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MULTIPLE STARS WITH LOW HIERARCHY: STABLE OR UNSTABLE?

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Abstract. A short review of the multiple star studies is presented. Various methods of observations and orbit constructing for multiple stars are discussed — visual, specle-interferometric, spectroscopic, photometric etc. The basic goal of such studies is to understand the origin and evolution of multiple stars. A new scheme of multiple star classification is suggested: a) Trapezia; b) high-hierarchical; c) intermediate class — low-hierarchical systems. The systems of the first class are unstable (the seldom exceptions are motions in the vicinities of stable periodic orbits). High-hierarchical systems are probably stable (possible exceptions are the systems with very strongly elongated orbits of outer pairs). The low-hierarchical systems can be either stable or unstable. A list of low-hierarchical multiple systems is compiled. Their main parameters (orbital elements and masses of components) are determined. A reliability of their orbits and masses, actual system multiplicity and other properties are discussed. The results of stability analysis for a few such systems are given. Scenaria of unstable system formation are proposed.

1. INTRODUCTION

In this work we introduce a new intermediate type of multiple stars — low-hierarchical systems. We discuss the orbital parameters of such systems and find a few possible unstable systems.

Next evident question is the origin of such systems. The first answer is that they could be due to errors of observations and their interpretation. The second one consists in actual instability. We suggest a few scenarios for unstable system formation.

Stability of a system is strongly connected with its dynamics, at the same time dynamics of the system is connected with its actual configuration. Historically, the configurations of multiple stars were separated into two types: Trapezium-type (or non-hierarchical) systems and ϵ Lyrae-type (or hierarchical) systems. We suggest to introduce an intermediate type of low-hierarchical systems. As one example of such systems we consider the probably quadruple system HD 40887 (see Tokovinin et al., 2005).

The systems with high hierarchy are stable with a high probability. The motions in such systems are almost Keplerian. Principally another situation is with Trapezium-type systems. As a rule, these systems are unstable. The evolution is finished by formation of a stable configuration: binary or hierarchical multiple. The actual Trapezium-type stars must be dynamically young. The low-hierarchical systems could be either stable or unstable. One needs to check carefully each such system.

2. SYSTEMS STABILITY AND THE METHOD OF STUDY

Stability or instability of a multiple system might be connected with its formation. We could consider a few formation scenarios:

1. Escape from unstable non-hierarchical small groups or clusters.

2. Common formation as stable or unstable unit (mostly in binary and triple systems according to Goodwin and Kroupa, 2005).

3. Capture in the galactic field or in a field of common gas-star complex.

In order to verify the stability of actual multiple stars, we compile a sample of 19 multiple systems with measured orbital elements of all subsystems. Amongst them there are 16 triple systems (close binaries with $P < 10^d$ were considered as single components) and three quadruple systems.

Two methods for stability check were used:

1. Stability criteria for triple systems.
2. Numerical simulations for all systems.

We consider future and past evolution for all systems during one million years (sometimes ten million years).

The data on orbital elements and masses have the uncertainties. In order to check the effect of these errors, we have used the Monte Carlo approach: orbital elements and masses were varied using the independent Gaussian distributions, where the mean values were taken as the observed values and the standard deviations are the same as their root mean square errors. One thousand runs were considered for each system.

In the next section we briefly discuss the most interesting systems showing instability. The orbits were taken from VBO 6th Catalogue.

3. SOME SYSTEMS OF INTEREST

HD 40887 is probably a quadruple system, its outer orbit is unreliable (Fig. 1). Further observations and their careful analysis are necessary. Especially the accurate radial velocities would be extremely useful for external orbit determination.

HD 76644 is quadruple, one of inner orbits has undefined angular elements, outer orbit has about a quarter of arc, however, its eccentricity is not so reliable (Fig. 2).

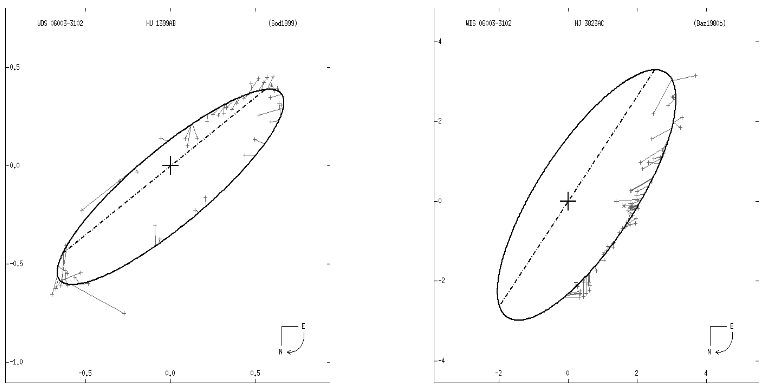

Figure 1: Inner and outer orbits for the system HD 40887.

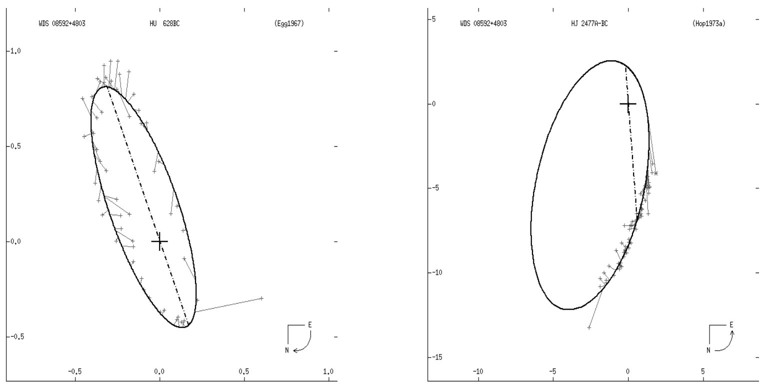

Figure 2: Inner and outer orbits for the system HD 76644.

HD 136176 is triple. It has a reliable outer orbit of a period of about 200 yr, however inner binary (with period of about 50 yr) is almost rectilinear in projection and may have significant errors (Fig. 3).

HD 150680 is astrometric triple whose faintest component was observed only once in infrared (Fig. 4). Inner orbit was found by analyzing perturbations, so it cannot be considered as reliable. The infrared specle interferometry is strongly desirable for this system.

HD 217675/6 has an undefined multiplicity (Fig. 5). Last orbit determinations which were made in Belgrade (Olević and Cvetković, 2005) may indicate stability.

HD 222326 is a triple system, where outer orbit was reconstructed from a 110° arc and is rather reliable (Fig. 6). Inner orbit is less reliable. It is based only on five speckle-interferometric observations made at Special Astrophysical Observatory (Balega et al., 1999).

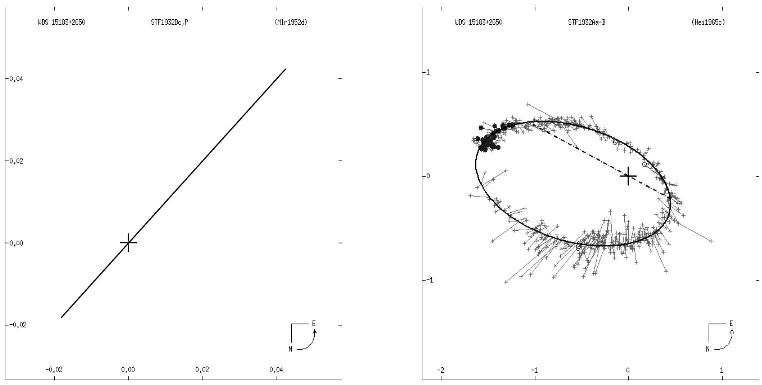

Figure 3: Inner and outer orbits for the system HD 136176.

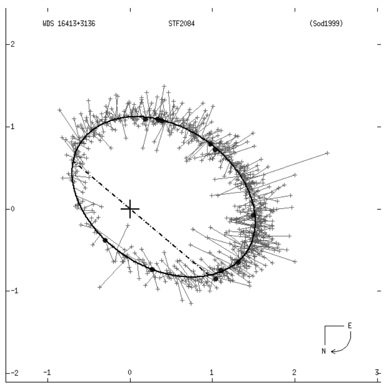

Figure 4: Outer orbit for the system HD 150680.

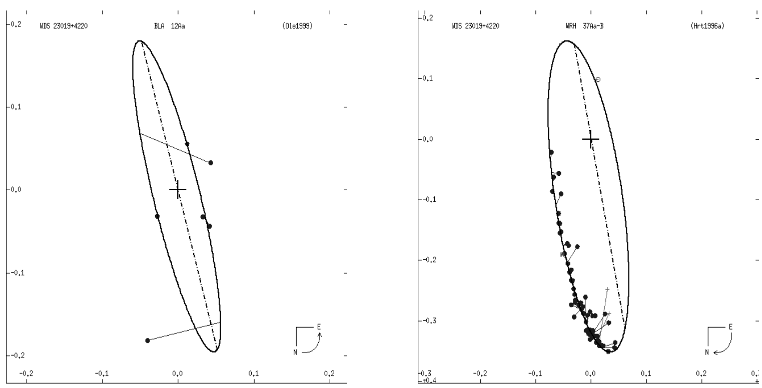

Figure 5: Inner and outer orbits for the system HD 217675/6.

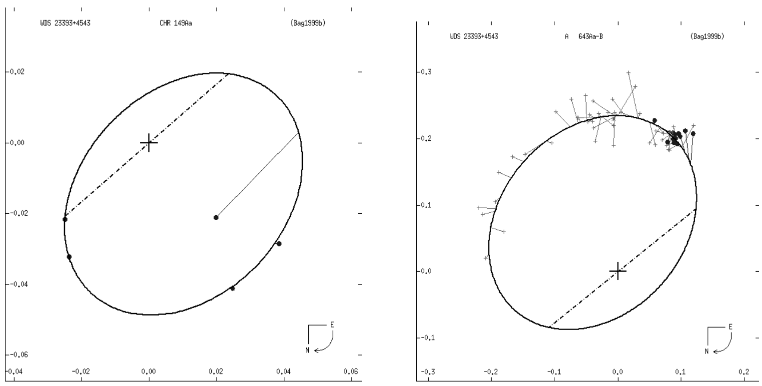

Figure 6: Inner and outer orbits for the system HD 222326.

4. RESULTS AND CONCLUSIONS

The main results of our analysis are as follows. Two populations of multiple stars were found: probably stable and probably unstable. The gap between these two populations is rather wide. We give the list of probably unstable systems. Among them there are one quadruplet, two probable quadruplets, and three triplets.

Possible explanations of unstable system phenomenon are as follows: 1) physical youth of components; 2) additional effects; 3) errors of observations and interpretation; 4) temporary capture; 5) stability loss via encounter with a massive object; 6) product of dissipation of stellar group or cluster. We think that the first point is not the only possibility.

We have roughly estimated the expected number of unstable systems within the solar neighborhood of two hundred parsecs due to the last three mechanisms, which turned out to be non negligible (about ten).

In conclusion, we can formulate a few propositions:

1. One can separate multiple stars into high-hierarchical, low-hierarchical, and non-hierarchical systems.

2. High-hierarchical systems are long-term stable.

3. Non-hierarchical systems usually disrupt.

4. Low-hierarchical systems may be either stable or unstable.

5. A few scenarios for their instability are suggested.

The future observations and their careful analysis would resolve the stability issue for the concrete low-hierarchical multiple systems.

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