Complementary Astrophysical Data for Hipparcos Stars

(1) Astrophysical Fundamental Parameters of Early-type Hipparcos Stars

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(2) Radial Velocities of Southern Late-type Hipparcos Stars

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The Hipparcos Mission: Accurate Astrometric Data for 120,000 Stars

Hipparcos, the satellite of the European Space Agency to be launched in July 1989, is the first satellite ever devoted to global astrometry (Fig. 1). The basic principle of observation is to scan continuously and systematically the whole sky with a telescope capable of measuring the angle between stars separated by a large angle (Fig. 2). The telescope is of Schmidt reflective type, the angles are measured by superimposing – by use of a complex mirror – in the focal plane of the telescope two fields of view separated by a "basic angle" of 58°, each field containing one of the stars in a pair. The satellite is designed to spin slowly, scanning the entire sky by means of the combination of two motions: a spinning rotation around the axis normal to the two lines of sight and a revolution of the spin axis around the satellite-Sun line. The angle between the spin axis and the Sun is 43°.

As the satellite scans the sky, the star light is modulated by a grid consisting of a large number (about 3,000) of regularly spaced opaque and transparent slits and the modulated light is sampled by a detector, an image dissector tube, IDT (Fig. 3). 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 (diameter of about 30 arcsec) of the image dissector.

The observing time is distributed among the stars according to their magnitudes. From the phase difference between the modulated signals from two stars (Fig. 3) and the value of the basic angle, it is possible to determine very precisely the angle between the two stars. As the sky is scanned, each programme star will be linked to several others in different directions during the nominal lifetime (2.5 years), allowing to build a dense set of angular distances between stars covering the entire sky. After appropriate reduction of the data, the astrometric parameters: positions, parallaxes and proper motions for the programme 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 (Fig. 3).

From these considerations it is clear that the programme stars should be evenly distributed over the sky and their magnitude distribution should be compatible with the satellite observing possibilities. The list containing the 120,000 stars to be observed and all the data necessary to satisfy satellite operation is called the Input Catalogue. It has been elaborated by the INCA Consortium, constituted by 26 European Institutes from eight countries (Perryman and Turon, 1989), from the stars of about 200 proposals submitted by the astronomical community and a large stellar sample complete down to a well defined limiting magnitude called the "survey".

The Input Catalogue constitutes the best possible compromise between

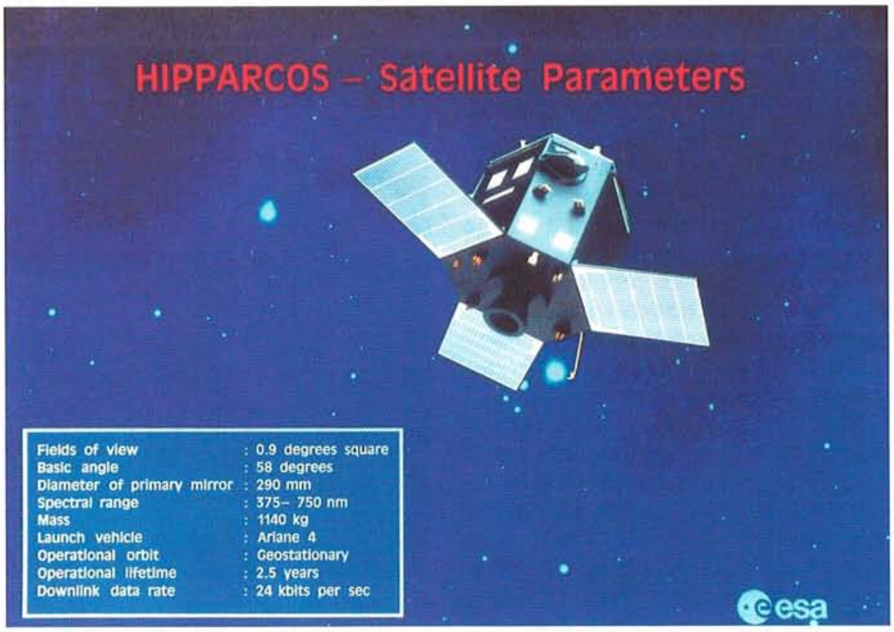

Figure 1.

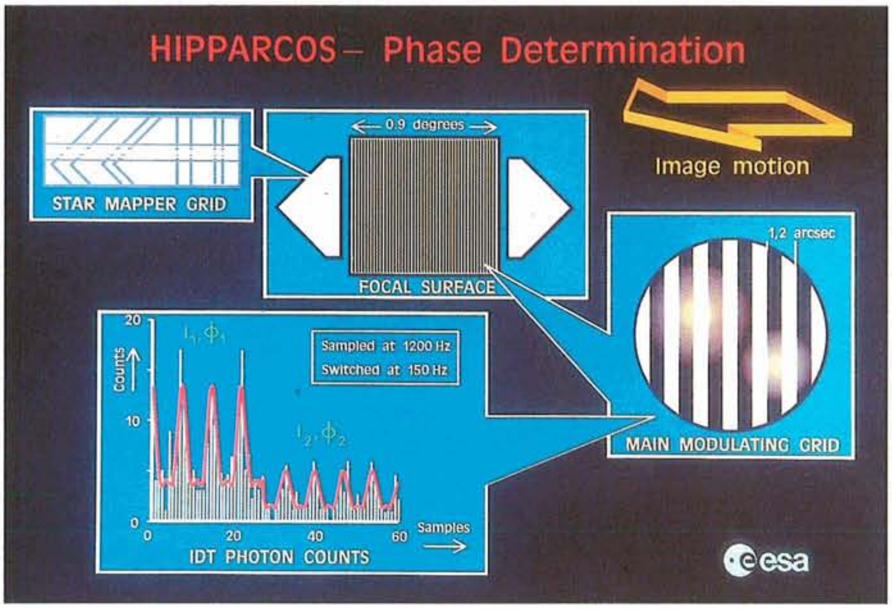

Figure 2.

satellite operation, data reduction requirements, and the scientific objectives of the mission.

The raw data produced by the satellite – consisting essentially of photon counts from the IDT and the stars mappers – will be reduced by two independent European Consortia: FAST and NDAC (Perryman et al., 1989).

Hipparcos will observe stars down to the magnitude B = 12, the accuracy of the main mission results is about 0.002 arcsec on positions and parallaxes, and 0.002 arcsec/yr on proper motions for stars brighter than B = 9 (Perryman and Schuyer, 1985). Trigonometric absolute parallaxes will be obtained up to distances of about 500 pc for a large variety of stars, the relative accuracy will be higher than 20 % for about 30,000 stars within a volume of 100 pc around the Sun (Gómez, 1988) (Fig. 4).

Major Progress Expected in the Study of Galactic Stellar Populations

Stellar population studies require the knowledge of many parameters: position, velocity, metallicity, age and mass. The unprecedented quality of Hipparcos parallaxes and proper motions, five to ten times more accurate than the present ones, will lead to major revisions of our knowledge of the galactic and even extragalactic domain.

The Hipparcos programme results from the combination of 200 proposals, having specific scientific goals, with the limited-magnitude "survey" sample. The limiting magnitude of the survey is a function of the stellar colour, fainter for early-type stars, and of the galactic latitude, the aim being a uniform star density over the sky and to select a maximum number of stars for which the ages and distances may be precisely defined.

From distant luminous stars, within about 1000 pc, a precise description of the galactic velocity field, including spiral wave perturbation, will become possible since the proper motions are quasi-absolute and so accurate. The formation of clusters and associations will also be described and their subsequent evolution characterized by the observed internal motions and expansion rates. Birth places of clusters and young stellar objects will also be traced back. In addition to the tangential velocities, accurately obtained from Hipparcos measurements, the availability of radial velocities will allow to reconstruct individual stellar orbits.

Half of the programme stars are formed by the Hipparcos survey where intermediate and old populations dominate heavily. The local velocity field will therefore become extremely well defined statistically. In order to distinguish among the different stellar populations, data like effective temperature, gravity and metallicity are necessary. The relations age-metallicity-kinematics should be clarified, at least in the solar vicinity. The situation is the same for the past rate of star formation.

As the survey is deeper towards the galactic poles, an accurate determination of the velocity field perpendicular to the galactic plane is expected, leading to a new estimate of the local total mass, hidden and visible, of the Galaxy. An important improvement of the luminosity function is foreseen, mainly for the massive stars, but also for the lower main-sequence stars and in the red giant domain. The fine structure of the main-sequence will be described in relation with metallicity and helium abundance.

The possibility of obtaining parallaxes of rare and luminous objects: old stars like RR Lyrae or Mira variables, or young stars as blue or red supergiants, will allow to determine distances to old galactic objects like globular clusters or irregular and spiral galaxies, and to improve, ultimately, our knowledge on the extragalactic distance criteria.

Most astrophysical applications of Hipparcos astrometric results require that parameters like temperature, gravity, metallicity, radial velocity and stellar rotation are made available from ground-based observations with an accuracy consistent with that of Hipparcos.

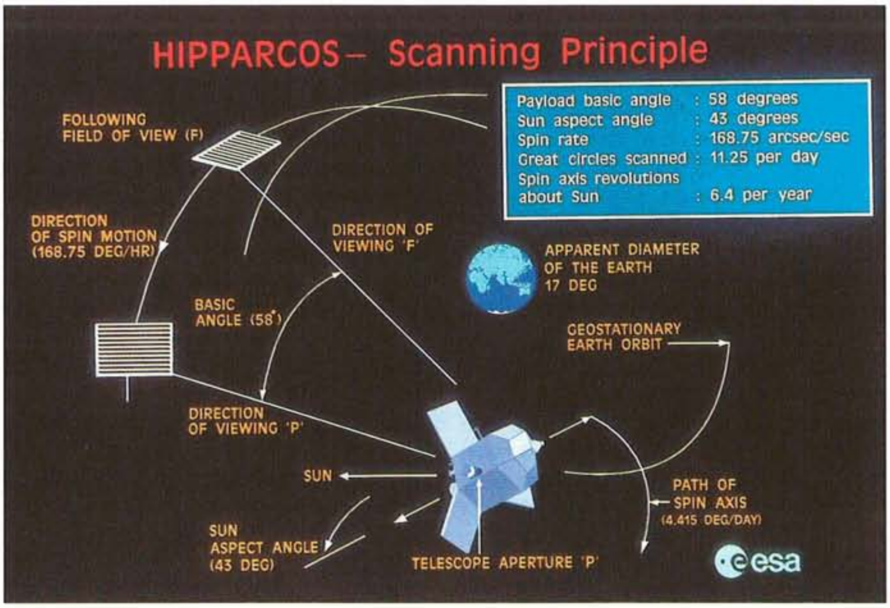

Figure 3.

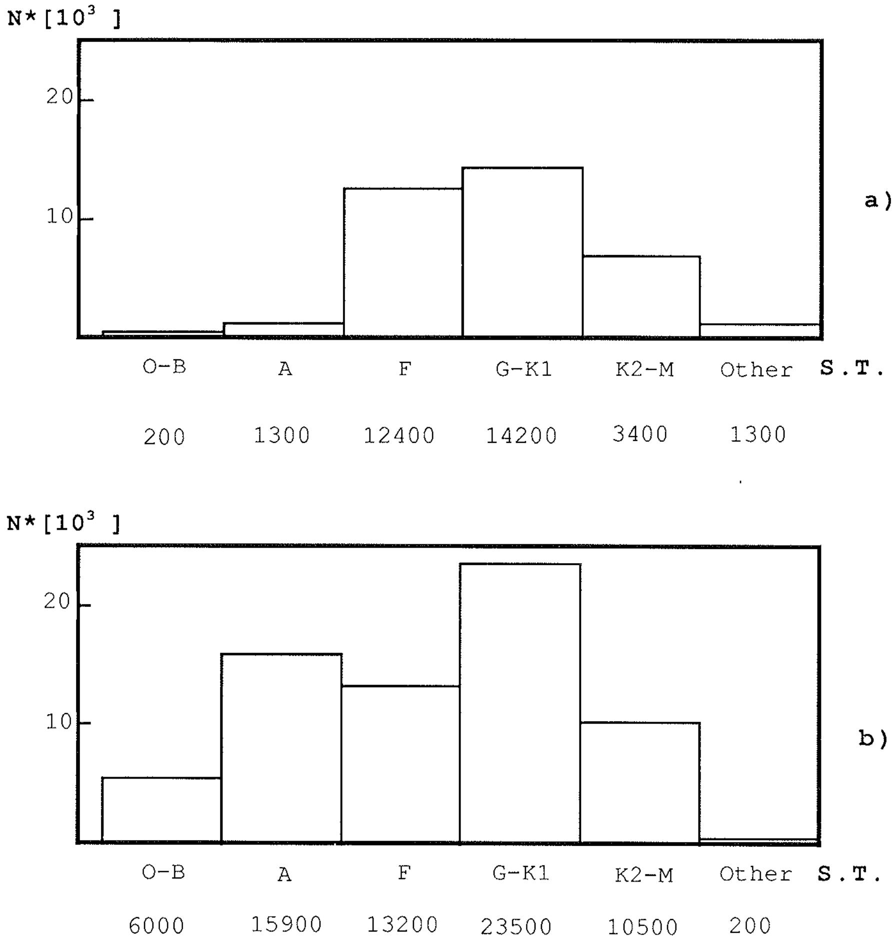

Figure 4: *Number of stars versus spectral type for different ranges of heliocentric distance (r), a) $r \leqslant 100$ pc; b) 100 pc $< r \leqslant 500$ pc.*

The two Key Programmes cover the blue and the red Hipparcos stars respectively; they will allow to obtain basic complementary astrophysical data for the stars in the solar neighbourhood.

Astrophysical Fundamental Parameters for Early-type Southern Stars

About 20,000 southern early-type stars will be observed by Hipparcos, and complementary astrophysical data for this large amount of stars cannot be reasonably obtained from ground-based observations in a five-year period. Moreover, many of these stars present abundances anomalies. In fact, in this area of the HR diagram, a large variety of spectra is found among the A-type stars.

In order to obtain a representative sample of early-type stars, well suited for galactic studies and compatible with the observational possibilities, we have focused our attention on non-chemically peculiar B-, A- and early F-type stars of the southern sky closer than 100 pc (about 1800 stars).

Spectroscopic observations will be performed with the Echelec Spectrograph and the CCD Camera at the 1.5 m ESO telescope, in the spectral range centred at 4500 Å (Hγ). This spectral region is well suited for radial velocity determinations as well as for the determination of $v \sin i$, T_{eff}, log g and metallicity.

Radial velocities will be obtained with an accuracy of the order of 2–3 km/s, the accuracy limit being mostly due to the stellar structure itself.

The sample defined above has been selected from spectral classification which permits to distinguish normal from peculiar stars, but there is a growing evidence that among the so-called normal stars mild peculiarities exist. Even Vega, the prototype of the normal dwarf A0-type star, has recently been suspected to have a non-solar abundance. Mild peculiarities will be detected with these spectroscopic data and the sample of normal stars will be refined. Effective temperatures and gravities in connection with Hipparcos parallaxes will allow to obtain better age determinations. The distribution of $v \sin i$, related to star formation mechanisms, will also be analysed (Ramella et al. 1989).

We gratefully thank ESO for the allocation time to this key programme, allowing to obtain a set of astrophysical parameters of a well-defined sample of early-type Hipparcos stars in the solar vicinity.

Radial Velocities and Rotational Velocities for About 25,000 Red Stars in the Southern Sky

Some 70,000 stars of spectral type later than F5 have been selected to be measured by the Hipparcos satellite. Due to the important percentage of spectroscopic binaries in any star sample, at least two radial velocity measurements separated by two or three years will be necessary. This leads for stars later than F5 alone to some 100,000 radial velocity measurements over the next five years! Such an undertaking would be dispairing with conventional photographic techniques. Thanks to the development by R. Griffin of the photoelectric cross-correlation technique some twenty years ago, this survey now seems possible (Fig. 5).

Different cross-correlation spectrometers are operational, but most are located in the northern hemisphere where a coordinated effort of some of them might allow the determination of radial velocities.

In the southern sky, however, the situation is notably different. There, the CORAVEL spectrometer at La Silla would have to accomplish alone a large fraction of these measurements. In fact, CORAVEL (COrrelation RAdial VELocities) realizes the optical cross-correlation of the stellar spectrum with a template of some 1500 absorption lines (Baranne, Mayor, Poncet, 1979) optimized for late-type stars. If the position of the cross-correlation function is evidently related to the radial velocity, the width at half depth of this function is a fine measurement of line broadening mechanisms. For most of the stars, the width allows a precise determination of $v \sin i$ (Benz, Mayor, 1981). The area of the cross-correlation function is essentially a function of temperature and heavy element abundance (Mayor, 1980) and a straightforward way (almost reddening free) to obtain a metallicity determination (Fig. 6).

In operation since 1981 at the 1.54 m Danish telescope at La Silla, the CORAVEL has shown that accuracies of the order of 0.2 km/s of the velocity, 1 km/s of the $v \sin i$ and 0.15 dex of the heavy element abundance can be achieved. The cross-correlation technique is so sensitive to rotational broadening that only a few stars bluer than F5 can be measured. Conversely, the same template will allow the velocity determination of the latest M stars.

Thanks to the generous allocation of

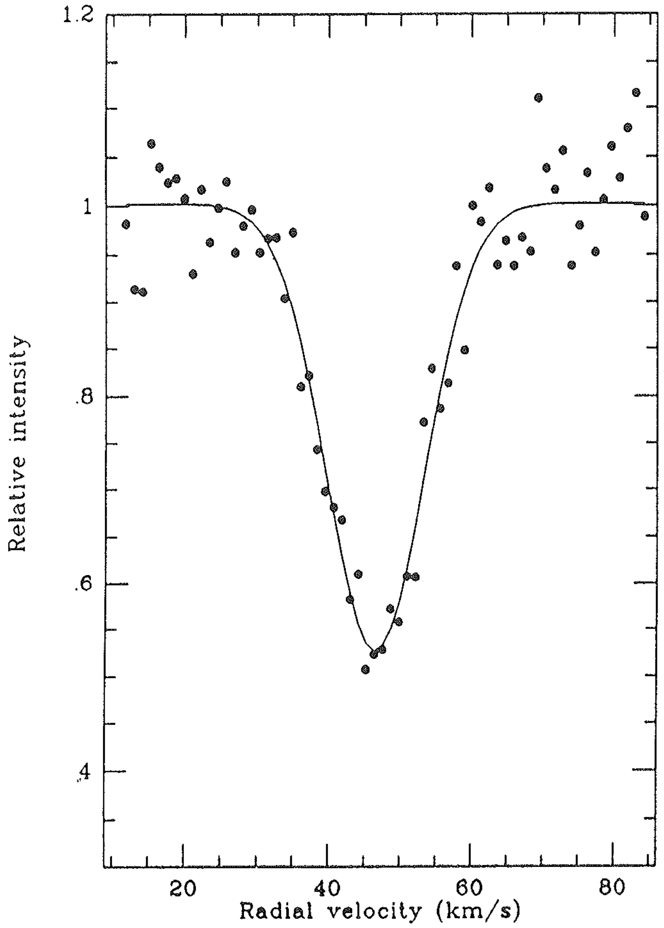

Figure 5: *The cross-correlation dip of a K2 III star of magnitude B = 10.4 after 60 sec of integration. After such a short exposure, the radial velocity uncertainty is about 0.5 km/s.*

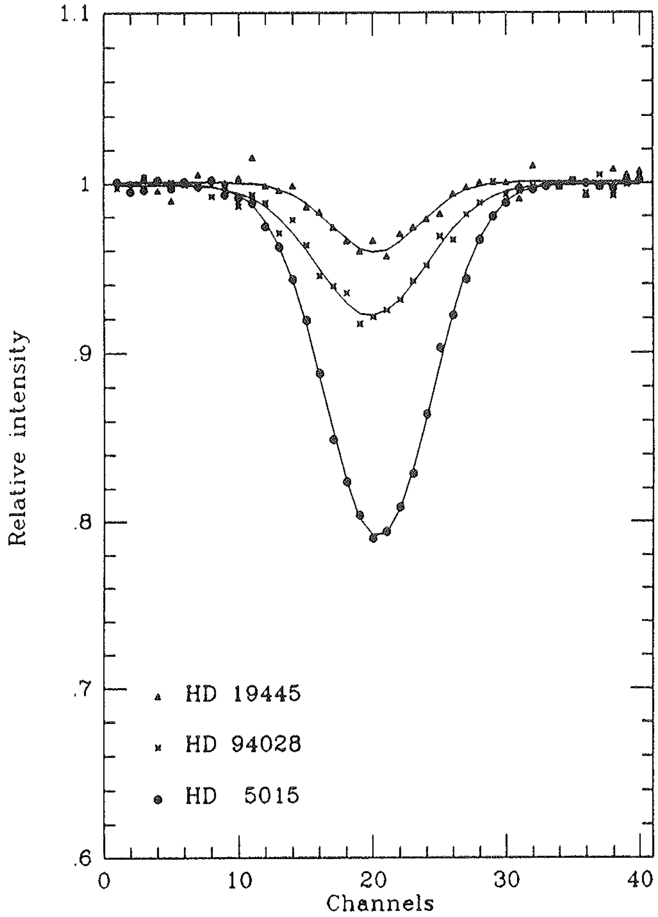

Figure 6: *The cross-correlation dips of three stars having about the same temperature, but quite different metallicities. The (Fe/H) are respectively +0.1, −1.4 and −1.8 for HD 5015, 94028 and 19445. Such a comparison shows the extreme sensitivity of the dip surface with metallicity.*

time by ESO and by the Danish Board for Astronomical Research, we are rather confident that all the red stars in the southern hemisphere of the Hipparcos mission will have known radial velocities in five or six years.

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PISCO Modifications

Recently, the software for PISCO has been extensively modified and improved. This has had the following effects:

- reliable on-line reduction
- possibility of hard copy of on-line data
- simplified calibration procedure
- simplified exposure definition form
- various bugs removed

During the night, the on-line results can now also be printed; this is useful for planning the next night's work. On-line reduction now works with the proper Fourier transform method and gives an accurate impression of the data quality obtained. It can be used with or without automatic sky subtraction.

The calibration menu has been simplified and is therefore more user-friendly, as is also the exposure definition form. Finally, some bugs were removed from other parts of the software.

The PISCO Observer's Manual is now available (ESO Operating Manual No. 13).

H.E. SCHWARZ, ESO

Joint ESO/CTIO Workshop in 1990

The European Southern Observatory and Cerro Tololo Interamerican Observatory will hold a joint workshop on "Bulges of Galaxies" in the period January 16–19, 1990, in La Serena, Chile.

The emphasis will be on the interaction between theory and observations of bulges of galaxies. Topics will include: dynamics and kinematics, stellar populations, chemical evolution and the bulge/disk/halo connections. The meeting will be in the form of relatively long invited reviews, shorter contributed papers and posters.

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