A VERY SPECIAL CATALOGUE : THE HIPPARCOS INPUT CATALOGUE.

C. Turon
Observatoire de Paris, Section de Meudon
D.A.S.G.A.L.
2, Place Jules Janssen
F-92195 Meudon Principal Cedex

ABSTRACT. The various characteristics of the HIPPARCOS Input Catalogue are described :
- How to select 110 000 stars for HIPPARCOS observation from the 210 000 proposed stars, taking into account the following sometimes conflicting requirements : satisfy a maximum of scientific programmes and respect the observational constraints inherent in the HIPPARCOS satellite operation ?
- What are the present results regarding the principal astrometric programmes ?
- How to process the specific problems which are raised by the HIPPARCOS observation of double and multiple stars and of stars in dense areas ?
- Which compilations and observations have been undertaken and are in progress within the frame of the Input Catalogue preparation ? What will be the quality of the final data ?

Finally, the contents of the catalogues and annexes that will be published are briefly presented.

1. INTRODUCTION

The HIPPARCOS mission, scheduled in 1989 for a 2.5 year duration, is being intensively prepared by the four scientific consortia appointed by ESA : construction of the Input Catalogue (INCA Consortium), preparation of the data reduction for the main mission (FAST and NDAC Consortia) and for the TYCHO experiment (TDAC Consortium). These consortia have been presented to the IAU Symposium N° 109 (1986) and to the New-Delhi General Assembly. The publication of the final HIPPARCOS catalogue is scheduled for 1995.

The present paper is devoted to the presentation of the content and various characteristics of the HIPPARCOS Input Catalogue, including all the stars to be observed by the satellite, and resulting from a huge cooperative effort aiming at its optimisation with respect to its scientific content but also with respect to satellite operation.

S. Débarbat et al. (eds.), Mapping the Sky, 245–257.

2. THE STAR SELECTION.

The basic material from which the stars are selected consists in the whole set of stars submitted by the world-wide astronomical community in answer to the ESA "Invitation for proposals". To these about 200 000 stars from 219 observation proposals dealing with a large variety of astrophysical and astrometric programmes, a basic list of nearly 60 000 bright stars (called hereafter "survey") has been added for the purposes of satellite operation, data reduction and future statistical uses of the Hipparcos catalogue. These survey stars have been identified in the SIMBAD* Data Base according to the following limits :

$$V_{lim} = 7.9 + 1.1 \sin |b| \text{ for spectral types} \leq G5$$
$$V_{lim} = 7.3 + 1.1 \sin |b| \text{ for spectral types} \rangle G5$$

Details about this choice can be found in Turon & Crifo (1986), and Crifo *et al* (1985).

The total list of the initially proposed stars contains more than 210 000 objects. Its spherical distribution shows a strong concentration towards the galactic plane, especially in the Southern hemisphere. Its magnitude distribution shows a demand for faint stars (fainter than 9) far beyond the HIPPARCOS observation possibilities, the discrepancy increasing with magnitude.

A first tentative catalogue, IC1, was issued in February 1987. It is already the result of several iterations. Each iteration involved more and more detailed numerical mission simulations and a detailed examination of the results at each step : attainment of the goals of the various proposals, special attention being paid to the highest priority ones ; optimum use of the satellite observing possibilities. This last point has in turn two aspects : verify that each star retained in a given iteration of the catalogue did actually obtain a satisfactory amount of observing time considering its magnitude and test that the target accuracy of the parallaxes is achieved, but also test if some areas of the sky are undersubscribed with respect to the available observing time. These simulations are explained in some detail in Turon & Crifo (1986), Crézé (1985), Nicolet & Crézé (1985), Feaugas (1985), and Turon *et al* (1985).

The spherical distribution of IC1 is much smoother than the distribution of the whole set of candidate stars, showing, however, some concentration toward the galactic plane, where almost bright stars only will be observed. The magnitude distribution is given in Table 1 as a function of the magnitude in the HIPPARCOS band pass, m_H, (wide band pass, intermediate between B and V, nearer to V) as well as the percentage of "successful" priority 1 and survey stars. 93% of priority 1 stars are indeed included in IC1. However, the percentage of "successful" stars with respect to the total number of candidate stars declines with magnitude, first slowly down to about magnitude 10 then very steeply for stars fainter than 12. Figure 1 illustrates these statistical figures in the very dense zone of η Carinae.

SIMBAD = Set of Identifications, Measurements and Bibliography for Astronomical Data, Centre de Données Stellaires de l'Observatoire de Strasbourg, France)

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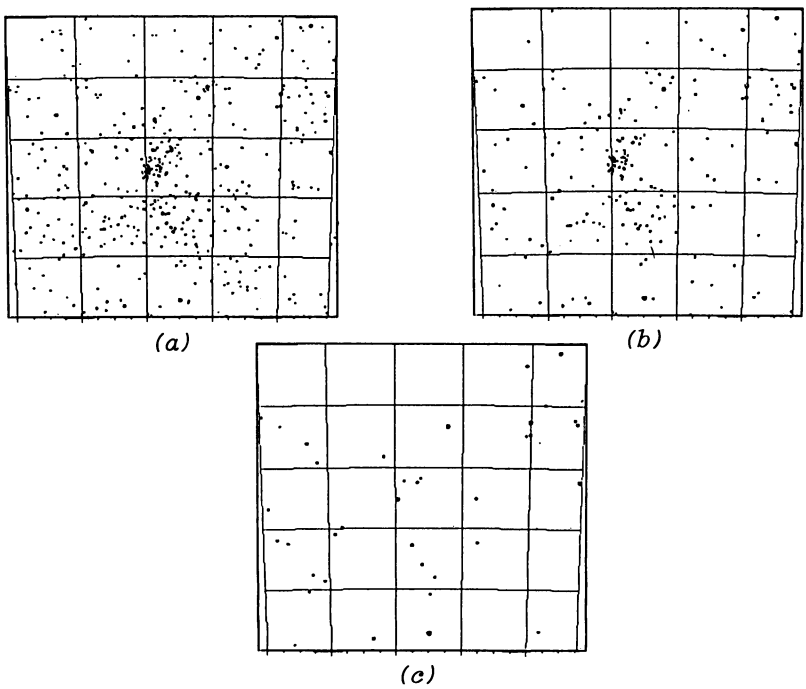
Table 1
IC1 : Magnitude distribution and percentage of "successful" stars

m_H	N (*)	Percentage of successful priority 1 stars	Percentage of successful survey stars
< 6	4 400	98	95
6 - 7	8 300	97	95
7 - 8	22 500	97	91
8 - 9	42 600	95	91
9 - 10	26 300	91	87
10 - 11	7 200	80	—
11 - 12	2 100	80	—
> 12	950	57	—
TOTAL	114 500	93 % 72 000 *	92 % 53 000 *

Figure 1
Comparison, for a same field, between :
the stars in the SIMBAD data base *(a)* ; all the proposed stars *(b)* ;
and the stars in IC1 *(c)*.



Center : 10h 42m 00.0s -59° 25' 00" ; 2°/2°

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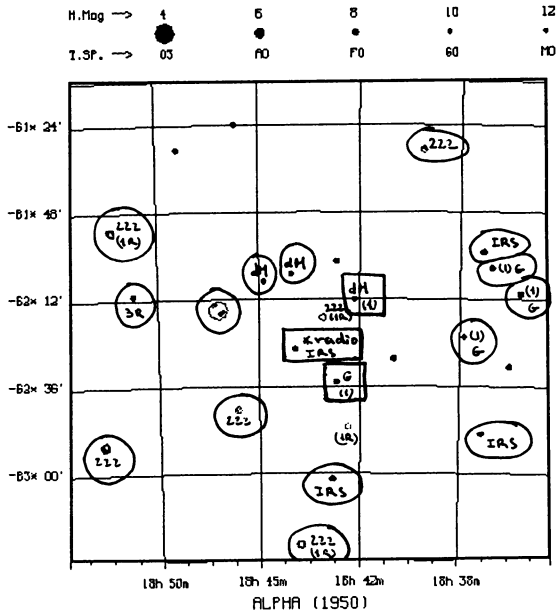
Figure 2
First example for competition between priority 1 candidate stars : field around HD 173397, a radiostar having superpriority.



An example of competition between priority 1 candidate stars is shown in Figure 2. All circled stars in the zone are observable by HIPPARCOS. The competition is between the 3 stars in the square boxes : on the one hand, a faint M dwarf star (m_H = 12.5), on the other hand, two brighter stars (m_H = 9.3 and 9.4), one of them being a radio-emitter selected to link the HIPPARCOS frame to an extragalactic reference system. As there are many more M dwarf stars than radio emitters, the choice here is to retain the two bright stars at the expense of the M star.

A second example is shown in Figure 3. The "superpriority" given to "link stars" (stars very near a QSO to be jointly observed by HIPPARCOS and by the Hubble Space Telescope) forced the inclusion of a third link star (I 221 112) at the expense of a much brighter IRS star in the close neighbourhood (but outside the 18′ radius circle around the QSO). However, more detailed simulations showed that this forced inclusion is not satisfactory as the observing time available for each of the three link stars (I 221 111, 112, and 113) is far from sufficient, which would lead to a diminished precision of the final positions. As a diminished precision is not acceptable for link stars, the choice here is to retain only two link stars, the two brightest ones. The IRS star is then also retained in the programme, and the observing times alloted to the 3 stars are satisfactory.

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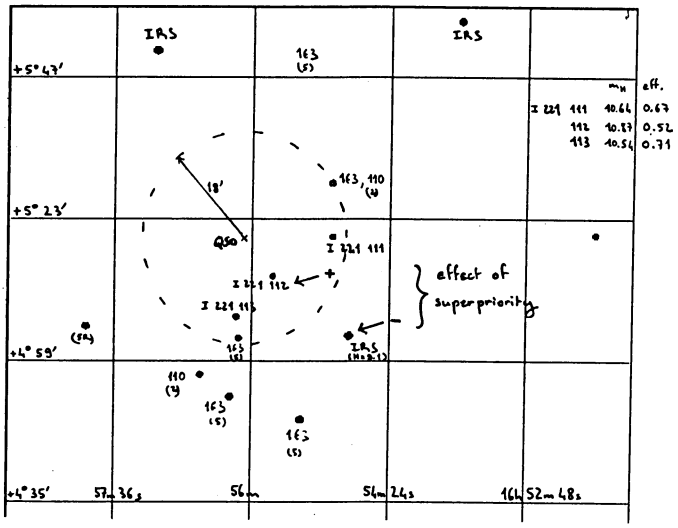
Figure 3
Second example of competition :
link stars around QSO (α = 16h 56m 5.7s, δ = 5° 19′ 47")



3. PROVISIONAL RESULTS FOR SOME PRINCIPAL ASTROMETRIC PROGRAMMES.

As shown in Table 2, a very high percentage of the stars submitted for the principal astrometric programmes is included in IC1 :

Table 2

Programmes	Number of stars	Number of stars in IC1	Percentage
FK4	1 535	1 535	100
FK5 candidate stars	2 013	2 004	99.6
NPZT	1 717	1 702	99
IRS	40 500	38 800	96
GC	33 200	28 600	86
AGK3 Lick stars	28 800	13 300	46
Earth rotation	6 100	5 500	92

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Remark on the IRS : a little higher proportion of northern stars is retained in IC1 (97 % of AGK3R stars), to be compared with southern stars (95 % of SRS stars, 93 % of "Supplement" stars). Most nonselected IRS stars are concentrated towards the galactic centre where the competition is greatest.

Stars for linking the HIPPARCOS reference frame to an extragalactic reference frame : Special attention has been paid to the selection of radio-stars and"link" stars, and their observability by HIPPARCOS has been carefullly checked. The topic is described in detail by A.N. Argue (this volume).

Minor planets : 63 minor planets have been proposed for HIPPARCOS observation. About 50 will be observable. Which of these can be observed depends on the date of the launch.

4. DOUBLE STAR AND "VEILING GLARE" PROCESSING.

Due to the peculiarities of satellite operation and data reduction, special processing is required when the signal received from one star will be perturbed by the signal emitted by a neighbouring star. If the perturbation due to the neighbouring star is too high as compared with the signal expected from the candidate star, the latter will be excluded from the Input Catalogue. This phenomenon will make it possible (or not possible) to observe stars in dense areas such as galactic clusters, and components within double and multiple systems.

Different processing modes are being used as a function of the separation ρ between the two target stars (or components) and of their magnitude difference, Δm.

a) If ρ is smaller than 0.1", only one entry is retained in IC : the satellite will be pointed at one unique position and the observing time will be alloted as if there was only one star with a magnitude equivalent to the total flux received from both components. If Δm is larger than 3 magnitudes, the secondary is neglected.

For the needs of data reduction, all available information on all known components is, however, retained and will be given in an annex catalogue.

b) If ρ is larger than or equal to 0.1", zero to two entries may be retained in IC, as a function of ρ, Δm, and of the proposers' requests. We will successively deal with the various possibilities :

b1) 0.1" $\leq \rho <$ 0.3", "small" Δm : If the difference in magnitudes is smaller than a quantity varying from 3 magnitudes for components brighter than 7, to 0 for components at the limiting magnitude of HIPPARCOS (m_H^ = 12.8), special alternating observing strategy is required to determine the astrometric parameters of the two components accurately. As a consequence, both components will be retained in IC, even though one of them has not been requested by any proposer.

b2) 0.1" $\leq \rho <$ 0.3", "large" Δm : In this case, only the brightest component is retained in IC and observed by the satellite. The secondary is rejected (the perturbation is negligible).

b3) $\rho \geq$ 0.3", the candidate star is brighter than the perturbing star. This range of separations corresponds to the veiling glare processing. If the candidate star is perturbed by a fainter neighbouring star and if the perturbation is larger than a given limit (varying with the magnitude of the candidate star), then the fainter star should also be included in IC. The data reduction for the candidate star requires the simultaneous knowledge of the photon counts from the perturbing star.

b4) $\rho \geq$ 0.3", the candidate star is fainter than the perturbing star. In this case, there may be

0 to 2 entries in IC, as a function of the size of the perturbation with respect to the size of the signal from the c andidate star. If the perturbation is too high, the candidate star will be excluded. If the perturbation is faint, it will be neglected (1 entry in IC). If the perturbation is noticeable, but still within the limits where a correction is possible, the bright perturbing star needs to be added to IC (2 entries).

In all the above situations (*b1* to *b4*), all available information on all known components will be given in an annex catalogue.

The consequences of the above statements are illustrated in the following figures :

Figure 4 : an extreme situation. The observation of the A component is not at all perturbed by the presence of the four other components. On the contrary, these four components are clearly not observable, even though they have been proposed.

Figure 5 : a multiple system. The two components P and C are not observable, because they are too close to the bright AB system (1 entry because the separation between A and B is smaller than 10"). Their perturbation on AB is negligible (cf. *b2*). AB and D require special alternating observing strategy (cf. *b1*). The perturbation due to AB on E is such that E can only be retained in IC if AB is also in IC (cf. *b4*).

Figure 5

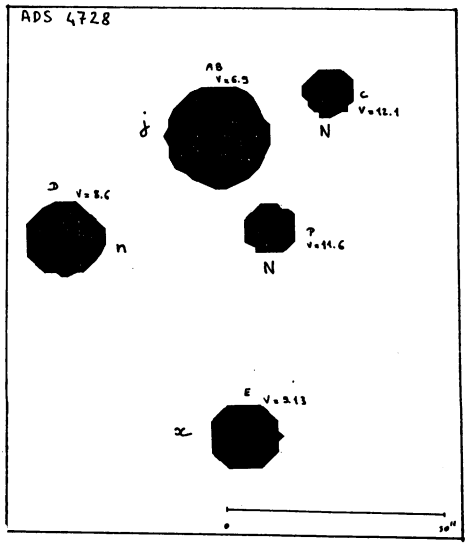

Figure 4

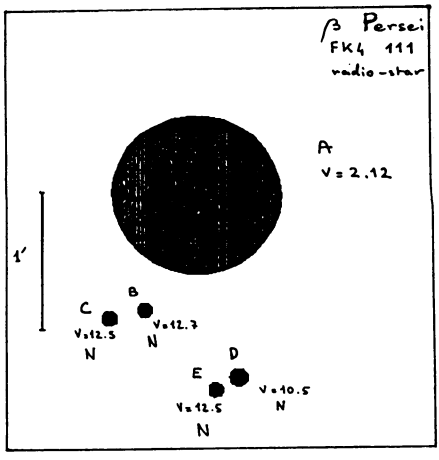

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Figure 6 : a galactic cluster. The observation of its members is completely perturbed by the veiling glare effect due to a bright star in the middle of the cluster (N° 1). The only observable cluster stars are N° 100, 6 or 10.

Figure 7 : a nearby galactic cluster. Unlike the previous example, this cluster is nicely spread out and many cluster members are observable with no noticeable veiling glare effect.

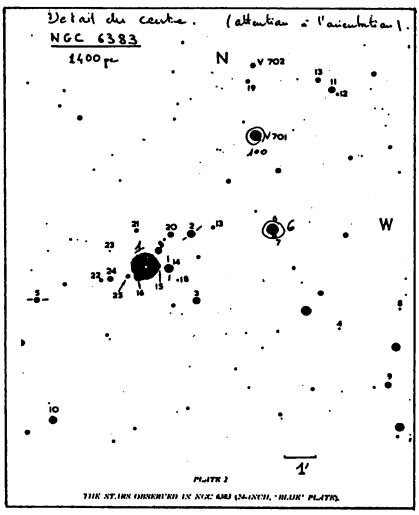
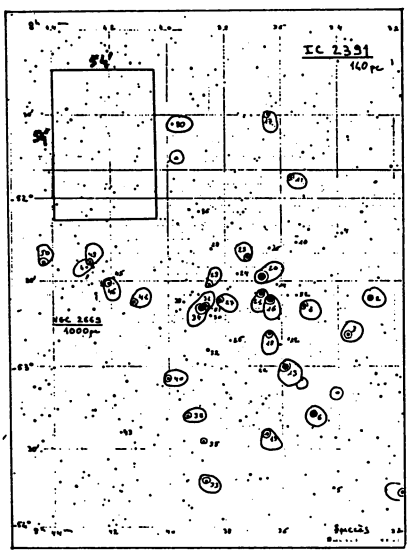


Figure 6

Figure 7



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5. NEW COMPILATIONS AND OBSERVATIONS. QUALITY OF THE DATA.

5.1. Positions.

* A hierarchy of astrometric catalogues (including a provisional CPC 2, courtesy Ch. de Vegt, Hamburg Observatory, F.R.G., and C.A. Murray, R.G.O., U.K.) has been established at the Astronomisches Rechen Institut (Heidelberg, F.R.G.). The place of the new observations and measurements in this hierarchy is being tested.

* New observations, on the Automatic Meridian Circles of Bordeaux (for stars in the northern hemisphere) and La Palma (for stars with $-25^0 < \delta < 0^0$) : about 9000 stars with positions of low precision and SAO stars with poor astrometric history have been observed.

* New measurements on ESO and SRC sky survey plates : about 100 000 stars have been measured ($\delta < -17^0$) at the Bordeaux, Greenwich, Leiden, and Marseille observatories.

These new observations and plate measurements are coordinated by Y. Réquième (cf. Réquième, 1985 and Turon & Réquième, 1986).

5.2. Magnitudes and colours.

* New compilations of photoelectric and photographic photometry have been performed, mainly in Lausanne (unpublished updating of the "CAGE" = Catalogue Général des photométries), but also in Geneva. Spectral types have been compiled at Meudon.

* New photoelectric observations have been performed for about 8000 stars (multicolour photometry), the type of photometry being suited to the spectral types of the considered stars. These observations are coordinated by M. Grenon, Geneva, (cf. Grenon, 1985).

* Special studies have been performed for estimating the m_H magnitude of the various types of variable stars (Mennessier, 1985).

5.3. Double and multiple stars.

Very extensive work is being performed on double and multiple stars, coordinated by J. Dommanget, Brussels (cf. Dommanget, 1985).

* Reorganisation of the existing data and construction of a new catalogue (CCDM = Catalogue of Components of Double and Multiple stars), presently mainly based on the 1976 IDS.

* Computation of relative positions of components at epoch 1990 for about 2000 stars (computation performed in Bonn from individual data made available by C. Worley, U.S.N.O., Washington D.C.).

* New observations (refractor, CCD) and plate measurements for the determination of components' relative positions for about 8000 stars. In addition, the CCD observations supply the magnitudes.

5.4. Stars in galactic clusters.

In addition to a careful examination of each cluster for an optimum star selection, an extensive compilation of magnitudes has been performed by J.C. Mermilliod (Lausanne) as well as a big effort of cluster stars cross-identifications (Lausanne, Meudon).

Positions of all cluster stars with no accurate coordinates have been remeasured on plates : in Hamburg for the northern hemisphere, at Münster for the southern hemisphere.

5.5. Stars for extragalactic link.

cf. A.N. Argue (this volume).

In addition to the general remeasurements of positions, magnitudes, and colours, VLA and VLBI observations have been performed on radiostars, speckle observations on link stars.

5.6. Minor planets.

Position observations are being regularly performed by the two Automatic Meridian Circles of Bordeaux and La Palma, as well as new plate position measurements at San Fernando. These new data are used in Paris (Bureau des Longitudes) and Barcelona for improving the orbital elements of the target minor planets (coordinated by A. Bec-Borsenberger ; cf. A. Bec-Borsenberger, 1985).

5.7. Precisions.

The precisions on positions and magnitudes at three stages of the work are given in Table 3 : precisions in proposals, in the Input Catalogue, and as expected in the HIPPARCOS Catalogue.

Table 3
Some precisions

	Proposals	Input Catalogue	Hipparcos Catalogue
Positions	$< 0.1''$ to 1 or 2'	$< 0.1''$ to $1.5''$	$\leq 0.002''$ to $0.004''$
Magnitudes	0.1 mag. to 2 or 3 mag.	< 0.01 to 0.5 mag.	0.02 to 0.1 mag.

6. CONTENT OF THE INPUT CATALOGUE FOR HIPPARCOS.

It is planned to publish the Input Catalogue in the following form :

* A main catalogue, including all the basic data for satellite operation (position at epoch 1990, system J 2000, and accuracy ; components of proper motion ; m_H magnitude, flag for variability and for standard stars ; observation parameters computed from numerical mission simulations), and additional data useful for HIPPARCOS data reduction and/or future astronomical use (B and V magnitudes, sources and precisions ; information on duplicity and multiplicity ; parallaxes ; spectral types ; radial velocities ; flags for indicating the existence of multicolour photometries ; identifiers).

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* Two annex catalogues on double and multiple stars :
a) detailed information on each known component ;
b) updated catalogue of orbital systems.

* Two annex catalogues on variable stars :
a) detailed information on the variability curves, type of variability, type of the magnitude adopted in the main catalogue (maximum, minimum, mean or weighted mean, as a function of the type of variability) ;
b) ephemerides for large amplitude variable stars.

* Two annex catalogues on solar system objects :
a) Minor planets : for successive epochs, every 30 days, Chebychev coefficients for ecliptic longitude and latitude, geocentric distance and m_H magnitude are given for each minor planet. These coefficients will be updated every 6 months.
b) Titan and Europa : for successive epochs, parameters for X,Y (relative position to the major planet) and m_H magnitude will be given for each satellite.

It is also planned to publish all the new data gathered on the stars proposed for HIPPARCOS observation but not retained in the Input Catalogue.

It is planned to publish these two catalogues by 1990.

7. CONCLUSION.

The preparation of the Input Catalogue represents a very big cooperative effort aiming at collecting precise and as homogeneous as possible data for all the target stars. In addition, a very big effort has been put on cross-identifications.

Future users should however keep in mind that this catalogue is neither strictly complete up to any magnitude fainter than 7, nor strictly limited to a stellar density of 2.5 star/square degree but it has been completely suited to HIPPARCOS observing possibilities and optimised not only with respect to the scientific content, but also taking into account the peculiarities of satellite operation.

8. ACKNOWLEDGEMENTS.

My best acknowledgements are due to the unknown referee for his careful reading of the English mistakes

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Discussion:

LASKER Can you please comment on the magnitude distribution of the new photoelectric photometry?
TURON Mainly stars fainter than 9.
WESTERHOUT I congratulate you on a very complete undertaking. I urge that a version of the Input Catologue be published very soon, long before 1990, so that astrophysists and astrometrits, expecially those with long-range programs, can select stars to put on their programs. Early publication of at least a rough version of the Input Catalogue will be invaluable for the final success of the HIPPARCOS project and for Astronomy in general (a "rough version" could be as little as a list of positions to $\pm$ 10" and magnitudes to $\pm$ 1m).
TURON My answer will be multiple:
1) The first priority will obvioulsy be given to the addition of the ESA version of the Input Catalogue, necessary for HIPPARCOS operation.
2) It is very unsatisfactory for people working for years with the aim of producing a nicely worked out catalogue to publish a rough version which may later stay on your shelves even though the new one is issued.
3) Even though this rough version could be considered, this would only be about one year before the final one. I don't think that this would present an appreciable benefit.
UPGREN I want to emphasize the importance in making the Input Catalogue available as soon as possible. Not only would it help astrometric programs to make choices among program stars with the greatest lead time, but it will help to calibrate the zero-point of the entire parallax system which HIPPARCOS will help to define. The data from the ground-based programs will be more useful with a generous mutual overlap between their program stars and its Input Catalogue.

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