THE DYNAMICAL EVOLUTION OF THE ORION TRAPEZIUM

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RESUMEN

Con datos observacionales recientes sobre las velocidades transversales y radiales de las estrellas más brillantes del Trapecio de Orión estudiamos la evolución dinámica de grupos de sistemas múltiples como el Trapecio. Para ello, realizamos integraciones numéricas de N cuerpos con las posiciones y velocidades observadas, con posiciones z al azar, y con perturbaciones compatibles con los errores de observación. Discutimos los resultados de la evolución dinámica y las propiedades de las binarias resultantes.

ABSTRACT

Using recent observational data on transverse and radial velocities of the bright Orion Trapezium stars we study the dynamical evolution of ensembles of systems mimicking the Trapezium. To this end we perform numerical N-body integrations using the observed planar positions and velocities, the radial velocities, and random z-positions for all components. We include perturbations in these quantities compatible with the observational errors. We discuss the dynamical outcome of the evolution of such systems and the properties of the resulting binaries.

Key Words: binaries: general — stars: early-type — stars: formation — stars: kinematics and dynamics — stars: pre-main sequence

1. INTRODUCTION

The Orion Trapezium is one of the best studied multiple systems. However, it still presents us with many challenges, both observational and theoretical. So, for instance, the masses and radial velocities even of the brightest components are quite uncertain. The dynamical state of the Trapezium is still unclear. To cast light on the latter problem, we use a recent determination of the transverse velocities (Olivares et al. 2013) and radial velocities from the literature to study the dynamical evolution of ensembles of systems mimicking the Orion Trapezium in the plane of the sky, by means of numerical N-body integrations.

2. THE NUMERICAL MODEL

For the numerical integrations we use the well-tested code of Mikkola & Aarseth (1993). In view of its large uncertainty, we use three different values for the mass of Component C, the most massive one (Allen et al. 2017 and references therein). We take the planar positions and velocities, along with their errors, from Olivares et al. (2013). The radial velocities and masses, as well as their errors, were taken from the literature (see Allen et al. 2017 and references therein, for an extensive discussion). The z-positions were assigned randomly, preserving the trapezium configuration. For the distance to the Orion Trapezium we adopted the value of Menten et al. (2007), namely, 414 pc. To model the ensembles, we employ a Monte Carlo approach, perturbing each observed value by amounts compatible with the observational uncertainties. We assumed that all components are point masses. This is allowable since we found that during the integrations no close encounters occurred.

3. RESULTS

Taking 45 $M_\odot$ for the mass of Component C, the lifetimes of the systems turn out to be extremely short. Figure 1 shows the number of trapezia surviving at different values of the crossing time, corresponding to different ages. As the figure shows, after about 10,000 years, only 5 percent of the systems survive as trapezia resembling the original configuration. After about a million years, our results indicate that 81% of the systems completely disintegrate, leaving only a binary. Adopting larger values for the mass of Component C, namely 65 or 70 $M_\odot$ we obtain lifetimes that are still short, but more plausible, about 30,000 years. Figure 2 displays our results, with a larger mass for Component C, namely 65 $M_\odot$. It is seen that the lifetimes, while still short, increase substantially. They are now approximately 30,000 years. These lifetimes are, in fact, similar to the value we found for one of the components of the Orion Trapezium, θ^1Ori B, the minicluster (Allen et al. 2015), in a completely different study. We also

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Fig. 1. Number of different systems generated from 100 initial trapezia ($M_C = 45M_\odot$) as a function of crossing time or age. t stands for trapezia of both types (1, 2, 3, 4) and (1-2, 3, 4), NHT for Non-Hierarchical Triples, HT for Hierarchical Triples, H for Hierarchical Quadruples and B for Binaries.

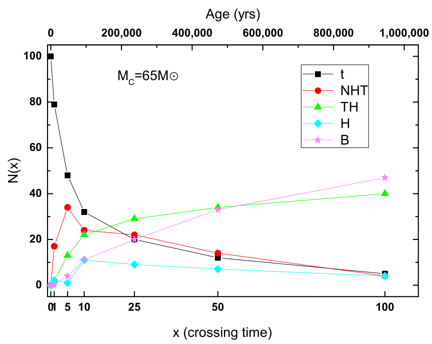

Fig. 2. Number of different systems generated from 100 initial trapezia ($M_C = 65M_\odot$) as a function of crossing time or age. Labels as in Figure 1.

find that Star E always escapes right at the beginning of the integrations. Reversing the integrations in time, we find that Star E is captured in about 25% of the cases, within about 2000 years. This shows that it is possible that the escaping spectroscopic binary θ^1Ori E (Costero et al. 2008) was bound to the system in recent times, and that it acquired its escape velocity as a result of dynamical interactions.

We now look at our results from an observational point of view. Observers would not be likely to identify a multiple system as such if the components are separated by more than about 100 arc seconds. Figures 3 and 4 are similar to Figures 1 an 2, but now plotting the numbers of “observable” systems, as described above. Note that some multiples will be observed as binaries. It is clear that for the small value of the mass of component C the lifetimes become even shorter than previously found. Again, with the larger value for the mass of Component C, the “observable” results appear more plausible.

At the end of the numerical integrations we usually find a binary, sometimes a hierarchical triple. We study the distribution of semiaxes and eccentricities of these binaries, and find that the semiaxis distribution has a maximum around 2000 AU. Thus, the dissolution of multiple systems similar to the Orion Trapezium may be partly responsible for populating the field with wide massive binaries. The binaries show an eccentricity distribution approximately thermal. The dynamical evolution of Orion Trapezium-like multiple systems does not produce

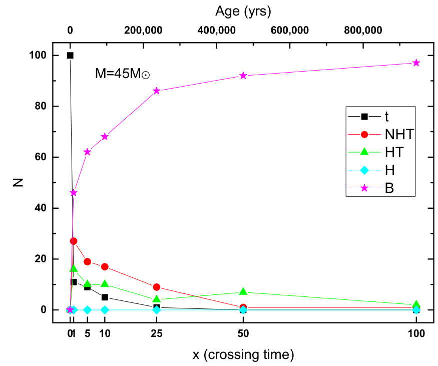

Fig. 3. Number of different “observable” systems generated from 100 initial trapezia ($M_C = 45M_\odot$) as a function of crossing time or age. Labels as in Figure 1.

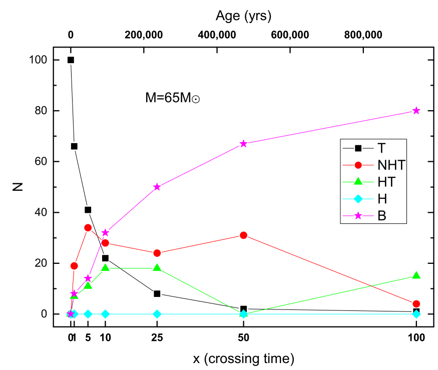

Fig. 4. Number of different “observable” systems generated from 100 initial trapezia ($M_C = 65M_\odot$) as a function of crossing time or age. Labels as in Figure 1.

runaway stars. Instead, the escaping stars have velocities close to the escape velocity.

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