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HIPPARCOS. THE INPUT CATALOGUE

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RESUMEN. Se describen los principales aspectos de la misión Hipparcos de la Agencia Espacial Europea. Se da cuenta del proceso de preparación del Catálogo de Entrada para la misión, presentándose su contenido actual para diferentes tipos de estrellas.

ABSTRACT. The main aspects of the European Space Agency's Hipparcos mission are described. We briefly explain the procedure used to prepare the Input Catalogue, and show its present content for different types of stars.

Key words: ASTROMETRY — CATALOGUE — PARALLAXES — POSITIONS — PROPER MOTIONS

I. INTRODUCTION.

The European Space Agency's Hipparcos mission (acronym for High Precision Parallax Collecting Satellite) is the first one ever devoted to global astrometry. The principle in which the satellite is based (the superposition of two stellar fields using a complex mirror), has been developed by P. Lacroûte in 1966. Since then several meetings and inquires (as example Frascati Colloquium (Italy), 1974 ,Eds. Nguyen and Battrick; Padova Colloquium (Italy), 1979, Eds. Barbieri and Bernacca) showed its interest not only for astrometry but also for other topics in astronomy and astrophysics. In 1980 the Hipparcos project finally received E.S.A.'s approval and the definition phase of the mission was completed in 1983. Now the mission is in the design and development phase. The launch of the Hipparcos astrometric satellite is forecast for mid 1988 with a nominal lifetime of 2.5 years.

The aim of the Hipparcos mission is to obtain positions, proper motions and parallaxes of a set of about 100,000 stars up to the magnitude B=13, evenly distributed over the sky, most of them being brighter than B=10. The expected mean errors on the astrometric parameters vary from less than 0.0015 arcsec to 0.005 arcsec depending on both stellar apparent magnitude and ecliptic coordinates. On the average, accuracies of 0.002 arcsec in positions and parallaxes and 0.002 arcsec per year in the proper motions components are expected (see Table 1). In order to achieve the mission an a priori list of 100,000 stars - the Input Catalogue - has to be built.

In addition to the Hipparcos mission, the exploitation of the satellite's "star mappers" (originally used only for the attitude determination) will perform the Tycho experiment (Høg, 1986). Tycho will provide positions and photometric data for about 400,000 stars, accuracies of 0.03 arcsec in positions and 0.05 magnitude in B and V magnitudes are expected.

We shall give in the next paragraphs a short description of:
a) the instrument and its observing procedure,
b) the work carried out by the Input Catalogue Consortium (INCA) and
c) the contents of the present version of the Input Catalogue.

II. THE HIPPARCOS SATELLITE.

The technical aspects of the Hipparcos satellite have been discussed extensively in specific papers (see for example: ESA, 1979; Kovalevsky, 1980, 1986; Perryman and Schuyer, 1985), so we shall describe only some basic aspects of the mission in order to show why an Input Catalogue is necessary.

TABLE 1. Basic Accuracy Status for the Main Mission. (Taken from Perryman and Schuyer 1985).

B	NUMBER OF STARS	COMPLETENESS	MEAN ERRORS (SKY AVERAGES) λ,β	μ_λ,μ_β	π
		%	(10^{-3} Arcsec)		
< 6	3 000	100	1.2	1.7	1.6
6 - 7	5 400	100	1.2	1.7	1.7
7 - 8	14 800	100	1.2	1.8	1.7
8 - 9	40 800	100	1.3	1.8	1.8
9 - 10	16 000	15	1.4	2.0	2.0
10 - 11	12 000	4	1.7	2.3	2.3
11 - 12	6 000	0.8	2.4	3.4	3.3
12 - 13	2 000	0.1	3.4	4.9	4.8
TOTAL	100 000				
AVERAGE			1.5	2.0	2.0

The basic principle of observation is to scan continuously and systematically the whole sky with a telescope capable of accurately measuring the angle between stars separated by a large angle. The angles are measured (see Fig. 1) by superimposing - by use of a complex mirror - in the focal plane of a single telescope two fields of view separated by a "basic angle", each field containing one of the stars in a pair. The size of each field is $0^{o}.9 \times 0^{o}.9$.

The satellite scans the entire sky by means of the combination of two motions:
- a spinning motion around an axis perpendicular to the plane containing the two lines of sight, at a rate of about 11 revolutions per day, and
- a slow revolution of the spin axis around the satellite-Sun line, at a mean rate of 6.4 revolutions per year. The angle between the spin axis and the Sun is 43^{o}.

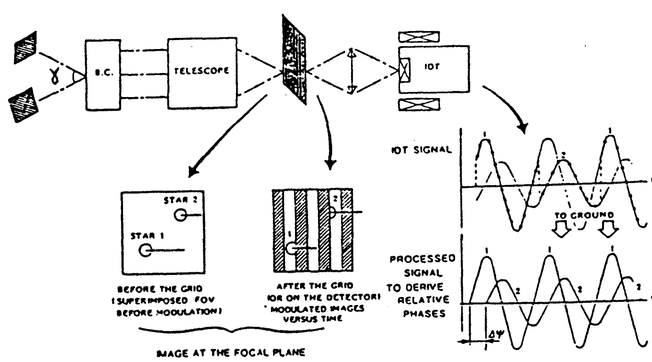

Figure 1. Measurement principle. γ = 58º (basic angle). B.C.: beam combiner (complex mirror). Telescope: All-reflective Schmidt type, ϕ = 29 cm. (Taken from Matra Espace: Hipparcos Critical Design Review, 1986).

As the satellite scans the sky, the star light is modulated by a grid consisting of a large number (about 3000) of regularly spaced opaque and transparent slits (the slits are normal to the scanning direction) and the modulated light is sampled by a detector (an image dissector tube ,IDT). At any one time about four or five of the programme stars are simultaneously visible in the telescope but only one star is observed at a time with the small instantaneous field of view (IFOV, diameter of about 30 arcsec) of the image dissector. The IFOV is rapidly switched from one to another of the programme stars as they cross the observing field, which takes about 20 sec. The observing time is distributed among the stars according to their magnitudes and priorities. From the phase difference of the modulated light of two stars (see Fig. 1), and the value of the basic angle, it is possible to determine the actual angle between the two stars. As the sky is continuously and systematically scanned, each programme star may be linked to several others in different directions allowing to build a dense net of angular distances between stars covering the entire sky. After appropriate reduction of these data, the astrometric parameters for the 100,000 program stars can be finally obtained.

The satellite attitude is determined by two redundant "star mappers" composed by a small number of slits unequally spaced, some of them being parallel to the main grid and some others being oblique (see Fig. 2).

From these considerations it is clear that the 100,000 programme stars should be evenly distributed over the entire sky and their magnitude distribution should be compatible with the satellite observing possibilities. In order to position the IFOV correctly and to divide the observing time optimally among the programme stars, their positions and magnitudes must be known to an accuracy of 1.5 arcsec and 0.5 magnitudes respectively and their priorities must be defined. Moreover the positions of about 60,000 stars must be known to 1 arcsec in order to reconstitute the satellite attitude.

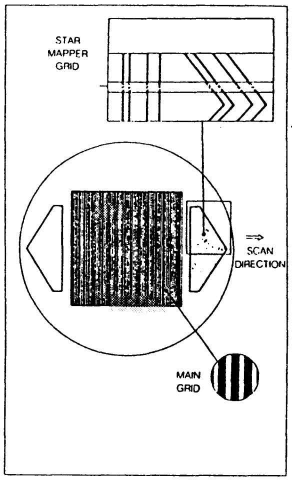

Figure 2. Main and star mappers modulating grids. (Taken from Perryman, 1985).

Consequently, an Input Catalogue satisfying the above mentioned requirements has to be built and tested before the beginning of the mission itself. This work is being performed by the Input Catalogue Consortium (INCA) constituted by 26 european Institutes.

The raw data produced by the satellite - consisting essentially of photon counts from the IDT and star mappers- will be reduced by two independent Consortia (FAST and NDAC).

The Data Reduction tasks have been extensively described (see Kovalevsky, 1985; Lindegren, 1986) their goal is to provide the astrometric parameters of the programme stars. The Hipparcos Catalogue will be the final product of the analysis of the results obtained by both FAST and NDAC Consortia.

Finally a fourth Consortium (TDAC) is devoted to the preparation of the Tycho Input Catalogue and to the processing of the data of the Tycho experiment.

III. THE INCA CONSORTIUM TASKS.

The Input Catalogue will provide all astronomical data on the 100,000 programme stars necessary to optimally satisfy satellite operation, data reduction requirements and scientific objectives of the mission. The structure of the INCA Consortium devoted, as stated before, to the preparation of the Input Catalogue, is given in Fig. 3 (see Turon, 1983).

At the beginning of 1983, ESA sent to INCA the stars proposed by the astronomical community following the ESA invitation for proposals (ESA, 1981). As a result more than 200 proposals were received, containing about 700,000 stars with redundancies. In addition, a basic list of 58,000 bright stars, called the survey was included (Crifo et al., 1985).

All proposals have been examined by the ESA Scientific Selection Committee headed by Prof. A. Blaauw in order to evaluate the scientific interest of each of them. Following the recommendations of this Committee a priority flag has been given to each star.

One of the main tasks was to handle all the proposed stars and merge them into a unique list without repetitions (Gómez and Crifo, 1985). For this purpose a long and tedious process of cross-identifications was carried out using extensively the Simbad Data Base of the "Centre des Données Stellaires" of Strasbourg (Jaschek, 1985; Wenger, 1985). Only about 10,000 stars were not in SIMBAD and were checked by hand. The final list including all the proposed and survey stars without repetitions contained about 210,000 stars. All these stars are now included in the Inca Data Base specially created to facilitate the work within the Consortium. The Inca Data Base is a subset of the Simbad Data Base but also includes specific data necessary for the Input Catalogue preparation (Morin and Arenou, 1985), as well as the non-Simbad stars (about 5,000).

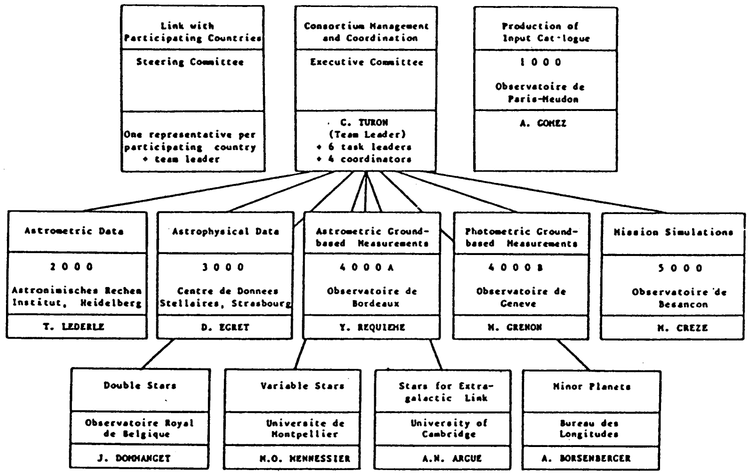

Figure 3. The Input Catalogue Consortium structure. (From Guyenne and Hunt, 1985).

In order to optimize the list of stars to be observed, a series of computer simulations are being performed within INCA (Crézé, 1985; Nicolet, 1985), each simulation's result allowing to improve the catalogue. The succesive versions of the Input Catalogue are then constructed by an iterative process. The tentative list recently obtained contains about 120,000 stars. The final version will be a subset of this present list.

To build the astrometric and photometric parts of the Input Catalogue, compilation and critical analysis of the astrometric and photometric available data are needed. The astrometric data will be reduced to the FK5 system (Bastian and Lederle, 1985) and the photometric colours suitably homogenized (Egret, 1985). Furthermore new ground-based astrometric and photometric measurements and observations are being performed for the stars not satisfying the requirements for the successful execution of the mission (Requième, 1985; Grenon, 1985).

Stars in double and multiple systems (Dommanget, 1985), variable stars (Mennessier,1985) and stars in overcrowded regions like clusters and Magellanic Clouds (Mermilliod, 1985; Prévot, 1985) have received special treatment.

Since the Hipparcos reference system is not free of a rotation, it is necessary to include in the observing list appropriate stars for linking the positions and proper motions of the Hipparcos stars to a quasi-inertial system based on extragalactic objects (Argue, 1985).

Finally Hipparcos will observe also a list of about 60 minor planets. Their inclusion in the Input Catalogue makes necessary the knowledge of the ephemerides and magnitude of each one at the epoch of observation (Bec-Borsenberger, 1985).

The final version of the Input Catalogue will contain about 60,000 bright stars (limiting magnitude V = 7.7 in the galactic plane and about V = 8.7 in the poles) and 40,000 fainter stars selected from the proposals according to the recommendations of the ESA Scientific Selection Committee.

IV. CONTENT OF THE PRESENT VERSION OF THE INPUT CATALOGUE.

The scientific impact of the Hipparcos mission in astrometry, astronomy and astrophysics has been emphasized in several papers (see for example the Padova Colloquium, 1979, Eds. Barbieri and Bernacca ;and the ESA Strasbourg Colloquium, 1982, Eds. Perryman and Guyenne). Here we will describe the content of the Input Catalogue bearing in mind their implications in astrophysical problems.

The Input Catalogue will contain different types of stars:

- field stars of different spectral types (O to M), luminosity classes and ages (disk and halo populations),
- binary stars,
- variable stars: RR Lyrae, Cepheids, Miras, etc...,
- special types of stars like Wolf-Rayet stars, central stars of planetary nebulae, white dwarfs, etc...,

- stars in about 200 open clusters,
- stars belonging to the Magellanic Clouds, etc.

One of the main results of the Hipparcos mission will be to obtain significant parallaxes ($\sigma_\pi/\pi < 0.2$) for the stars closer than 100 pc, together with high precision proper motions and statistical parallaxes for more distant stars.

Tables 2 to 9 show some statistics for different types of stars contained in the more recent version of the Input Catalogue.

TABLE 2. V-Magnitude versus Distance Distribution for OB stars.

m_V \ r(pc)	<=100	100-250	250-500	500-1000	>1000	TOTAL
<=6	132	520	203	137	40	1032
6-8	54	1277	1635	721	602	4289
8-10	7	138	1371	1673	960	4149
>10	1	3	4	52	161	221
TOTAL	194	1938	3213	2583	1763	9691

TABLE 3. V-Magnitude versus Distance Distribution for A0-A5 Stars.

m_V \ r(pc)	<=100	100-250	250-500	500-1000	>1000	TOTAL
<=6	693	75	4	5	20	797
6-8	163	5090	1401	16	54	6724
8-10	0	574	6166	612	42	7394
>10	0	0	15	244	45	304
TOTAL	856	5739	7586	877	161	15219

TABLE 4. V-Magnitude versus Distance Distribution for A6-F0 Stars.

m_V \ r(pc)	<=100	100-250	250-500	500-1000	>1000	TOTAL
<=6	240	1	4	2	2	249
6-8	1105	882	5	18	22	2032
8-10	1	2313	363	1	21	2699
>10	0	1	137	15	1	154
TOTAL	1346	3197	509	36	46	5134

TABLE 5. V-Magnitude versus Distance Distribution for F1-F8 Stars.

m_V \ r(pc)	<=100	100-250	250-500	500-1000	>1000	TOTAL
<=6	434	7	16	5	26	488
6-8	5229	56	2	55	77	5419
8-10	5644	6376	15	0	59	12094
>10	0	861	181	0	3	1045
TOTAL	11307	7300	214	60	165	19046

Tables 2 to 5 give the statistics concerning stars of spectral types O to F, according to their heliocentric distances (in parsecs) and apparent V-magnitudes. The distances were estimated from the HD type (or MK if available) and apparent magnitude, only in the case of O and B type stars a reddenning correction was applied (Guarinos, 1986). As was expected, a few O-B type stars (2%) are closer than 100 pc and only 50% nearer than 500 pc (most of them being B8 and B9 type stars). On the other hand 80% of the O-B stars are strongly concentrated to the galactic plane (z distance < 200 pc). Considering now A and F type stars, 6% of (A0-A5), 26% of (A6-F0) and 59% of (F1-F8) are closer than 100 pc while less than 10% are beyond 500 pc.

TABLE 6. Stars from Gliese's Catalogue. Number of Stars per Magnitude Range.

m_V	<=8	8-9	9-10	10-11	>11	TOTAL
N	768	208	278	219	93	1566

TABLE 7. Red Dwarf Stars. Number of Stars per Magnitude Range.

m_V	<=8	8-9	9-10	10-11	>11	TOTAL
N	195	387	724	327	113	1746

TABLE 8. Variable Stars for Distance Scale Calibration. Number of Stars per Magnitude Range.

m_V	6-8	8-10	10-12	TOTAL
Cepheids	82	91	16	189
RR Lyrae	6	33	70	109

TABLE 9. Binary Stars with known Orbit. Number of Stars per Magnitude Range.

m_V	<=6	6-8	8-10	>10	TOTAL
N	167	329	221	16	733

In Tables 6 and 7 statistics on V-magnitude for nearby stars are given. Table 6 contains the stars from Gliese's catalogue (1969) and its supplement (Gliese and Jahreiss, 1979), while Table 7 contains those coming from several proposals dealing with red dwarfs (spectral types K0 to M8) (Guarinos, 1986). Obviously these two samples may have stars in common. The comparison between these two tables shows that the number of fainter red dwarfs (V > 9 magnitudes) will be significantly increased.

Table 8 gives the V-magnitude statistics for variable stars that are useful to calibrate the distance scale of the Universe (RR Lyrae and Cepheids), and Table 9 the corresponding statistics for binary stars with known orbits which are of interest to calibrate the mass of the stars.

Even if the statistics shown here are rough, we can see that the number of stars that will have very accurate parallax and/or proper motion data will be dramatically increased. This amount of new and very accurate data will allow to study a wide variety of astrophysical problems.

V. HIPPARCOS SCHEDULE.

Final version of the Input Catalogue: mid 1987.
Launch: 1988
Mission: 2.5 years (up to 1991).
Data Reduction: 1988 to 1992.
Hipparcos Catalogue: 1992 - 1993.
Tycho Catalogue: 1994.

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