The TYCHO Project on-board the HIPPARCOS Satellite

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ABSTRACT. The Hipparcos mission had to be revised because the satellite did not reach the circular geostationary orbit. Observations from the elliptical transfer orbit will be degraded in the sense that good quality observations are expected, but only during less than 50 percent of the total time, and the mission duration will probably be less than 2.5 years. If the mission lasts 12 months a Tycho catalogue is expected containing at least 200 000 stars with typical accuracies of 0.10 arcsec for positions and 0.10 mag for B and V magnitudes.

Introduction

In the Tycho data analysis, see Høg (1989), the photon counts from the Hipparcos star mapper are processed to detect slit transits exceeding a certain signal-to-noise ratio. These detections or transits, collected throughout the mission, are identified with stars contained in a Tycho Input Catalogue. A limiting magnitude of about $B = 11$ mag, depending on star colour, was expected in the nominal mission of 2.5 years within small areas of 40 arcsec diameter centred on each Tycho Input Catalogue position, corresponding to a final Tycho Catalogue of at least 400 000 stars. The typical astrometric and photometric accuracy of a mean value in the Tycho Catalogue was expected to be 0.03 arcsec and 0.03 mag, respectively, for the majority of faint stars. Double stars with separations larger than about 2 arcsec would also be resolved.

A revised mission is now foreseen because the satellite could not be placed in the planned geostationary orbit due to failure of the apogee-boost-motor. Observations will be obtained from the elliptical orbit, as explained by Perryman (1989). The performance in this orbit is not yet known with any certainty, but probably the mission will last at least 12 months and result in a Tycho catalogue containing at least 200 000 stars with typical accuracies of 0.10 arcsec and 0.10 mag.

Observations and Data Analysis

The primary purpose of the Hipparcos star mapper is to observe the transit

J. H. Lieske and V. K. Abalakin (eds.), Inertial Coordinate System on the Sky, 307–310.

time of bright stars of known position when they cross the slit system. The slit system consists of two groups of narrow slits, each of 40 arcmin length. The four slits in one group is perpendicular to the motion of stars in the field, the other group is inclined by 45 degrees, as has been illustrated and discussed by Høg (1986). By means of known star positions and observed transit times, the attitude of the satellite is determined. The satellite attitude must be known with a precision of about 1 arcsec during the mission in order to point the light sensitive area of the main detector at the individual programme stars as they cross the main field of view. A good attitude knowledge is also required later on to achieve the best astrometric precision in the data analysis of the programme stars, and here the attitude must be known with a precision of 0.1 arcsec.

Since stars used for the real-time attitude determination are a subset of the main mission programme stars, which are in turn a subset of all stars brighter than the star mapper detection limit, it became evident during the development of the Hipparcos project that observations of transit times for many stars, other than those required for attitude determinations, can be exploited to derive the positions of these stars. The photometric results for the stars are obtained from the analysis of the stellar photon fluxes at the slit transits.

The raw photon counts from the star mapper will undergo a sequence of processing steps, see Høg (1989). Firstly, the 'detection' process will be used to detect slit transits above a certain signal-to-noise threshold, and to estimate the epoch, amplitude and background associated with each such transit. Each transit is identified or associated with a star by means of a series of processes: 'prediction', 'identification' and 'recognition'.

These later processes are carried out at the three institutes Astronomisches Rechen-Institut in Heidelberg, Astronomisches Institut der Universität Tübingen, and Observatoire de Strasbourg, respectively. The 'detection' and 'photometry' are also carried out at Tübingen and the 'astrometry' process at Copenhagen University Observatory.

The Tycho Input Catalogue containing 2000 000 stars with an accuracy of positions about 1 arcsec at the epoch 1990 has been compiled at Strasbourg from the INCA data base and the Space Telescope Guide Star Catalogue, see Egret et al. (1989).

The Revised Mission

The accuracy obtained for a given star with Tycho is proportional to the inverse square root of the number of observations because photon statistics is the dominating error source. Since each star mapper crossing gives a practically complete determination of position and magnitudes it is much simpler to estimate the accuracy from a revised Tycho mission than from a revised Hipparcos main mission where many scans over a long interval of time is required before the position, parallax and proper motion components can be solved for. For the same reason the sky coverage during a certain mission length will be more uniform for Tycho than for the main mission, and the non-uniformity for the Tycho mission will not be considered here.

We do not expect difficulties in the data reductions from the fact that the observations are split up in shorter stretches. The number of reference

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stars should still be sufficient for all photometric and astrometric calibrations, provided the instrument stability is not degraded.

The average number of observations per star is proportional to the "useful observing time", and for the revised mission we must presently assume a useful observing time of only 25% of real time, compared to nearly 100% for the nominal mission. We know for certain that the observing time is less than 47% due to limited visibility from 3 ground stations and because the dark count of the photomultipliers is too high (>2500 counts per second) less than 2.25 hours from the perigee, due to Cherenkov radiation in the optics. A further decrease to one half must at present be assumed due to frequent attitude re-acquisitions and other presently unpredictable operations, thus leaving a useful Tycho observing time about 25% of real time.

The Table shows that the accuracy from a revised mission is much inferior to that of a nominal mission, but even 12 months provide an accuracy unavailable from the ground for such a large number of stars.

For shorter durations than 12 months the number of recognized stars will be further reduced due to too few crossings and to non-uniform sky coverage.

A severe reduction of scientific value is expected with respect to detection of new variable stars from photometry. This is due to the smaller number of observations in a given interval of time, and to the predicted shorter mission length.

Table 1. Number of Tycho stars and typical accuracy for the faint ones

Mission	Nominal	Revised	Revised
Duration (months)	30	12	30
Number of stars	400000	200000	400000
Astrometry (arcsec)	0.03	0.10	0.06
Photometry (mag)	0.03	0.10	0.06

References

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Discussion

MORRISON: You quoted the mean error for an automatic meridian circle to be 0.15 arcsec per observation. However, by repeated observations, the asymptotic mean error of a published position is 0.10 arcsec or better. This is the figure that should be compared with the TYCHO accuracy.

HØG: This means that 200 000 positions expected from a 1-year TYCHO mission is in the same sense worth as much as 10 years of observations with the Carlsberg Meridian Circle!

CHUBEY: What are the moments of inertia of the spacecraft in the present situation?

HØG: The moments of inertia are considerably larger due to the 500 kg of solid fuel, and this is taken into account in the attitude control.

WALTER: Is a weekly grid calibration sufficient bearing in mind that the stability of the grid may be impaired by the varying Earth albedo heating owing to the highly eccentric orbit of HIPPARCOS?

HØG: The varying Earth albedo will be minimized by phasing the satellite rotation so that the instruments point away from the Earth at perigee. The still remaining thermal effects will be studied.