ESCAPE VELOCITIES FROM UNSTABLE TRIPLE STARS

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In order to investigate a possible origin for stars with high peculiar velocities in the thick disc of our Galaxy, the dynamical evolution of 16 000 three-dimensional triple systems which consist of a binary with equal or comparable masses of components M_1 and M_2 and a low-mass third body M_3 is considered. We examine an extensive range of initial conditions with positions of the body M_3 randomly distributed around and inside the binary orbit. M_3 was given the initial radial velocity V_0 with respect to the center of inertia of the binary. The following dynamical system of units is used in this work: the unit of distance is the semi-major axis of the binary orbit, the unit of time is the period of the binary; the universal constant of gravity is unity. In these units the total mass of the close binary is $4\pi^2$.

For all cases under consideration, before the ejection of a particle from a triple system we observe a close approach of the low-mass body to the center of inertia of the system. After this, for most cases, the small body escapes; we have here a 'gravitational slingshot'. The final velocity V_{fin} of an escaper was evaluated with respect to the center of gravity of the triple system at the time T_{esc} when the criterion of escape (Marchal, Yoshida & Sun-Yu-Sui 1983) is satisfied. The distribution and average values of final velocities and distances of escapers from the center of gravity of triple systems were obtained. They show that stars escaping by direct ejection from unstable triple systems can have large peculiar velocities with respect to field stars of the Galactic disc. Table 1 shows distributions of final distance R_{fin} and of the ratio V_{fin}/V_{crit} for the low-mass body after time $T = 40$, where V_{crit} is the critical escape velocity for M_3. These results are obtained for $R_0 = 2$,

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TABLE 1. Distributions of final velocities and distances of escapers.

V	0-1	1-2	2-4	4-6	6-8	
$f(V)$	0.178	0.179	0.231	0.162	0.097	
V	8-10	10-12	12-14	14-16	16-18	18-20
$f(V)$	0.065	0.038	0.023	0.017	0.008	0.002
R	0-5	5-35	35-70	70-105	105-140	
$f(R)$	0.028	0.139	0.187	0.196	0.180	
R	140-175	175-210	210-245	245-280	280-320	320-355
$f(R)$	0.116	0.076	0.040	0.020	0.014	0.003

TABLE 2. Final velocities in km/s for actual triple stars.

a	$1au$	$10au$	$100au$	$f(N)$
$V^* = 18V_{crit}$	$758km/s$	$232km/s$	$76km/s$	0.02%
$V^* = 15V_{crit}$	$632km/s$	$200km/s$	$63km/s$	1.8%
$V^* = 10V_{crit}$	$421km/s$	$133km/s$	$82km/s$	8.8%
$V^* = 4V_{crit}$	$168km/s$	$53km/s$	$17km/s$	41.2%

masses of components of the binary $M_2 = 0.5M_1$, initial radial velocity of low-mass body (1) $V_0 = 0.1V_{crit}$ and (2) $V_0 = 0.5V_{crit}$ (1000 initial conditions for each), and $M_3 = 10^{-2}$. For these parameters we obtained the largest final velocities of escapers. The number of escapers was 870 for case (1) and 808 for case (2). The average values of R_{fin} and V_{fin} are $< R_{fin} >= 103.87 \pm 68.50$ and $< V_{fin} >= 4.12 \pm 3.65$. At the final time, only 3% of particles have distance from the system center of $R_{fin} < 5$, but 73.0% have $R_{fin} > 50$; 47.6% of particles have $R_{fin} > 100$, 9.9% have $R_{fin} > 200$ and 1.0% have $R_{fin} > 300$. In our previous work (Kiseleva, Anosova, Colin 1994) we have shown that whan $R > 50$ the influence of the remaining binary on the escaping star is negligible.

Table 2 gives the possible values V^* of V_{fin} (in km/s) for escapers and fractions of escapers with $V_{fin} > V^*$ for different kinds of remaining binary stars. One can see that sometimes escapers with very high velocities can be produced by unstable triple stars. Thus, the dynamical evolution of close triple stars can sometimes produce high velocity stars in the Galaxy although there is no clear estimate of the number of such unstable triple stars in the initial stage of galactic formation and evolution. But at least it seems realistic enough that a certain number of highly energetic stars could be the results of escaping processes in unstable triple and multiple stars.

References

Kiseleva L., Anosova J. , Colin J. IAU 164 Proceedings, 1994,in press.