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How Double Star Astronomy May Develop After HIPPARCOS[1]

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ABSTRACT: Now that the HIPPARCOS satellite safely revolves on its "degraded" orbit — after the exploit of the ESA technicians to rescue it from the faulty ignition of its apogeum boost motor — and regularly provides the information expected for reaching the initial aim of the project, one may turn to examine the possible exploitation of the final HIPPARCOS Catalogue.

In the present paper, we describe how double and multiple stars have been introduced in the *Input Catalogue* and what may be expected from their observation. We also try to evaluate how much the final HIPPARCOS data may influence future researches on these celestial bodies and what kind of ground-based observation programmes should be conducted in order to support the space results.

1. THE HIPPARCOS MISSION AND THE DOUBLE STARS

It is well known that the HIPPARCOS mission — which is already now a great success — will provide an important amount of accurate astrometric and photometric data for the 118,000 objects that have been selected following priority rules and technical constraints. Besides a first part of 52,000 bright stars, called Survey, 66,000 fainter objects have been selected from 214 proposals of research made by the astronomical community. Twenty–two of these proposals concerned double and multiple systems which finally led to 14,167 systems of which 11,434 are double, 1,960 are triple, 536 are quadruple and 237 are multiple (more than four components) in the *Input Catalogue*.

The proportions of the systems with all components considered in the *Input Catalogue* are respectively:

66%	for double systems with	$\rho < 10''$
39%	for double systems with	$\rho > 10''$
21%	for triple systems	
7%	for quadruple systems	
4%	for multiple systems (n > 4)	

Accurate positions, proper motions, absolute parallaxes (to $\pm 0\farcs002$) and magnitudes (to ±0,01m) will be obtained for all these components except for secondaries whose influence appears to be negligible in the measurement of the bright nearby principal component. Theoretically these secondaries should be at less than $10''$ from the brightest component with a difference in magnitude larger than 1,2m or at separations ranging from $10''$ and $30''$, with a difference in magnitude larger than 3m. In this case, HIPPARCOS data will finally be available for both components for at least 40% of the 11.421 non-astrometric double stars.

[1] **A more detailed version of the present paper will be published in *Astrophysics and Space Science*.**

Similar considerations have to be taken into account for triple, quadruple and multiple (n > 4) systems. These data will lead to significant improvements of our knowledge, amongst others, in the fields hereunder described.

2. EXPECTED CONTRIBUTIONS TO DOUBLE STAR ASTRONOMY

2.1. The census of the double and multiple stars:

This probably will be one of the most important contributions of HIPPARCOS to double star astronomy. The systematic survey of all bright stars of both hemispheres as well as of all nearby ones with equipment having a resolution power of the order of 0.″1, will lead to the completion of double star catalogues at least for some categories of binaries. Detection will be more effective in the southern hemisphere where ground–based surveys have not been so much developed. In addition, the production of parallaxes and proper motions for the components of thousands of systems, will permit to recognize optical systems and thus to clean the double star samples used for researches in formation and evolution. Fundamental in that respect will be a better knowledge of the frequency diagramme of the true component separations.

2.2. Relative positions:

Relative positions of the components of double and multiple systems will be provided by HIPPARCOS for separations larger than 0.″1 adding some thousands of new measurements to the extensive material already available from ground–based techniques. The higher accuracy will unfortunately not contribute to any particular improvement in double star orbit computation, because the operational period of the satellite is significantly shorter than most of the orbital periods: except for a few visual systems with periods less than 10 years, the vast majority of the known orbital systems have periods ranging from 10 to 1000 years. In these cases, the HIPPARCOS measurements will appear as any other measurement but of high accuracy. These data may be of particular interest when the HIPPARCOS measurement falls in the apparent periastron region where no other technique has been successful. In case of short periods (less than ten years), the separations will be very small and orbit computation based on the sole HIPPARCOS measurements will appear to be very difficult. This last situation is also considered under the next item.

2.3. Total mass:

Two different situations occur according to whether or not the orbit of the system is already known. From the expression of the total mass of a binary system, the *relative error* on the total mass is given by the formula:

$$E_{M_{AB}} = \pm\sqrt{E^2_{(a^3/P^2)} + 9E^2_{\pi}} \ .$$

One may deduce that, for instance, for a relative accuracy of 14% on the total mass, the relative accuracy of the ratio a^3/P^2 should be at least 10% and that on the parallax 3.2%. This means that, with an absolute accuracy of 0.″002, only systems having a parallax larger than 0''.060 may lead to an accuracy of 14% on the mass.

In case of the known orbital pairs, they number approximately 90. With the highly precise HIPPARCOS parallaxes, a sensible effort should now be done to improve the ratio a^3/P^2 in order to increase the amount of accurate mass data.

In case of new very close systems discovered by HIPPARCOS, one may expect a few new mass determinations. An illustration of this expectation may be shown in a $(\log P, \log a)$ diagramme (based on the mass–luminosity relation and the third law of Kepler). The region where such binary discoveries may provide interesting data is delimited by conditions depending on the resolution power of the equipment, the minimum wanted accuracy of 14% on the total mass and parallax limitations and appears to be quite small.

2.4. Mass ratio:

The relatively short operational period of the satellite compared to the orbital periods of the known visual double stars is also here a handicap. Only in a very few cases, the sole HIPPARCOS data will be able to provide accurate values for the mass ratios. Ground–based observations will be of greater assistance in that matter.

2.5. Photometry:

This is probably the second most important contribution of HIPPARCOS to double star astronomy. Because of the present scarcity of accurate and homogeneous photometric observations of the individual components of double and multiple systems, the HIPPARCOS mission represents a major turning–point in the collection of photometric data for double and multiple stars: the output of homogeneous magnitudes in a unique photometric system for all observed components down to separations as small as 0''.1, with an accuracy of the order of 0,01m, represents a huge amount of precise photometric information never attained before for this class of objects. Accurate Δm values will be in reach for many thousands of systems. It should have a tremendous impact on the understanding of the formation and evolutionary mechanisms of double and multiple (but also of single) stars.

2.6. Mass–luminosity relation:

The increase of mass data and the valuable improvement on the magnitudes of the components of the orbital pairs as well as a few new mass determinations, will lead to a better knowledge of the mass–luminosity relation either from improvement of the quality of the already existing data or from an increase of the material for a given accuracy. One may expect such an increase by some 50% and the possibility to better separate the part due to observational errors from the part having real physical significance in the departure of the observed from the theoretical masses.

3. GROUND–BASED COMPLEMENTARY OBSERVATIONAL PROGRAMMES

The need for complementary ground–based programmes is evident: systematic observation of any kind of the components that have been ignored in the *Input Catalogue* are a must. This concerns 2,414 double, 1,553 triple, 499 quadruple and 228 multiple systems. Similar programmes may be needed for those components recorded in the *Input Catalogue* but for which no information will be available from HIPPARCOS because of the proximity of a brighter star. In order to improve mass determinations, long–term astrometric programmes using accurate techniques should be pursued and intensified to acquire more precise values of the ratio a^3/P^2 for the known orbital pairs. Moreover accurate relative positions may lead to the knowledge of the parallax of the ignored secondary component, since the parallactic ellipse is similar for both components.

Observations by speckle techniques of the newly discovered close HIPPARCOS binaries should be made in view of orbit determinations, as well as meridian observations for mass–ratio determinations.

For the photometric part, the systematic collection of accurate photometric data with the aim to supplement the HIPPARCOS magnitudes by astrophysically significant colour indices and to complete the information for the components not included in the *Input Catalogue*, is an equally important goal. The use of new techniques (speckle, CCD, scanning techniques, etc.) may be of great help to provide the necessary data.

4. CONCLUSION

From a comparison of the present situation in double star astronomy with the future situation expected after the HIPPARCOS mission, there appears two fundamental remarks:

1. HIPPARCOS is the first instrument that will provide data for an extended sample of 118,000 stars in astrometric and photometric uniform systems. This concerns also a large subset of double and multiple systems representing more than 10% of the *Input Catalogue* without even considering the large amount (some thousands) of newly detected HIPPARCOS (generally close) pairs! In particular, the census and the photometry will largely benefit from this satellite mission.
2. Although HIPPARCOS increases the accuracy of the expected data for many kinds of research by a factor of 10 (and sometimes more), the fact that it has an operational period 10 or even 100 times shorter than the majority of the known orbital periods of visual double stars, is a serious drawback for some of the expectations for double and multiple systems as for example: orbit computation, total mass and mass–ratio determinations. Still the gain in these fields remains very sensitive.

The HIPPARCOS mission will thus lead to an extended and homogeneous material for astrophysical research and galactic dynamics in double star astronomy. It will appear as a mile–stone for such research and will certainly increase the interest of the astronomical community for this too often neglected domain.