used to look for potentially false stars in the Tycho Catalogue for this magnitude range. There are 76 such entries in the Tycho Catalogue:

- 42 had a PPM or other identification. Their magnitude in SIMBAD is compatible with V_T : thus there is confidence that they are real stars. The fact that the HD

number is missing can be generally explained by a multiple system or by a failed cross-identification in case of PPM/SIMBAD discrepancy;

- 34 remaining stars were searched in the Guide Star Catalog and on the SIMBAD and ALADIN sky images:
 - 9 have a faint Guide Star Catalog magnitude (in the range 11–12 mag) while $V_T \simeq 8 - 9$ mag. They have an astrometric quality $Q = 9$; they are most probably false stars, generally generated by transits from a nearby bright star. ALADIN confirms their faint Guide Star Catalog magnitude;
 - 2 are typical wide companions, real components of double systems, but not recorded in the HD Catalogue: TYC 5961–3346–1 and 8317–1714–1. For the first object, located in the cluster NGC 2287, one can see close by on the digitized sky image two stars of magnitude $\simeq 10.0$ mag not catalogued in the Guide Star Catalog (because of overlapping spikes) and also missed by Tycho. These stars were probably already beyond the limits of the Tycho serendipity mode;
 - a problem occurred with a double system, where Tycho contains:

6510-569-1	$V_T = 7.5$ mag	CCDM = A	quality = 9
6510-569-2		CCDM = B	HIP-only star
6510-2299-1	$V_T = 7.6$ mag		quality = 9

at a place where there is actually, on the sky, a double system with a bright star ($V = 7.5$ mag) and a fainter one ($V = 11.2$ mag; the Catalogue of Components of Double and Multiple Stars (CCDM) = B star). Tycho reduction did not perform well here: if the quality flag is neglected two bright stars are found, while only one is actually there. If the quality flag is taken into account, no bright star remains;
 - the remaining 20 entries are confirmed stars, not recorded in the HD Catalogue for various reasons.

In conclusion, bright Tycho entries, provided they are flagged with an astrometric quality better than 9, proved to be of very high reliability.

17.3. Completeness of the Tycho Catalogue at the Faint End

A histogram of all stars in the Tycho Catalogue as a function of V_T magnitude is given in Figure 17.1. For 1 per cent of the stars another magnitude was used because no V_T was available. The slope indicates that the completeness ratio stays constant until $V_T = 10.0 - 10.5$ mag. From the comparison with bright PPM stars we found a completeness ratio of 99.9 per cent at $V_T = 9$ mag. After $V_T = 10$ mag, the number of HIP-only stars begins to rise more steeply and we might expect a decline in the completeness ratio to begin there. Extrapolating the distribution in Figure 17.1, the completeness ratio is estimated to at least 90 per cent at $V_T = 10.5$ mag, 65 per cent at 11 mag and 10 per cent at 11.5 mag. In order to avoid a bias in $B_T - V_T$ colour index (see Figure 16.20), it is recommended to select stars on the basis of the T magnitude, which may be derived with the approximate formula: $T = (B_T + V_T)/2$. The completeness ratios are then 90 per cent at $T = 10.8$ mag, 65 per cent at $T = 11.5$ mag and 10 per cent at $T = 11.8$ mag.

Table 17.3. The quality distribution of ‘new Tycho Catalogue entries’ (see text).

Quality	Number
1	8
2	41
3	349
4	627
5	14
6	12
7	112
8	161

The Tycho Catalogue includes, on the distribution tail, stars as faint as $V = 12.0$ mag. The analysis of a statistical sample (with V_T in the range 11.0–12.1 mag) confirmed that these are appropriate entries in the Tycho Catalogue. There are a few thousand stars in the Tycho Catalogue fainter than 12.0 mag, but these magnitudes are quite uncertain, see Table 16.3.

Additional Tycho Catalogue Entries

From the whole Tycho Catalogue 1584 entries carry a new Guide Star Catalog number, not already present in the Tycho Input Catalogue; they are mainly Tycho serendipity entries and wide companions; see Chapter 5. The Tycho Input Catalogue already contained additional stars with respect to the Guide Star Catalog Version 1.0; see Chapter 3.

Out of these 1584 entries, 260 are ‘HIP-only stars’ in the final Tycho Catalogue and are not considered in the following. Thus there are 1324 ‘new Tycho Catalogue entries’ in terms of the Guide Star Catalog/Tycho Input Catalogue identifications.

The quality distribution for these entries is given in Table 17.3.

A random sample of 30 stars was also analyzed:

- 13 (43 per cent) are rather bright stars for which the position has been substantially revised, so that the former Guide Star Catalog number could not be kept, at least from our automatic procedure. Some high proper motion stars may also fall into this category. An example (one of the brightest) is TYC 6445–990–1, which is the new number of GSC 6445 986 ($V_T = 3.97$ mag). Ideally the original Guide Star Catalog number could have been kept, but this would have meant a careful assessment of each entry which would have delayed the catalogue production;
- 14 (47 per cent) are components of double systems for which the Guide Star Catalog gives the position of the photocentre, while the Tycho Catalogue gives the position of (at least one of) the individual components. An example is: TYC 6085–1618–1 and –1619–1 (GSC 6085 94);
- 3 (10 per cent) are ‘serendipity’ or ‘wide companion’ entries. It has already been shown by Egret *et al.* (1992) why the Guide Star Catalog missed such entries (confusion with spikes or halos of bright stars, etc.). An example is TYC 8317–1714–1, which is new. The companion star 8317–1709 was in the Guide Star Catalog, from the INCA Data Base.

17.4. Cross References

The Tycho Catalogue gives cross-identifications to the Hipparcos Catalogue (HIP), the Catalogue of Positions and Proper Motions (PPM), the HD Catalogue, the DM Catalogues (partly) and it flags stars from the General Catalogue of Variable Stars (GCVS) and the New Catalogue of Suspected Variable Stars (NSV). Except for the Hipparcos Catalogue and the PPM Catalogue, these catalogues are of poor astrometric quality. For a catalogue the size of the Tycho Catalogue, it is therefore not always possible to provide fully correct and consistent identifications. Even for the Hipparcos Catalogue and the PPM Catalogue there were many non-trivial cases. The Hipparcos Catalogue also provides (in the machine readable version) references to the HD and DM Catalogues, and the critical user of the Tycho Catalogue may take advantage of this in order to detect possible mis-identifications for Hipparcos stars in the Tycho Catalogue. It is also advisable to check the notes of the Hipparcos Catalogue. These notes may give corrections to the identifications of some stars in the Hipparcos Input Catalogue, and such stars are likely also to have a wrong identification or a wrong flag in the Tycho Catalogue.

An example of a partly mis-identified star is GQ Ori (TYC 734-627-1). This Cepheid is the southern component of a visual double with separation 31 arcsec and both components around 9 mag. In the discovery paper (Kukarkin & Kurochkin 1947), it was erroneously identified with HD 42532 (TYC 734-1163-1) situated 5 arcmin away. HD 42532 was therefore included in the Hipparcos Catalogue (HIP 29386), flagged as known variable in the Tycho Catalogue and included in the Tycho Epoch Photometry Annex A. The true GQ Ori is in Annex B, it is not flagged as known variable and was not included in the Hipparcos Catalogue. To make things worse, the HD numbers of TYC 734-627-1 and its companion (TYC 734-2337-1) have been confused in the Tycho Catalogue, as they are in the Catalogue of Positions and Proper Motions (PPM). They should have been HD 253058 for TYC 734-627-1 and HD 253057 for the companion.

17.5. Concluding Remarks

The analysis of the stellar contents of the Tycho Catalogue, summarized in this chapter, shows that the Tycho Catalogue presents unique characteristics making it the first reference survey of the one million brightest stars in the sky. The catalogue will, for this reason, be a very important tool for supporting cross-identification with other catalogues, surveys or wide-field images obtained from ground- or space-based telescopes, in the optical as well as in other wavelength ranges.

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