3. OBSERVING PROGRAMME

The Hipparcos observing programme was defined, during successive steps, over the period 1982–1991, on the basis of scientific proposals submitted to ESA, while taking into account the operational requirements and the observing possibilities of the satellite. Considerable attention was paid to the selection of stars in order to enhance, as far as possible, the scientific return expected from the mission. In parallel, extensive ground-based programmes were organised to obtain, before launch, good positional and photometric data about the programme stars. This information was used to optimise the observations by the satellite, through proper positioning of the instantaneous field of view, and careful determination of the observing time to be devoted to each star, which were observed only one-by-one. The Hipparcos Input Catalogue, published in 1992, contained the most up-to-date, comprehensive and homogeneous information on the 118 209 stars selected for observation with Hipparcos at the time of the satellite launch.

3.1. Introduction

The Hipparcos mission was primarily designed to provide a uniform whole-sky catalogue of stellar positions, proper motions and parallaxes. However, from the very beginning, it was recognised that a major enhancement of the scientific return might result from also selecting stars on the basis of their relevance to major astrophysical questions. The resulting catalogue has enormous value for a wide variety of detailed astrometric and astrophysical studies. Compared with existing stellar catalogues, the Hipparcos Catalogue offers a significant improvement on the errors of these quantities, absolute rather than relative parallaxes and proper motions, a relatively dense reference network, and homogeneous sky coverage. Some of the most spectacular advances expected from the mission were always expected to arise from the significant increase in the precision of measurements of trigonometric parallaxes compared with typical Earth-based observations, and from the very much larger number—and the very much wider variety—of stars which were measurable.

The construction of the Hipparcos Input Catalogue, which included, with relevant data, all stars retained for the Hipparcos Observing programme, is decribed in detail in Perryman & Turon (1989). It was published in printed form (Turon *et al.* 1992a), a tape version (Turon *et al.* 1992b, 1993) is deposited at the Centre de Données astronomiques de Strasbourg, and it can be interrogated through their WWW pages (VizieR and

SIMBAD). A CD-ROM version with extensive interrogation, sampling, and mapping facilities was also released (Turon *et al.* 1994).

3.2. The Stellar Inputs

Scientific Proposals

In answer to an Invitation for Proposals issued by ESA in 1982 to the scientific community, 214 proposals were submitted, comprising suggestions for the observation of both stars and minor planets. Amongst the scientific proposals submitted, programmes to determine distances, motions, luminosities, masses, radii, and ages of a wide range of stellar types including white dwarfs, normal dwarfs, giants, radio and X-ray stars, variables and binary stars were well represented. Studies of star cluster dynamics and distances, stellar physics (including studies of atmospheric convection and mass-transfer phenomena) and studies of the interstellar medium were proposed. Determination of the optical reference frame and its relationship to the radio and infrared reference frames was proposed, and major collaborative projects between the Hubble Space Telescope, VLBI and other important ground-based astrometric and astrophysical programmes were initiated. Proposals also covered studies of solar system dynamics, including the dynamics, structures and masses of asteroids, the major planets and certain planetary satellites; Earth rotation, polar motion and continental drift; and lunar occultation phenomena. Galactic dynamics and evolution, dynamics of the Magellanic Clouds, determination of the extragalactic distance scale from Cepheids, and investigations of the validity of general relativity are other examples of the broad scientific interest generated by the Hipparcos mission.

Altogether, the proposals submitted amounted to about 500 000 stars. It was eventually recognised by the INCA Consortium, through an extensive automated use of the SIMBAD database (Egret *et al.* 1991) and manual cross-identifications (Turon, Gómez & Crifo 1989), that there were many redundancies in the stars proposed: finally, about 210 000 individual objects were contained in the 214 proposals submitted.

In addition to stars, 48 minor planets and three satellites of major planets (Europa, Titan and Iapetus) were observed by Hipparcos, mainly for improving the definition of the dynamical reference system and for linking it to the Hipparcos reference system. Preparatory work undertaken within the INCA Consortium to optimise their observability with the satellite is described by Bec-Borsenberger (1992).

The INCA 'Survey'

The 'Survey' is a basic list of bright stars, largely complete to a given magnitude limit, resulting from a compromise between various, possibly conflicting, requirements: (i) the satellite operations and the data reductions required a list of about 50 000 – 60 000 stars with $V \leq 9$ mag and with good positions (to better than about 1 arcsec), uniformly distributed over the celestial sphere; (ii) from a purely scientific point of view, it was considered highly desirable to define a sample over the whole celestial sphere, complete to the faintest possible magnitude limit, in order to enhance future statistical uses of the whole catalogue.

In practice, stars were selected automatically from the SIMBAD Data Base of the Centre de Données astronomiques de Strasbourg (CDS), considered to be essentially complete down to about $V = 9.0$ mag (Egret *et al.* 1991), using the following criteria:

$$V \leq 7.9 + 1.1 \sin |b| \quad \text{for spectral types earlier or equal to G5}$$
$$V \leq 7.3 + 1.1 \sin |b| \quad \text{for spectral types later than G5}$$

When no spectral type was available, the break was taken at $B - V = 0.8$ mag. Special attention was subsequently given to variable stars, for which the SIMBAD magnitude is usually the one at maximum brightness.

The choice of the above limits was made after the study of the statistical properties of various possible selections obtained from SIMBAD (Crifo *et al.* 1985, Crifo 1988, Turon *et al.* 1989a). In order to reduce the very high contribution of red giant stars (43 per cent, mostly situated between 300 and 500 pc) in favour of A, F, and early G-type stars, statistically closer to the Sun, and for which the ages may be better predicted, a brighter limiting magnitude was chosen for late-type stars than for early-type stars. The magnitude difference was a constant, adjusted in order to have the bulk of giant stars within 200 pc in the galactic plane, thereby avoiding the most disturbing interstellar clouds.

As a result, about 55 000 objects were selected. This sample of stars was then processed during the numerical simulations of the mission just like any other proposal. However, special care was taken to maintain its statistical properties as much as possible.

Due to uncertainties in the knowledge of magnitudes and spectral types, inevitably some stars were erroneously included or rejected from the selected sample. The effect of these errors has been estimated to be about 1000 missed stars, with some 2500 incorrectly included. The sample finally retained contains 52 000 stars, 95 per cent of them being closer than 500 pc. Less than 6 per cent of the complete sample failed to be retained after the selection process, due to operational constraints on the satellite (Gómez *et al.* 1989).

Additional INCA Proposals

In addition to the 214 proposals submitted to ESA by the worldwide astronomical community, five additional proposals were defined during the course of the work of the INCA Consortium. In particular, it was necessary to make a global and dedicated study of all proposals submitted on certain specific topics in order to optimise their observation by Hipparcos. This was implemented for programmes dealing with stars in the Magellanic Clouds (Prévot 1989) and in galactic open clusters (Mermilliod & Turon 1989), for stars used for the geometrical calibration for the Hubble Space Telescope (within the cluster NGC 188), and for programmes for linking the Hipparcos system to an extragalactic reference system, i.e. radio stars and stars around compact extragalactic radio sources (Argue *et al.* 1984, Jahreiß *et al.* 1992).

These proposals were made in close cooperation with members of the data analysis consortia, and after detailed studies on proximity effects, and on the requirements of the link to an extragalactic reference system (Turon *et al.* 1989b).

3.3. From Scientific Proposals to a Tentative Input Catalogue

The steps taken to arrive at the composition of the final Hipparcos Input Catalogue were not at all obvious at the outset of the project, and the final inclusion or rejection of some objects was rather arbitrary. The main steps taken were as follows:

(a) a Scientific Selection Committee, appointed by ESA, ranked the proposal, or subsets of the proposals, in five priority classes, from objects with a high scientific interest which were to be included in the Hipparcos Input Catalogue if at all possible (priority 1), through to objects which were not to be retained in the Hipparcos Input Catalogue selection process unless there were no other competing stars in the relevant area of sky (priority 5). Different priorities were often awarded for a given proposal for different magnitude ranges, since it was known that the observation of fainter objects would be expensive in terms of observing time, and that only a decreasing percentage of all stars in the sky at fainter magnitudes could be included;

(b) based on these recommendations, the INCA Consortium constructed distributions of the proposed objects as a function of priority, magnitude and position on the sky. After the first round of priority allocations, it was immediately obvious that a large amount of work was needed to achieve a sky and magnitude distribution better suited to the satellite's capabilities;

(c) methods were developed within the INCA Consortium to simulate numerically the observation with Hipparcos, and to control the observing time allocated to each star throughout the mission. This allowed the Consortium to establish the feasibility of observations of any given star, according to its magnitude and the detailed properties of its surroundings, as well as the expected precision of the astrometric parameters. Different algorithms prescribing the allocation of observing time as a function of magnitude were studied at the start of the work, allowing a decision to be made on the total number of stars to be retained in the Input Catalogue as a function of magnitude, based on the final expected accuracies implied by these distributions. Nine successive selections were submitted to a chain of numerical simulations (Crézé 1985, Crézé & Chareton 1988, Crézé *et al.* 1989), allowing the statistical representation of the various proposed programmes and the expected precision on the astrometric parameters to be assessed;

(d) the proposers were given the opportunity to express their comments, first on the priorities allocated to their proposed programmes, and later, once a close-to-final star selection was obtained, on the individual stars retained from their proposal. This dialogue, albeit unusual, was felt desirable for two important reasons: (1) the first round of recommendations from the ESA Selection Committee and the corresponding treatment of the data by the INCA Consortium was necessarily somewhat statistical in nature. It was realised that such a coarse treatment might be satisfactory for many proposals, but quite unsuitable for others, and (2) since the observing programme of Hipparcos remained fixed throughout the satellite lifetime (it was not possible to add new objects to the observing list throughout the mission, nor to undertake new rounds of proposals) it was important to satisfy the scientific requirements of each proposal from the very outset and to check, further on, that the final star selection would not exclude one specifically important object in the opinion of the proposer;

(e) the INCA Consortium presented the results of this work to the Scientific Selection Committee, in the form of detailed statistics and 'performances' for each proposal. This presentation, which took place four years after the commencement of the INCA Consortium's work, allowed the Selection Committee to verify that their original recommendations, and other scientific goals that were identified during the course of the INCA Consortium's work, had been satisfactorily implemented.

3.4. Resulting Catalogue Content

Global Content

The sky distributions of all candidate stars and of stars selected in the final catalogue are shown in Figures 3.1 and 3.2 respectively. Though much smoother than the distribution of proposed stars, the distribution of observed stars still shows a concentration along the galactic plane. This was allowed by the fact that, in these regions, the only stars which were observable are relatively bright, and their individual target observing time relatively small. The global distribution of selected stars versus Hp magnitude (i.e. the magnitude in the Hipparcos band) is given in Table 3.1, along with the percentage of success obtained for priority 1 stars and for all survey stars (the Hp band has an effective wavelength close to that of the V band of the Johnson system, but much wider, as shown in Figure 14.1, and in Table 1.3.1 in Volume 1). The bulk of stars observed by Hipparcos are brighter than $Hp = 10$ mag, and few of them are fainter than 12 mag. The effect of the weight placed on high priority stars is also clear from the comparison of columns 2 and 5.

Astrometric Programmes

The general 'success' of the astrometric programmes was very high, since they contained mainly bright stars spread all over the sky or over large areas. The number of stars proposed for each main programme and the percentage of observed stars in each case, are given in Table 3.2. Particular attention was paid to the inclusion of fundamental stars (FK5, FK5 extension, IRS), and to guarantee that radio and 'link' stars (stars in the close neighbourhood of quasars compact in the optical and radio wavelengths) would be observed by Hipparcos in an optimum way, in order to prepare the link of the Hipparcos reference frame to an extragalactic reference system, via VLBI and Hubble Space Telescope observations.

Astrophysical Programmes

As described in Section 3.2, a very large variety of astrophysical programmes was proposed for observation on Hipparcos. Table 3.3 shows the mean rate of inclusion for the main categories of programmes. The Hipparcos Input Catalogue contains field stars of almost all spectral types and luminosity classes belonging to various stellar populations, most types of binary and variable stars, very specific objects such as white dwarfs, central stars of planetary nebulae, and Wolf-Rayet stars, stars in about 280 open clusters, and stars in the Magellanic Clouds (Gómez 1988; Gómez & Crifo 1988). In most cases, the closest stars of each category were retained. The result is that more than 85 per

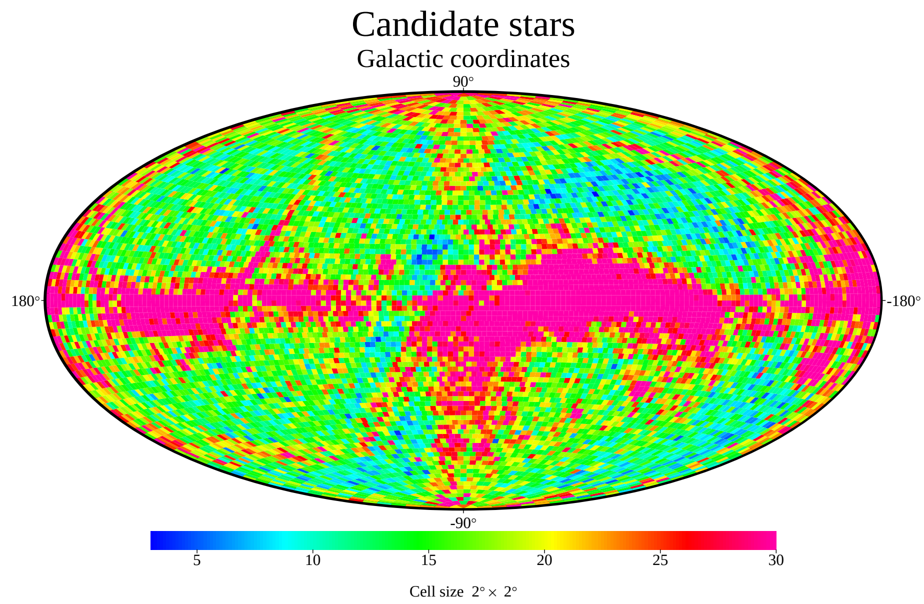

Figure 3.1. *Sky distribution of candidate stars shown as a function of galactic coordinates. The most prominent feature is the concentration of candidate stars along the galactic plane. Stellar densities refer to the number of stars in an area of* $6^{\circ}\!.4 \times 6^{\circ}\!.4$.

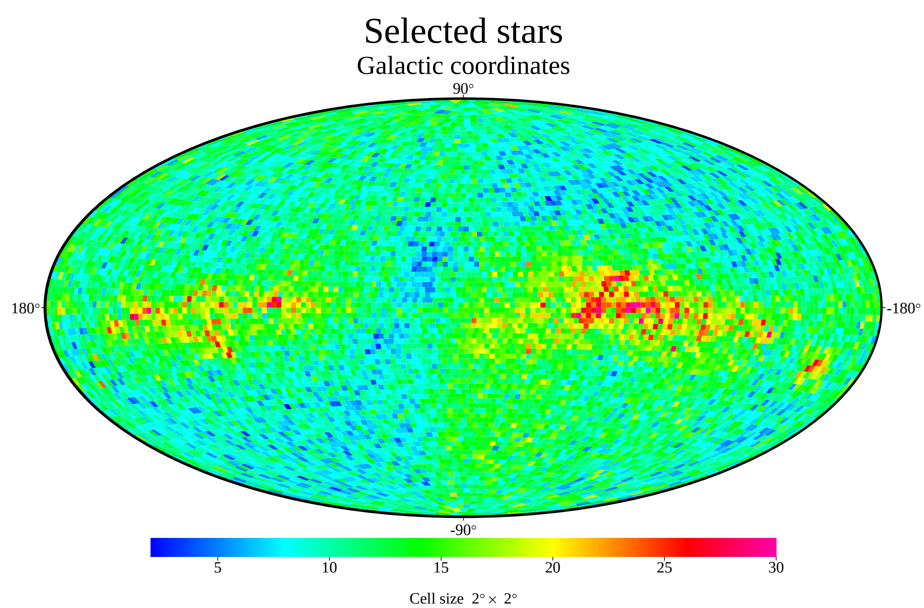

Figure 3.2. *Sky distribution, in galactic coordinates, of all selected stars. Stellar densities refer to the number of stars in an area of* $6^{\circ}\!.4 \times 6^{\circ}\!.4$.

Table 3.1. Final selection of stars in the Hipparcos Input Catalogue, and the global percentage of success for priority 1 and survey stars, as a function of the Hipparcos magnitude, *Hp*.

Magnitude (*Hp*)	Entries in INCA Data Base	Entries in Input Catalogue	Global success (per cent)	Success of priority 1 stars (per cent)	Success of survey stars (per cent)
< 6	4 200	4 200	100	100	100
6 – 7	8 540	8 510	99	99	99
7 – 8	24 160	22 250	92	98	93
8 – 9	55 290	41 100	74	96	93
9 – 10	70 970	29 410	41	91	91
10 – 11	36 270	9 330	26	83	-
11 – 12	10 190	2 930	29	86	-
≥ 12	5 140	650	12	44	-
Total	214 760	118 380	55	94	94
Retained				72 500	52 800

Table 3.2. Success of the main astrometric proposals in the Input Catalogue.

Catalogue or Proposal	Number of proposed stars	Success (per cent)
FK5	1 535	100
FK5 extension	2 013	99.8
NPZT	1 718	99.4
AGK3R	21 499	98.2
SRS	20 495	96.8
IRS Supplement	1 900	95
GC	33 100	90
Selected radio stars	189	98
Selected link stars	175	95
Photographic link stars	1 000	42
Lunar occultations	15 300	50
Jupiter occultations	4 900	42
Uranus and Neptune occultations	23	39
Pluto occultations	290	41
Parallax standard stars	64	95

Table 3.3. Success rates of various categories of astrophysical programmes.

Type of Proposal	Success (per cent)
Luminosity calibration	>70
Stellar masses	>95
Stellar atmospheres	>90
Stellar structure	>90
Galactic structure(1)	>50
Galactic structure(2)	>80
Magellanic Clouds	>50

1 if the number of proposed stars was ≥ 10 000
2 if the number of proposed stars was < 10 000

Table 3.4. Distribution of the selected stars as a function of spectral types and distance estimates (the total number is not 118 000, as it was impossible to make even a rough estimate of the distance of some stars).

Spectral Type	Distance (pc)				Total
	<100	100-500	500-1000	> 1000	
O-B	170	6 050	2 530	1 980	10 730
A0-A9	1 260	15 910	1 330	270	18 770
F0-F9	12 400	13 150	110	250	25 910
G0-K1.5	14 200	23 560	2 150	530	40 440
K2-M8	3 380	10 470	5 500	900	20 250
Total	31 410	69 140	11 620	3 930	116 100

cent of the selected stars are closer than 500 pc. The distribution of the selected stars by spectral types, with a rough estimate of the distance, is given in Table 3.4.

3.5. Tests of the Hipparcos Input Catalogue by Satellite Observations

Tests of the Hipparcos Input Catalogue Data

The Hipparcos Input Catalogue was probably the first catalogue ever tested before its publication, and with an instrument allowing a much higher accuracy on positions, proper motions, magnitudes and colours to be achieved. The specifications of ESA were standard errors of 1.5 arcsec on the positions at epoch 1990 (with a somewhat better accuracy on positions for a subset of stars used for real-time satellite attitude determination), and 0.5 mag on the B or V magnitudes for all programme stars. From comparisons made using the preliminary sphere solution obtained from 30 months of Hipparcos data (see Chapter 16), the accuracies achieved in the Hipparcos Input Catalogue were largely within these specifications: 0.3 arcsec on the positions, and 0.25 mag on Hp magnitudes, with accuracies of 0.02 mag or better for more than one third of the catalogue (Turon *et al.* 1995).

Entries with No Solution: Identification Errors

In the final Hipparcos Catalogue, 263 entries have no astrometric solution, 14 of these also have no photometric solution. The main reasons for these problems were that the position and/or proper motion and/or magnitude was wrong in the Hipparcos Input Catalogue and that, as a result, either the sky background was measured, or the star was too faint at the epochs of observation for an astrometric solution to be obtained. The stars entering these categories are mainly high proper motion stars and large amplitude variable stars. A few of them are components of double or multiple systems. Notes in the Hipparcos Catalogue indicate these problem stars.

In addition to these entries where no star was observed by the satellite, a small number of identification errors were detected, where the satellite observed a star which is not the star quoted in the Hipparcos Input Catalogue (at least with respect to the cross-identifications tabulated for such a star). Again, these entries are mainly high proper motion stars and large amplitude variable stars. Notes in the Hipparcos Catalogue also indicate these problems.

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