Section 2.6

Tycho Catalogue: Epoch Photometry Annex

2.6. Tycho Catalogue: Epoch Photometry Annex

A general introduction to the published data related to the Tycho experiment is given in Section 1.3.6. Details of the fields of the Tycho Catalogue, including an explanation of the quantities relevant for an understanding of the contents of the Annex, are given in the introduction to Section 2.2.

Results of the individual, calibrated, Tycho photometric measurements at each epoch of observation are made available as the Tycho Epoch Photometry Annex. In principle, an annex comprising individual transit data for every object in the Tycho Catalogue could have been provided. In practice, for most of the faint Tycho stars, the epoch photometry is not considered to be of sufficient importance to merit general publication.

Two subsets of the data have consequently been selected. Transit data related to Tycho Catalogue objects considered to be of greatest astrophysical value constitute the Tycho Epoch Photometry Annex A. It forms part of the ASCII CD-ROMs accompanying the printed Hipparcos Catalogue, where transit data for 34 446 objects are given. Epoch photometry for a significantly larger fraction of the Tycho Catalogue objects (481 553) is made available as the Tycho Epoch Photometry Annex B through the CDS, Strasbourg. Finally, the epoch photometry data for all Tycho Catalogue objects is kept in an archive of the Tycho Consortium.

Field T50 of the main Tycho Catalogue (see Section 2.2) indicates which objects are included in Annexes A and B, respectively. The selection criteria are detailed below.

Each Tycho Epoch Photometry Annex is ordered by the TYC identifier (see also Section 2.11). It consists of header records and transit records. The header records (Table 2.6.1) contain summary photometric data. When provided, the transit records contain the transit time (i.e. the observation epoch), estimated magnitudes and related quantities, and flags providing further details related to each observation, as well as information on the quality of the resulting data.

The number of valid transits, $N_{\rm transits}$ (i.e. including both detected and non-detected transits) are given in Field TH4 of the header record. The criteria used to determine whether the transit provides valid photometric data are described in the introduction to Section 2.2. As explained there, a valid photometric transit does not necessarily provide a statistically meaningful estimate of the object's magnitude.

Selection Criteria for the Presentation of Transit Records

The Tycho Epoch Photometry Annex A, provided on the ASCII CD-ROMs, gives epoch photometry for objects which fall into one or more of the following categories:

- a selection of 6100 photometric standard stars;
- known or suspected variable stars from the General Catalogue of Variable Stars (GCVS, 1985) and the New Catalogue of Suspected Variables (NSV). These stars have flags 'G' and 'N' in Field T47 of the Tycho Catalogue;
- stars showing strong indication of variability in the Tycho measurements (flag 'V' in Field T48);
- stars showing clear indication of (unresolved) duplicity in the Tycho measurements (flag 'D' in Field T49).

The selection of objects for Annex A was defined such as to provide the most interesting subset of the Tycho epoch photometry, while at the same time selected to fit onto a single CD-ROM. The number of objects with transit records in Annex A is 34 446.

The Tycho Epoch Photometry Annex B made available through the CDS includes all the above objects, supplemented by objects which fall into one or more of the following categories:

- all stars brighter than $V_T = 10.25$ mag;
- stars with weak indication of variability in the Tycho measurements, or photometric disturbance that may be due to other reasons (flag 'U' or 'W' in Field T48);
- stars with weak indication of duplicity in the Tycho measurements (flag 'R' or 'S' in Field T49);
- stars with astrometric quality flag '9' in Field T40;
- stars with the note flag set in Field T57.

Some of the criteria for Annex B especially select objects with low signal-to-noise ratio or with dubious astrometric or photometric results. They are included in Annex B so that a better summary photometry may be obtained by a more thorough study than was possible until now. Improved astrometry may in principle also be derived since the individual transit records (Table 2.6.2) contain the required information. The number of objects with transit records in Annex B is 481 553 (these are the 34 446 objects of Annex A, flagged 'A' in Field T50 of the Tycho Catalogue, and 447 107 additional objects, flagged 'B' in Field T50 of the Tycho Catalogue).

Description of the Header Record (Table 2.6.1)

Fields TH1–3: Tycho identifier

The Tycho identifier is described under Field T1 (Section 2.2). For double stars resolved in the special astrometry analysis, but not separated in photometry, the full set of transits are given under both entries.

Field TH4: Number of transit records following this header record, N_{transits}

If provided, these are the records belonging to 'valid' transits in the terminology of the Tycho photometry treatment. The introduction to Section 2.2 provides details of the criteria used to define the 'valid' transits.

Field TH5: Number of detected transits measured in the B_T band, $N_{B,\text{ measured}}$

The number of detected transits measured in B_T, referred to as $N_{B,\text{ measured}}$, corresponds to the total number of transits where bit 0 of Field TT13 is not set. An appropriate subset of transits classified as 'measured' and 'not-measured' were used to construct the summary photometric data given in the following fields (see the introduction to Section 2.2 for further details).

Each measured transit corresponds to a detection of the relevant star above a signal-to-noise ratio of 1.5 in the T channel. However, some detections may be 'not-measured' in either B_T or V_T. The total number N_{transits} for a given star is related to the number of transits 'measured' and 'not-measured' in each photometric band as follows:

$$\begin{aligned} N_{\text{transits}} &= N_{B,\text{ measured}} + N_{B,\text{ not–measured}} \\ &= N_{V,\text{ measured}} + N_{V,\text{ not–measured}} \end{aligned} \qquad [2.6.1]$$

where the values $N_{B,\text{ measured}}$ and $N_{V,\text{ measured}}$ are given in Fields TH5 and TH10.

Fields TH6–9: Summary photometric data for the B_T observations

These fields provide, for the B_T observations, the mean magnitude (either median or de-censored mean), the standard error of the mean magnitude, and the 15th and 85th percentile points (together providing an indication of the scatter of the measurements). More details can be found in the descriptions of Fields T32–T39 and Fields T45–46 in Section 2.2. The definition and derivation of the relevant quantities in the context of the Tycho observations are given in Section 1.3.6.

Field TH10: Number of detected transits measured in the V_T band, $N_{V,\text{ measured}}$

The number of detected transits measured in V_T, referred to as $N_{V,\text{ measured}}$, corresponds to the total number of transits where bit 1 of Field TT13 is not set. See Field TH5 for details.

Fields TH11–14: Summary photometric data for the V_T observations

See Fields TH6–9 for details.

Fields TH15–16: Header flags (see Table 2.6.1 and Volume 4 for details)

Table 2.6.1. Tycho Epoch Photometry Annex: star header

Field	Bytes	Format	Description
TH 1	1– 5	I4,X	TYC1 (GSC region)
TH 2	6–11	I5,X	TYC2 (star number)
TH 3	12–13	I1,X	TYC3 (component)
TH 4	14–17	I3,X	Number of transits in epoch photometry, N_{transits}
TH 5	18–21	I3,X	Number of detected and measured transits, $N_{B,\text{ measured}}$
TH 6	22–28	F6.3,X	Mean magnitude B_T (mag)
TH 7	29–34	F5.3,X	σ_{B_T} (mag)
TH 8	35–41	F6.3,X	15th percentile for B_T (mag)
TH 9	42–48	F6.3,X	85th percentile for B_T (mag)
TH10	49–52	I3,X	Number of detected and measured transits, $N_{V,\text{ measured}}$
TH11	53–59	F6.3,X	Mean magnitude V_T (mag)
TH12	60–65	F5.3,X	σ_{V_T} (mag)
TH13	66–72	F6.3,X	15th percentile for V_T (mag)
TH14	73–79	F6.3,X	85th percentile for V_T (mag)
TH15	80–82	I2,X	Header flags (bit): 0: approximate magnitude (see Field T36) 1: variable/suspected variable from GCVS/NSV (set if Field T47 non-blank) 2: variable/suspected variable from Tycho analysis (set if Field T48 = 'U', 'V' or 'W') 3: close pair, known from Hipparcos or Tycho (set if Field T2 non-blank) 4: double/suspected double, unresolved by Tycho (set if Field T49 = 'D', 'R' or 'S') 5: variable/suspected variable from Hipparcos analysis (set if Field H6 non-blank)
TH16	83–84	I2	Header flags (bit): 0: standard star for photometric calibration (in normal processing) 1: standard star for photometric calibration (in reprocessing) 2: photometric reduction used instrument parameters from reprocessing

See Section 2.11.1 for interpretation of bit settings in Fields TH15–16 (bit 0 is the least-significant bit).

Description of the Individual Transit Record (Table 2.6.2)

Field TT1: Observation epoch

This is specified in (barycentric) Julian Date, with respect to JD(TT) 2 440 000.0.

Observation epochs are given in Terrestrial Time (TT), and have been corrected for light propagation time to the solar system barycentre. They are therefore referred to as BJD(TT). Observation epochs are given with a resolution of 10^{-5} days = 0.864 s.

Fields TT2–4: Photometric quantities for the transit in B_T

These fields give the calibrated magnitude for the transit (B_T), the standard error (σ_{B_T}), and the background (b_B) in counts per sample (i.e. counts per $\frac{1}{600}$ s). If a magnitude is not measured, then the value $B_{\rm det}$, corresponding to the measurement limit, i.e. an upper limit on the brightness, is entered as B_T. The value is calculated assuming an appropriate value of the signal-to-noise ratio, the background, and the slit group (see Volume 4). It is noted that $B_{\rm det}$ is not a completely reliable upper limit on the brightness, because about 6 per cent of all transits are spurious non-detections. A value of 327.67 counts per sample in Field TT2 or Field TT4 means that the measured background was equal to or higher than that value. For further explanation see Section 2.2.

Fields TT5–7: Photometric quantitities for the transit in V_T

Details as for Fields TT2–4.

Fields TT8–9: Instrumental geometry for the transit

Field TT8 provides the z-coordinate at which the star transitted the star mapper slits at the given epoch. Field TT9 provides the corresponding position angle of the slit normal, p_n, reckoned positive in the direction of motion of the star in the field of view.

The position angle allows a photometric analysis to be made as a function of this parameter—a dependence is expected for close double stars, which might therefore be discovered in this way. The user must still distinguish between vertical and inclined slits with respect to resolution. The position of the slits on the sky can also be calculated at the transit time using the position angle p_n along with the z-coordinate (see Volume 4 for further details). The position angle is measured counterclockwise, as seen on the sky, from the $+\delta$ direction.

Field TT10: Astrometric residual of the transit, Δu

This is the difference between the transit time of the star and the transit time expected from the adjusted position of the star, the satellite attitude, and the geometric calibration of the instrument. This time difference is multiplied by the instantaneous scan speed of the slit group, giving an angular distance Δu expressed in mas.

The user may restrict further the range of Δu for which the photometric transits are to be accepted for an analysis of epoch photometry. If two detected transits from the same group crossing were accepted by the astrometric adjustment, the one with the smallest absolute Δu is selected as being associated with the photometric parameters of the candidate object.

Field TT11: Expected standard error of the astrometric residual σ_u

The expected standard error of the astrometric residual given in Field TT10 has been computed from the known uncertainties of the satellite attitude, the geometric instrument calibration, and the photon noise of the raw Tycho signal.

Field TT12: Goodness-of-fit

The numerical value of the goodness-of-fit indicates possible (unrecognised) duplicity, and unrecorded parasite disturbances. The goodness-of-fit has been constructed as described in Volume 4.

Field TT13: Transit flags

The bits are defined in Table 2.6.2. If a transit is not detected in the T-channel bits 0 and 1 are set = 1, Fields TT8–9 are given, but Fields TT10–12 are blank. These blank fields characterise unambiguously a non-detection.

Table 2.6.2. Tycho Epoch Photometry Annex: individual transit record

Field	Bytes	Format	Description
TT 1	1–11	F10.5,X	BJD(TT), (barycentric) Julian Date −2 440 000.0 (days)
TT 2	12–18	F6.3,X	B_T for the transit (mag)
TT 3	19–24	F5.3,X	σ_{B_T} (mag)
TT 4	25–31	F6.2,X	Background, b_B (cts/smp)
TT 5	32–38	F6.3,X	V_T for the transit (mag)
TT 6	39–44	F5.3,X	σ_{V_T} (mag)
TT 7	45–51	F6.2,X	Background, b_V (cts/smp)
TT 8	52–59	F7.1,X	z-coordinate, z (arcsec)
TT 9	60–65	F5.1,X	Position angle, p_n (degrees)
TT10	66–71	I5,X	Residual, Δu (mas)
TT11	72–76	I4,X	Standard error, σ_u (mas)
TT12	77–82	F5.1,X	Goodness-of-fit
TT13	83–84	I2	Transit flags (bit): 0: magnitude not measured in B_T 1: magnitude not measured in V_T 2: transit rejected in astrometry and in de-censoring (due to suspected parasite) 3: transit on the vertical/inclined slit (0 = vertical, 1 = inclined) 4: transit in following/preceding field (0 = following, 1 = preceding)

See Section 2.11.1 for interpretation of bit settings in Field TT13 (bit 0 is the least-significant bit).