VISUAL BINARY SYSTEMS IN THE SOLAR NEIGHBOURHOOD: THE MASS-RATIO DISTRIBUTION

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Abstract. Nearby visual binaries, with both components on the Main Sequence, have been considered in order to obtain information about the distribution of their mass ratios. These systems have their primary components ranging from A0 to G9. The data have been corrected for selection effects and the differences \( \Delta V \) of the visual magnitudes have been transformed into mass-ratio values.

The frequency distribution of the mass ratios appears to be bimodal, with a peak around unity and a maximum at about 0.25. It is suggested that this feature may be indicative of different mechanisms of formation for wide binaries.

1. Introduction

A high percentage of stars is gravitationally bound in binary or multiple systems. Due to the huge variety of the configurations, which range from contact binaries to common proper-motion pairs, many mechanisms are thought to be working in the binary formation (e.g., Zinnecker, 1984). Various theories have been elaborated on this subject but results, often in disagreement, are far from being universally accepted. Further difficulty is created by the lack of homogeneous sets of the observational data as, according to their separations, the double stars require different methods of detecting. Lastly, the observational data are biased by several selection effects.

The initial frequency distributions of the mass ratios and the orbital periods are high significance clues for the understanding of the processes of binary formation. As far as unevolved close binaries are concerned, the results achieved support either a clustering of the mass ratios at values not far from unity (e.g., Lucy and Ricco, 1979; Vansina and de Grève, 1982), or a bi-modal frequency distribution (e.g., Trimble, 1974; Fofi et al., 1983). For the wide, i.e., visual binaries, the mass ratios obtained from the masses of the single components are few and, for statistical purposes, they are evaluated from the differences of visual magnitudes. In this manner, among various authors, Kuiper (1935) and, more recently, Halbwachs (1983) found that the frequency-distribution of the mass ratios was a decreasing function of \( \mu (\mu = M_2/M_1 \leq 1) \). On the contrary, observed and theoretical distributions of the differences of magnitude, performed by Scalo et al. (1978) suggest a mass-ratio distribution with a trend opposite to that cited above; Trimble and Walker (1986), by analysing visual binaries with known orbits, obtain a distribution of mass ratios sharply peaked towards unity.

An extensive review of this subject – from the observational and theoretical points...
of view – has been given by Zinnecker (1984). According to his conclusions, a main problem concerning binary formation is to establish 'whether the frequency distribution of the mass ratios increases or decreases towards small mass ratios'.

In this paper we will examine a homogeneous set of visual binaries in order to throw some light on the problem.

2. Observational Data

A clear-cut division between close and wide systems, justified by intrinsic dissimilarities, has not yet been established. The assignment of a binary to each category depends on the nature of the observations and, therefore, mainly on the length of its orbital period. In this paper we consider those binaries, defined, in the current literature 'visual'; for those the magnitudes of the components are measured individually; in some cases, a system may be, also, a spectroscopic binary.

In order to limit the selection effects and, eventually, to compare apparent and absolute magnitudes, the data source has been Gliese's (1969, 1979) Catalogue of Nearby Stars and its supplement. Systems examined have a double entry in the Catalogue, one for each component; our distinction between visual binaries, and common proper-motion pairs agrees with the data of the Catalogue, to which the reader is referred to for further details.

Differences of the visual apparent magnitudes $\Delta V = V_2 - V_1$ have been calculated, only for the binaries for which each component is not, in turn, a double star, and with both components on the Main Sequence. In the multiple visual systems, the magnitude difference refers to the closest pair. At a first analysis, common proper-motion pairs have not been included. Errors in the data are, obviously, due only to the photometric measurements.

For several systems it would be possible to determine the difference between the bolometric magnitudes (via colour index and bolometric correction), which is more strictly related to the mass ratio; but the failure in applying this procedure to many faint companions, for which no colour index is available, would cause a bias towards the largest values of the magnitude difference.

The behaviour of the difference $\Delta V$ against the mass ratio $\mu$ depends on the mass of the primary component, owing to the changing slope of the mass-luminosity relation and to the different contribution of the visual to the total luminosity, along the Main Sequence. Thus, by combining the data of the masses and the absolute visual magnitudes (Allen, 1973) in the range of primary masses $3.2 M_\odot \geq M_1 \geq 0.16 M_\odot$, we have obtained various curves, of which the lower and the upper envelope are shown in Figure 1. The chosen range of the masses corresponds to the spectral types from A0 to M6, which cover the range of the primary components of the examined systems.

The histogram of the $\Delta V$-values is displayed in Figure 2. One system, not included, has a $\Delta V > 10$ mag. Small segments, in the upper part of the figure, represent the ranges of the magnitude difference, that correspond to fixed mass ratios as inferred from Figure 1.