THE IMPORTANCE OF WIDE-SYSTEM STUDIES FOR STELLAR EVOLUTION AND GALACTIC DYNAMICS*

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Abstract. Wide pairs and wide multiple systems have been too much neglected during many years by visual double star astronomers with the argument that only close visual pairs (short periods) may lead to mass-determinations in a relatively short time interval. But mass-determination should not be considered as the only interest of double star astronomy, even if it is of a fundamental nature.

Today, it appears that researches on the origin and the evolution of the wide systems are urgently wanted, not only for the understanding of the evolution of the stellar medium, but also for a better knowledge of galactic dynamics. Some examples are given.

Presently, the main task for double star specialists will be an important improvement in double and multiple star census for all kind of systems: close, medium, and wide. The Hipparcos satellite will probably add some important informations in that respect but ground-based observations also remain of the highest importance (radial velocities, photometry, astrometry, etc.).

1. Introduction

The discovery of the first double stars showing orbital motion has immediately led to the idea of the possible determination of the stellar masses with high accuracy because it was the first time that a perfect example of the two-body theory in its full pureness was discovered in the Universe.

In his report to M. D'Ouvaroff, President of the Imperial Academy of Sciences in St. Petersbourg (1837), F. G. G. Struve wrote:

"... Si deux soleils sont liés par l'attraction, il doit y avoir des mouvements en lignes courbes continues. L'astronomie, dans les siècles passés, ne connaissait de pareils mouvements que dans le système solaire; les étoiles doubles nous les offrent dans l'immense éloignement des étoiles fixes. C'est en observant ces mouvements que nous finirons par en découvrir les lois. Si les lois de la gravitation universelle de Newton sont la plus sublime découverte qu'ait faite l'esprit humain dans le cours de plusieurs milliers d'années, nous sommes bien près d'être à même de déterminer si ces lois n'appartiennent qu'au système solaire, ou si elles sont communes à l'univers entier. L'astronomie marche donc vers une nouvelle époque qui datera du moment où l'on fera voir que la mécanique céleste ne se borne pas aux phénomènes du système solaire, mais peut s'appliquer aux mouvements des étoiles fixes...."

The fact that the gravitational laws are applicable to all bodies in the Universe and that as a consequence the stellar masses can be determined through the orbital motion of the binaries, has dominate all double star astronomy for a long time and remains even today, for many astronomers, the basic reason for observing visual double stars.

However the regular discovery of new systems of all types by the visual method as well as by other techniques, such as spectroscopic, astrometric, speckle, and occulta-

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tions, has led to the occurence of an exceptionally high frequency of binaries – at least in the surrounding of the Sun – in comparison with all other stellar objects: single stars, triple systems, etc.

Unfortunately, this seems not to have brought any change in the attitude of astronomers regarding medium wide and wide pairs. Very close pairs, because of the astrophysical problems they revealed, have created a very interesting field of research for many astrophysicists, while close visual pairs remained the only interesting objects for astrometrists in view of orbit computations and mass determinations.

Of course, astrometric observations as well as astrophysical observations of components of medium wide and wide pairs do not favour a particularly great enthusiasm. But we have to decide whether we want to know more about binaries or whether we just want to conduct our activities in small areas ignoring the characteristics of the whole domain which we are interested in.

I would like to take the present opportunity to recall how important may be any interest for these particular but very numerous presently neglected binaries.

2. The Fundamental Problem of Double Star Astronomy

In addition to their exceptional frequency, the binaries show some important orbital features that should be clearly and continuously kept in mind.

Their periods have values regularly distributed between a few days and some thousand years without any particular gaps. Similarly, the semi-axis major (or the distance between the components when no orbits are known) are also spread over a large interval of values between some hundredths and a few thousands of AU, also without any particular gap.

Now, about the orbital eccentricity, a regular distribution of its values is observed between 0 and 1 with a sensible decrease of the frequency from the smallest values to the highest ones. Here also, no particular gaps are observed.

Knowing this, the most puzzling of all questions that arise in the field of double star astronomy is: "How have the medium wide and the wide binaries been formed?"

Of course, for the very close pairs, nobody will imagine any other formation process than those admitting a common origin of their components, starting from a unique protostellar cloud. At the contrary, for systems having sufficiently separated components, the situation is less evident and different opinions are present.

It seems that only two different ways may be accepted for the genesis of these binaries:

(a) a formation mechanism leading immediately to the presently observed orbital characteristics;

(b) a formation as close pairs, followed by an orbital evolution changing the original orbit into the presently observed one.

A third way – the formation by capture – is no longer considered because even if the change of an hyperbolic orbit into an elliptic one is perfectly possible, it cannot statistically lead to the high frequency of binaries presently observed.

In case of item (a), one should admit that there is no difference between the formation

of components of wide pairs and the formation of single stars. That means that, in both cases, the space distribution of the condensation centers leading to protostars was at random. However, the observed distribution diagram of the distance between any star or a component of a binary and all others in its surrounding shows a typical discontinuity around $A = 2 \times 10^3$ AU, as may be seen on Figure 1. As a consequence, the diagram for the binary components cannot be considered as part of that of the single stars. This fact seems to be sufficient for rejecting item (a).

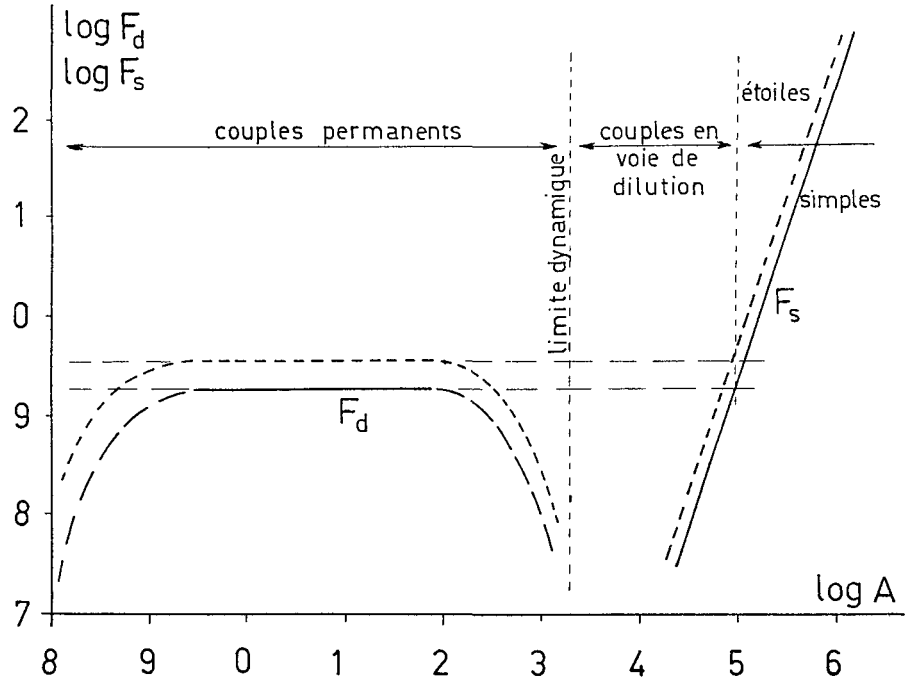

Fig. 1. Schematic distribution diagram of the true distances between the components of binaries and between single stars, following a statistical research of the author.
(*Comm.. Obs. Roy. de Belg., Série B*, No. 70, 1971.)

In case of item (b), wide pairs would appear as the result of an orbital evolution of close pairs. The first mechanism that should be considered seems to be a secular mass-loss that increases the period and the semi-axis major. About the eccentricity the situation is somewhat more complicated but it does not need to be considered here for the present discussion. The most crucial point for adopting this process lies in the need of admitting that *the great majority of stars are loosing mass* secularly and quite substantially.

It is thus clear that if we want to know more about the genesis of binaries, we should increase our interest for the *non-close pairs*, that may be considered in two different categories: the visual orbital pairs and the visual non-orbital pairs.

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3. The Visual Orbital Pairs

They are the only visual systems of which the orbital characteristics are known. From their study (some 900), some important results should be mentioned.

First, the assumption that there exists a permanent secular mass-loss for all components of any luminosity classes, has led to the discovery of the following important relation between mass and eccentricity in the case of pure binary systems*:

$$e^{2.8}\,\mathfrak{M}_{AB} < 3.60\,.$$

This relation fully explains the correlation between period and eccentricity long ago suspected for spectroscopic and visual systems. At the same time, it shows a similar behaviour of both of these categories of binaries.

Secondly, the poles of the orbital planes seem to be distributed in a particular way: inside space elements of the order of 20 to 30 parsecs, the orbital planes would show a certain organisation**. If this is really so, stars inside such elements would have been formed under a common dynamical process and one could imagine the formation of the stellar medium by steps, one of these steps being the formation of such space elements.

4. The Visual Non-Orbital Pairs

The extremely high frequency of these pairs, is sufficient to justify a special effort to make use of all of their characteristics in view to substantially increase the amount of information needed to contribute to the above mentioned researches on stellar evolution and galactic dynamics. The ignorance of their orbital elements can be replaced by appropriate statistical techniques. But such techniques need a first correct census of these stellar objects, at least inside a limited space element as the one surrounding the Sun to some 20 to 25 parsecs. A systematic search should thus be undertaken for discovering new systems and for recognizing the optical from the physical ones. Parallaxes, proper motions as well as radial velocities of their components are urgently needed.

The main object of such a systematic survey should be to correctly establish the distribution diagram illustrated by Figure 1. This means that the survey should concern systems where the components may show separation reaching 0.01 parsec. Using Hertzsprung's formula†:

$$\log\rho < 3.0 + 1.50I - 0.20m\,,$$

where I = color index, m = magnitude of brightest component, one finds, for stars of

* IAU Colloquium No. 59, Trieste, 1980, Proceedings, 1981, p. 507.
** *Bull. Astron. de l'Obs. Roy. de Belg.* **VI**, 6, 1968, p. 246.
† *Comm. Obs. Roy. de Belg., série B*, No. 17, 1967, p. 36.

class V, the following apparent separations:

Spectral type of A \ m_A	8	10	12	14	16
B	8″	3″	1″.3	0″.6	0″.2
A	25	10	4	2	0.6
F	79	32	13	5	2
G	180	71	28	11	5
K	370	150	59	23	9
M	3700	1500	590	234	93

This table shows that for instance a very 'classical' star of spectral type FV or GV with an apparent magnitude of the order of 10 to 12, may have a companion at a distance that may reach one arc-min! Some such systems are well known but how many have not been discovered and who will be interested in starting a systematic survey of such systems?

5. Multiple Stars

The genesis of the stellar medium does not concern only single stars and simple binaries but also multiple systems. Statistics on multiple systems is far from being complete, and their genesis remains a puzzle.

Here, also a correct census is urgently needed. A particularly important effort seems to be made for discovering close companions to components of already known visual binaries. But, once again, no special survey seems to have been undertaken to discover additional wide components to known spectroscopic or visual pairs.

Without such a correct census of the multiple systems, no useful statistics may be conducted to recognize any law or correlations concerning mass distribution, dynamical and astrophysical characteristics of their components, or to define a limit between multiple systems and open clusters.

6. Conclusion

From this rough survey of the problems related to double star astronomy it appears that medium wide and wide pairs are of a very great importance but that their study is extraordinarily neglected. Their high frequency and the difficulties of organizing in the most efficient way, a survey of discoveries, are fundamentally responsible of this situation. But this does not change the urgent need of undertaking this tremendous amount of work to complete the present statistical material.

Ground-based equipment will be needed in the field of photometry and spectroscopy (spectral classification and radial velocities) but expected new space techniques will be of the greatest efficiency. In particular the HIPPARCOS astrometry satellite may not

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only improve the census of double and multiple systems by new discoveries, but may also, by accurate parallaxes and proper motion determinations, make usable dynamical criteria to recognise optical from physical systems.

We must keep in mind that as long as a sufficiently correct census of all double and multiple systems will not have been realized, no valuable statistical research will be possible in this important field of astronomy for stellar evolution and galactic dynamics.