The Hipparcos and Tycho Catalogues

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The Hipparcos and Tycho Catalogues

Astrometric and Photometric Star Catalogues

derived from the

ESA Hipparcos Space Astrometry Mission

A Collaboration Between

the European Space Agency

and

the FAST, NDAC, TDAC and INCA Consortia

and the Hipparcos Industrial Consortium led by

Matra Marconi Space

and

Alenia Spazio

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Cover illustration: an impression of selected stars in their true positions around the Sun, as determined by Hipparcos, and viewed from a distant vantage point. Inset: sky map of the differences in parallax between the final NDAC and FAST sphere solutions, in equatorial coordinates.

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Volume 3

Construction of the Hipparcos Catalogue

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with the support of

members of the NDAC and FAST Data Reduction Consortia

Volume 3: Construction of the Hipparcos Catalogue

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Foreword

In March 1980, the Hipparcos mission was accepted within the scientific programme of the European Space Agency. It was approved on the basis of performance analyses predicting a standard error in parallax, at visual magnitude 9, of about 2.0 milliarcsec (mas), assuming an observing programme of 100 000 stars. The standard errors actually achieved are about 40 per cent smaller than these predictions, and the programme includes nearly 20 per cent more stars, most of them selected on astrophysical grounds; moreover, a wealth of accurate photometric data, variability and multiplicity information has been extracted, which was not anticipated in the original project. The Tycho experiment, resulting in a separate astrometric and photometric catalogue of over one million stars, was also totally unforeseen in 1980. Thus, it is no exaggeration to claim that the Hipparcos mission has achieved its original goals, and much more.

The planning and execution of the data reductions for Hipparcos required an immense and concerted effort from the astronomical community, bringing together expertise not only in many areas of astronomy but also in mechanics, numerical methods, geodesy, and related fields. The reduction task was unusual among astronomical satellite projects in the sense that it was an entity that could not be subdivided: no small subset of stars could be reduced separately. It was therefore necessary to regard the data reductions as an integral part of the project, which thus logically ends with the present publication of the Hipparcos and Tycho Catalogues.

Even before acceptance of the mission in 1980, there had been two independent groups of scientists planning to reduce all the observations of the satellite and produce an astrometric catalogue. When, in 1981, ESA issued an Announcement of Opportunity to participate in the processing of the scientific data, the two groups consolidated into the present data reduction consortia—*Fundamental Astronomy by Space Techniques*, under the leadership of J. Kovalevsky, and *Northern Data Analysis Consortium*, originally led by E. Høg and, from 1990, by L. Lindegren. These groups were subsequently entrusted with the task of producing a single output catalogue under the supervision of the Hipparcos Science Team. Between 1981 and 1989 the consortia developed independent software for the comprehensive simulation and reductions of the satellite data. Numerous comparisons were made between the partial reductions of simulated data, from which errors in the mathematics and algorithms were identified and corrected. Such comparisons continued during the mission, now using the real observations. Finally, two catalogues were produced that differed only slightly, and a rigorous method was developed to combine them into a single, agreed Hipparcos Catalogue—the only one that is published.

The point of making two independent reductions was not obvious to everybody—certainly judging by the many times we were asked what we would do if the two catalogues turned out to be different! Our point was simply that any significant difference in the results must be due to some error in the method or software, and that such errors should then be found and corrected. In retrospect, it was an extremely good idea to duplicate the main reductions. Not only did this eliminate many errors that might otherwise have gone unnoticed, but it was also found that the combined catalogue was superior to either of the consortia catalogues in terms of accuracy and reliability, for reasons which could be understood (and which are explained in this volume).

The full-scale scientific exploitation of the Hipparcos mission can now begin. Some users will perhaps at first be confused by the wealth of information, the rich diversity of results, the intricate relationships between the different parts of the catalogue, and the sometimes very detailed descriptions of what the data represent. Indeed, the Hipparcos Catalogue is vastly more complex than any previous astrometric catalogue. Apart from 'traditional' astrometric data—positions, proper motions, and parallaxes—the catalogue provides accurate photometric results, light curves and variability analysis, detailed information on resolved double and multiple stars, astrometric binaries, minor planets, etc. The complexity of the catalogue reflects the non-trivial nature of celestial objects revealed by an instrument of pioneering excellence.

The full complexity of the data analysis, in particular the multiple inter-relationships of the various results, was not fully appreciated before launch. It demanded great flexibility and ingenuity within the data analysis teams to cope successfully with this complexity, with the additional complications brought by the unforeseen satellite orbit, and to converge towards a single goal in a very short space of time. The linking of the combined catalogue to the extragalactic reference frame, making the Hipparcos proper motions inertial and enabling the positions to be compared immediately with radio catalogues, was another example of an immensely successful collaboration involving many more institutes throughout the world and the completion of a very difficult task according to a tight schedule. Finally, the preparation of the results, their verification and presentation on various media—printed volumes, machine-readable files, *Celestia 2000*—was itself a formidable task.

A huge effort was thus invested in making these results accessible to the scientific community, and to do so in a form preserving as much as practicable of the scientifically useful information hidden in the raw data stream. However, the extraction of this information was necessarily based on certain assumptions, e.g. that stars generally move in straight lines through space. When these assumptions were clearly contradicted by the data, alternative assumptions (models) had to be used, thus, for example, uniformly accelerated motion or orbital motion. The division between different models is always a matter of compromise between random and systematic errors, and thus to some extent arbitrary. Similar considerations applied to all aspects of the processing, for instance regarding the choice between constant and variable models in the photometric reductions. The additional information in the Epoch Photometry Annex, the Intermediate Astrometric Data, and the Transit Data, is provided partly with a view to allow these considerations to be re-assessed by the users of the catalogue.

The published Hipparcos Catalogue represents the reduction consortia's interpretation of the satellite data in terms of a certain range of models and criteria for selecting between them. For most astrophysical applications it can be taken for granted that the interpretation is reasonable and adequate. In other cases the user may wish to understand precisely what has been done, why it was done in that way, and how these choices are reflected in the final data. The present volume is intended to provide an account of the reductions which is by no means complete, but sufficient to permit a detailed understanding of the properties of the catalogue.

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