A GENERAL SCHEME OF NEWTONIAN INTERACTIONS IN SYSTEMS OF GRAVITATING MASSES

(Letter to the Editor)

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Abstract. This Letter reviews the results by computer simulations on the three-body problem carried out at Leningrad University Astronomical Observatory (Anosova, 1986, 1988, 1989). The intensive systematic studies of triple systems with negative and positive total energies have yielded the general features of the evolution of these systems. The processes of formation of the wide and hard binaries have been studied in details. The scenario of the general class of the final motions of the triple systems with negative total energy is considered, the necessary conditions of disruption of these systems are formulated.

1. Introduction

The multiple systems of the different objects are the general elements of the structure of the Universe at the different scales. The nearest star to the Sun (α Cen) is the triple system. Our Milky Way and the Magellanic Clouds as well as Andromeda and its two satellites are the triple galaxies.

The multiple stars and galaxies are observed inside the galactic and metagalactic fields; the ratios of a number of the single, double, triple, and more multiple systems inside the both fields are close to 0.45 : 0.35 : 0.10 : 0.10. Often, the stars of the different spectral classes as well as the luminosity classes and peculiar stars included in one system. The galaxies of the different morphological types (spiral, elliptic, irregular in any combination) are observed in the multiple systems. Some interesting examples of the multiple galaxies are the interacting and Seyfert galaxies. Multiple stars and galaxies are inside the clusters of these objects – moving, open, and globular star clusters, star associations and complexes, clusters and superclusters of galaxies. Some multiple star clusters are inside the Galaxy, some multiple clusters and superclusters are inside the metagalaxy. The multiple cores are observed in the central regions of some galaxies, the multiple QSOs are discovered.

The gravitational N-body problem was applied to celestial mechanics soon after the discovery of Newton’s universal law. However, in the course of three centuries the analytical studies have not provided an effective solution to the main problems. Today, numerical methods may be used for obtaining detailed solutions. Computer simulations of the N-body problem were first performed by von Hoerner (1960) who studied the evolution of small systems (N = 4–25). Further advances of the direct method as well as increased computer power have yielded significant results for systems with N = 500 components (Aarseth, 1973; Wielen, 1974).
A wide range of triple systems occur among stars and galaxies, and their kinematics and dynamics are of considerable cosmologic interest. Moreover, studies of dynamical evolution of $N$-body systems with $N = 10 - 500$ have shown that three-body interactions play a crucial role in the central regions of open and globular clusters, as well as galaxy clusters. Consequently, the study of the three-body problem is relevant to the subjects of celestial mechanics and stellar dynamics alike.

It should be noted that the study of large $N$-body systems requires considerable amounts of computer time (roughly proportional to $N^3$), hence, the number of different initial conditions which can be examined is relatively limited. On the other hand, small $N$ systems offer good prospects of systematic investigations, particularly in the case of $N = 3$. The shortening of computer process-time permits statistical methods to be used for studying the behaviour of triple systems. This is achieved by selecting a representative sample of initial conditions which then reveal general features of the evolution.

As a rule, the multiple stars inside the galactic field are isolated form the background objects. The probability of the random encounters of the star components of the multiple stars in the solar neighbourhood as small. Therefore, one may consider the members of such systems as the genetically connected between themselves, formed together, in the majority of cases. Thus a study of the multiple stars may be closely connected with a problem of star formation in the Galaxy. It is well-known that the non-hierarchical multiple stars (Trapezium systems) are often inside the young open clusters and associations – possibly the active zones of the star formation. The star density is large inside the central regions of the open and especially globular clusters; here some formation of the binary, triple, and more multiple stars is possible by a capture as result from the often close encounters of the stars. Therefore, in such systems the components may have any genetic connection.

The genetic connection among the members of the multiple galaxies is more complicated problem, as usually the galaxy groups are in a smaller degree isolated from a background in comparison with the multiple stars in the solar neighbourhood.

Therefore, a study of dynamics of the multiple star and galaxy systems, the problem of their stability is one of the fundamental and actual problems of the astronomy and cosmology.

2. Triple Systems with Positive Total Energy; Formation, Evolution, and Disruption Binaries in the Field

The isolated triple star and galaxy systems with a positive total energy are unstable, their disruption (a dissipation of the components having a positive energy) must be during a short time. The dynamics of such systems may result the formation, evolution, and disruption of the binaries in the field.

A continuous variation of a share of binaries takes place in general field. This variation is observed in a field until the establishment of the quasi-equilibrium state. The strict equilibrium of field is impossible.

The dynamical processes of changes of binary number in field are the following: