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DINAMICAL EVOLUTION OF WIDE BINARIES

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RESUMEN

Simulamos numericamente encuentros de binarias de periodo largo con estrellas del campo y nubes moleculares gigantes, mediante la aproximación de impulso. Analizamos la evolución temporal de las distribuciones de excentricidades y semiejes mayores de binarias de periodo largo con condiciones iniciales dadas a intervalos de 10^9 hasta 10^{10} años (edad supuesta para la Galaxia). Estimamos la fracción de binarias que sobreviven encuentros estelares, con nubes moleculares y una combinación de ambas y, de ahí, el tiempo dinámica para diferentes semiejes mayores y masas (0.5, 1.0, 1.2, 1.5, 2.5, y 3.0 $M_\odot$). Para encuentros con nubes moleculares analizamos la influencia de la inclinación inicial del plano orbital de la binaria con el plano perpendicular al vector de la velocidad relativa entre la binaria y la nube. Encontramos que el efecto perturbador es máximo cuando el ángulo es mínimo.

ABSTRACT

We simulate numerically encounters of wide binaries with field stars and Giant Molecular Clouds (GMCs) by means of the impulse approximation. We analyze the time evolution of the distributions of eccentricities and semimajor axes of wide binaries with given initial conditions, at intervals of 10^9 yr, up to 10^{10} yr (assumed age of the Galaxy). We compute the fraction of surviving binaries for stellar encounters, for GMC encounters and for a combination of both, and hence, the dynamical lifetime for different semimajor axes and different masses of binaries (0.5, 1, 1.2, 1.5, 2.5, and 3 $M_\odot$). We find that the dynamical lifetime of wide binaries considering only GMCs is half than that considering only stars. For encounters with GMCs we analyze the influence of the initial inclination of the orbital plane of the binary with respect to the plane perpendicular to the relative velocity vector of the binary and the GMC. We find that the perturbation is maximum when the angle is minimum.

Key Words: **STARS: DYNAMICS — WIDE BINARIES**

1. THE MODEL

We consider samples of 500, 1000 or 5000 fictitious binaries with initial semimajor axes (a_i) ranging from $5 \times 10^3 AU$ to $9 \times 10^4 AU$. The binaries have a combined mass of 1.5 $M_\odot$. For the passing stars we adopt a flux of ten stars with an average mass $M = 0.88$ $M_\odot$ per million of years passing to less than 2.5×10^5 AU with a mean relative velocity of $V_* = 30$ km s^{-1} (Fernández 1980). For the GMCs we adopt a flux of one GMC per 10^9 yr with a mass $M = 5 \times 10^5$ $M_\odot$, and a radius of 27 pc with a mean relative velocity of $V_{GMC} = 20$ km s^{-1} (Brunini & Fernández 1996) . The mass of the GMC is distributed into 2500 clumps of mass M_c with a differential mass distribution $\propto M_c^{-1.5}$, ranging between $8 M_\odot$ and $5 \times 10^3 M_\odot$. For the fast encounters we consider the relative trajectory to be a straight line. We have randomly chosen the orbital parameters of the binaries as well as the impact parameter of the A component, $\vec{p_A}$, and recomputed them after every encounter with a star or a clump.

The radius R_c of each clump was computed with a density of $10^{4.5} H_2$ molecules cm^{-3} if its mass is > 1000 $M_\odot$ and with a density of $10^{5.5} H_2$ molecules cm^{-3} if its mass is < 1000 $M_\odot$. If the impact parameter

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$p_{A,B}$ is larger than the radius we apply for each component of the binary the impulse approximation

$$\Delta\vec{v}_{A,B} = \left(2GM/V_{*,GMC}\right)\,\left(\vec{p}_{a,b}/p^2_{a,b}\right)\ ,$$

to calculate its variation of velocity, either for an encounter with a star or a clump within a GMC, of mass M. If the impact parameter $p_{\vec{A},B}$ is smaller than the radius we apply a modification of the impulse approximation (Biermann 1978) for the case of a penetrating encounter with a GMC assumed to be homogeneous and spherical

$$\Delta\vec{v}_{A,B} = \frac{2GM}{V_{GMC}}\frac{\vec{p}_{a,b}}{p^2_{a,b}}\left[1-\left(1-\frac{p^2_{a,b}}{R^2}\right)^{\frac{3}{2}}\right].$$

2. RESULTS

For $a_i = 2.5 \times 10^4$ AU we obtain $\tau_{1/2} = 3.0 \times 10^9$ yr (time for which the initial number of binaries reduces by a factor of 1/2). As a comparison Hut & Tremaine (1985) obtained $\tau_{1/2} = 2.8 \times 10^9$ yr, while Weimberg et al. (1986) obtained $\tau_{1/2} = 2.3 \times 10^9$ yr for $a_i = 0.12$ pc $\approx 2.5 \times 10^4$ AU and $M_{AB} = 1\ M_\odot$. For different semimajor axes we obtain a relationship between a_i and $\tau_{1/2}$ well fitted by the formula

$$\tau_{1/2} \approx 1.37 \times 10^{16}\ \mathrm{yr}\,(a_i/A.U.)^{-1.52} \approx 1.14 \times 10^8\ \mathrm{yr}\,(a_i/\mathrm{pc})^{-1.52}\ .$$

As a comparison, Weimberg et al. (1986) find for binaries of $M_{AB} = 1M_\odot$ the expression $\tau_{1/2} \approx 6 \times 10^7 \mathrm{yr}\,(a_i/\mathrm{pc})^{-1.4}$. For different masses of binaries and $a_i = 4.5 \times 10^4$ AU we obtain a relationship between M_{AB} and $\tau_{1/2}$ well fitted by the expression $\tau_{1/2} \approx 10^9 yr\,(M_{AB}/M_\odot)^{0.67}$.

We also compare the percentage of binaries with semimajor axes $\geq 10^4 AU$ with respect to those with semimajor axes $\geq 10^3 AU$ in: (A) observed sample taken from the catalog by Poveda et al. (1994), (B) the computed sample with initial semimajor axes randomly selected between $10^3 AU$ and $8.5 \times 10^3 AU$, and (C) the computed sample with initial semimajor axes selected between 10^3 and $8.5 \times 10^3 AU$ with equipartition of energy. The limit of $8.5 \times 10^3 AU \approx 0.04$ pc is suggested by Larson (1995) from the analysis of a bimodal distribution of separation of pre-main-sequence binaries. For sample A the percentage for all binaries (young and old) is 19.3. For B and C they increase with age up to 14.83 for 10^{10} yr and 4.11 for 10^{10} yr, respectively.

3. CONCLUSIONS

Our conclusions are: (i) The evolved distributions of semimajor axes show a large spread, in agreement with the observed long tails in the distribution of semimajor axes; (ii) We find a dynamical lifetime $\tau_{1/2} = 3.0 \times 10^9$ yr for binaries with $a_i = 2.5 \times 10^4$ AU, which is in fairly good agreement with results obtained by other authors; (iii) We find a exponential relationship (with index –1.52) between $\tau_{1/2}$ and the binary semimajor axes; (iv) We find a potential relationship (with index 0.67) between $\tau_{1/2}$ and the binary masses; (v) We find a fairly good fit of our computed distribution of semimajor axes for samples with initial semimajor axes smaller than $8.5 \times 10^3 A.U. \approx 0.04$ pc to the observed distribution presented by Poveda et al. (1994).

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