ASTROMETRIC AND ASTROPHYSICAL INSIGHTS INTO THE HIPPARCOS DATA QUALITY[1]

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Abstract. Internal error estimates and external verifications indicate that median errors for the 120000 stars in the Hipparcos Catalogue, for each of the five astrometric parameters, will be in the range 1–1.5 mas. This paper illustrates some of the statistical investigations that have been conducted so far, including comparisons with catalogues of ground-based positions and proper motions, the structure of the Hertzsprung-Russell diagram, results of the reanalysis of meridian circle and photographic plate data using the positions determined from the satellite, and expected results on double and multiple stars and photometric variability.

1. Introduction

The final stages of the Hipparcos Catalogue construction are well advanced; the final catalogue is expected to be completed and distributed to 'internal proposers' at the end of 1995, and to be made fully available to the scientific community at the end of 1996. While astrophysical exploitation or interpretation of the astrometric and photometric data will only commence after the catalogue has been finalised, some statistical comparisons have already been made with existing catalogues, and certain other tests undertaken, with the intention of validating the quality of the preliminary Hipparcos data.

Details of the progress of the data analysis for the Hipparcos and Tycho experiments can be found in Kovalevsky *et al.* (1994) and Høg *et al.* (1994) respectively.

[1]Based on observations made with the ESA Hipparcos satellite

E. Høg and P. K. Seidelmann (eds.),
Astronomical and Astrophysical Objectives of Sub-Milliarcsecond Optical Astrometry, 83–86.

2. Illustrations of the Hipparcos Data Quality

A detailed comparison of the preliminary Hipparcos Catalogue with positions and proper motions from the FK5 and PPM Catalogues can be found in Lindegren *et al.* (1994). The most rigorous external verifications of the astrometric parameters (Lindegren 1994) are given by comparisons with (a) the USNO (optical) Mk III interferometer and VLBI interferometry (for positions); (b) the FK5 Catalogue (for proper motions; and (c) a variety of possible zero-point determinations (for parallaxes). These investigations suggest that the formal standard errors derived in the sphere solutions by the FAST and NDAC Data Analysis Consortia are likely to be very close to the true external errors of the derived astrometric parameters. In the following, other tests or applications of the Hipparcos data which provide further evidence for the overall data quality are reported.

2.1. MERIDIAN CIRCLE ANALYSIS

Réquième *et al.* (1994) report the re-analysis of meridian circle observations (from the Bordeaux and Carlsberg instruments) using preliminary positions from the 18-month Hipparcos Catalogue, H18, compared with reductions made using the FK5 Catalogue. A significant decrease in the residuals is found in both α and δ. The form of the residuals in α as a function of declination differ between the Carlsberg and Bordeaux instruments, and amount to as much as 30 mas, suggesting that the origin of the differences cannot lie within the preliminary Hipparcos Catalogue, but arises rather from small defects in the instruments or their calibration, masked up until now by the errors in the astrometric reference positions. Again, different signatures in δ of up to 50 mas suggest that modelling of refraction may be improved once better reference star positions become widely available.

2.2. PHOTOGRAPHIC PLATE ANALYSIS

A variety of photographic plate reductions have already been carried out using the preliminary Hipparcos positions; these confirm the previously-held suspicions that the limited precision of the available reference catalogues has compounded the difficulties of determining the proper choice of plate model. For example, Platais *et al.* (1994) have completed a preliminary analysis of the plates from the Yale/San Juan Southern Proper Motion program, using the preliminary 30-month Hipparcos Catalogue, H30, to provide a reference system with negligible random errors. They have inferred the presence of a consistent magnitude equation and certain significant cubic terms, concluding that the Hipparcos positions offer a very powerful tool for detecting systematic errors in wide-field photographic astrometry.

2.3. THE HERTZSPRUNG-RUSSELL DIAGRAM

One of the primary goals of the Hipparcos mission was to furnish high quality trigonometric parallaxes for tens of thousands of stars, in order to refine the detailed structure of the observational Hertzsprung-Russell diagram and to extend the determination of absolute magnitudes to stars significantly more luminous than $M_v \sim 0$ mag. With a significant fraction of parallaxes having standard errors below 1 mas, and systematic errors at 0.1 mas or better, distance estimates to many tens of thousands of stars in the Hipparcos Catalogue within 100 pc will have an accuracy of better than 10%. A dramatic indication of the quality of the parallaxes is given by the HR diagram constructed from the preliminary 30-month Hipparcos Catalogue, H30. A presentation and discussion of this diagram is given by Perryman *et al.* (1994).

3. Miscellaneous Applications of the Hipparcos Reference Frame

3.1. THE OPTICAL/RADIO EMISSION FROM SN1987A

Preliminary Hipparcos positions have been used by Reynolds *et al.* (1994) to allow registration of high-resolution optical and radio images of SN1987A to the 100 mas level. The significance of the problem is illustrated by the radio-optical overlay published by Staveley-Smith *et al.* (1992), which shows a 0.5 arcsec displacement between the radio and optical centroids. In a careful succession of reference frame links, Reynolds *et al.* (1994) have been able to show that this mis-registration was the result of an inadequate (optical) astrometric reference frame, at least in the vicinity of SN1987A; they are thus able to conclude that the radio emission originates from the interaction between the whole of the expanding shock wave and the surrounding medium.

3.2. EPHEMERIDES OF ASTEROIDS AND COMETS

While the use of the preliminary Hipparcos Catalogue has been largely restricted to 'internal' tests and verifications, preliminary positions have been circulated to groups requiring timely availability to improved astrometric data—thus the Hipparcos results have been used by ESO observers to improve the prediction of the time of impact between Comet Shoemaker-Levy 9 and Jupiter (West & Hainaut, private communication), and were used to assist navigation of the Galileo satellite for its encounter with the asteroid Ida (Owen & Yeomans, 1994; see also ESA Bulletin No. 77, p143).

3.3. METRIC DETERMINATION

The Hipparcos data have been reduced within a relativistic framework, including accounting for gravitational light-bending by the Sun (and Earth). Unlike previous determinations of light-bending, either in the optical or in the radio (see, e.g., Soffel 1989) the regions over which the effect is significant for Hipparcos are no longer restricted to a few solar radii, but extend to most of the celestial sphere. Within NDAC, L. Lindegren (private communication) has determined a value of $\gamma = 0.9893 \pm 0.014$ from the 12-month Hipparcos sphere solution. This preliminary result suggests that a precision on γ of better than 0.5% will be available from the final sphere solution.

4. Double/Multiple Stars and Photometry

This summary only provides space to underline the fact that the Hipparcos mission will provide a wealth of data related to double and multiple and stars—roughly 10,000 known systems were contained within the Hipparcos Input Catalogue, and a similar number of newly-discovered systems with $\Delta\rho > 0.1$ arcsec and $\Delta m < 3-4$ mag will have their astrometric and photometric characteristics tabulated within the final Hipparcos Catalogue. The photometric data available from Hipparcos and from Tycho will yield light-curves on an unprecedented scale, permitting characterisation of variability over the entire HR diagram.

References

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