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DYNAMICS OF PLANETARY SYSTEMS IN DIFFERENT GALACTIC ENVIRONMENTS

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RESUMEN

En términos orbitales, los discos planetarios son entidades muy frágiles. Las interacciones gravitacionales con otras estrellas generan cambios en los parámetros orbitales de los planetas. La Vía Láctea contiene diferentes ambientes, algunos de los cuales pueden generar órbitas extremas disminuyendo o incluso haciendo desaparecer la posibilidad de habitabilidad. En este trabajo estudiamos los efectos causados por encuentros estelares con los parámetros adecuados a los diferentes ambientes Galácticos, sobre un modelo planetario simple.

ABSTRACT

In terms of orbital dynamics, planetary and debris discs in general are very fragile entities. Gravitational interactions with other nearby stars can generate changes in the orbital parameters of planets. The Milky Way has different environments, some of which might generate extreme planetary orbits, diminishing or even removing completely the possibility for habitability. In this work we have studied gravitational effects caused by stellar encounters with the appropriate masses, velocities and stellar densities, representing different Galactic environments, using a simple model of a planetary system (test particle discs).

Key Words: Galaxy: globular clusters: general — planetary systems: protoplanetary disks

1. SOLAR NEIGHBOURHOOOD

For this Galactic zone we have constructed a code that provides us, for any star with known 3D position in the sky, its trajectory, its closest approach to the Sun and the time for the encounter. This code differs from others in that, instead of a straight-line approximation to calculate the stellar trajectory, it uses a full axisymmetric Galactic potential that includes bulge, disc and halo (Allen & Santillán 1991). The motion equations are solved with the Bulirsh-Stoer integrator. With this code we have calculated the trajectories of the 58 nearest stars to the Sun (with known 3D position and velocity), from the Hipparcos catalogue and the literature (e.g. García-Sánchez et al. 1999). From this, and depending on their radial velocity we have run 30 stars toward the past and 28 stars toward the future. From these potential perturbers of the Solar system, we find the star Gliese 710 has the closest approach to the Sun at approximately 0.34 pc, 1.36 Myr in the future. The closest approach distance vs time of past (negative times) or future (positive times) encounters is shown in Figure 1. We calculate an example for Gliese 710 with a stellar mass of 0.6 $M_{\odot}$ and a velocity of approximately of 13.9 km s^{-1}. In the Solar Neighborhood environment, even the closest approach effects are negligible for the Solar planetary disc (although they might be important for the Oort cloud).

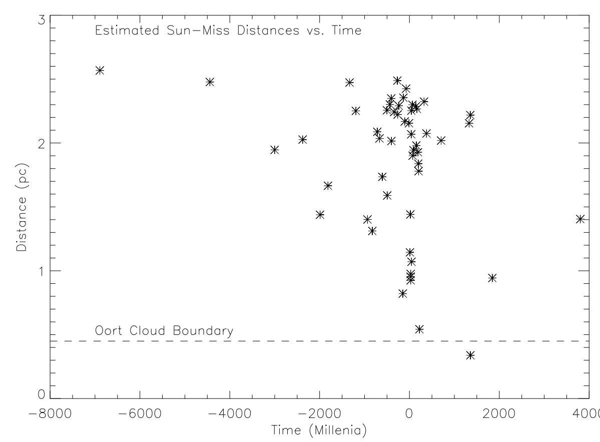

Fig. 1. Missing distance (pc) vs. time (Millenia) of stellar approaches in the Solar Neighborhood.

2. STAR FORMATION: SUN BIRTH CLOUD

Stars in general and the Sun in particular seem to be born in clusters or groups (Looney et al. 2006). In such an environment close encounters that affect orbital parameters of discs are probable (Spurzem et al. 2006). In particular, the Kuiper belt, located between 30 and 50 AU, presents several characteristics that might be explained in a simple manner by

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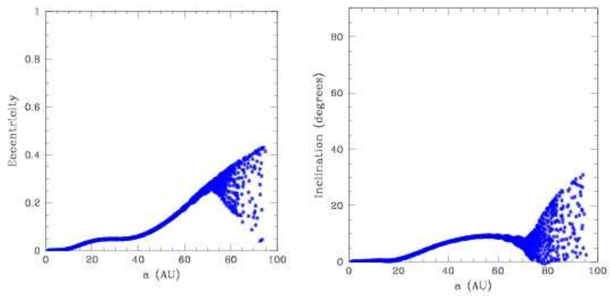

Fig. 2. Left frame: eccentricity, right frame: inclination. Both frames are plotted vs the semimajor axis.

a flyby star, such as the heating of the classic Kuiper belt among others . The densities in clouds of stellar formation change for each cloud, but they are sufficiently high to produce approaches to approximately 200 AU between a pair of stars. The typical velocity dispersion is around 1 km s^{-1}. We have chosen a flyby stellar mass of 1 $M_\odot$. The results are shown in Figure 2. The flyby effect is significant on the external part of the disc where we obtain eccentricities of up to 0.4.

3. GLOBULAR CLUSTERS

Some of the most interesting regions of a galaxy are the globular clusters, due to their extremely crowded environment. We have taken a sample of 15 globular clusters with known parameters (such as core radius and central density) from the literature (Beccari et al. 2006). For the 3D density law necessary for our calculations, we employed a particular case of the generalized Schuster density law (Ninkovic 1998), which results in a much simpler version of a King profile (King 1962) with a finite boundary and fits as well as a King profile for a globular cluster with known core radius and central density. With this information and the velocity dispersion we calculate the number of approaches within radii smaller than 100 AU as a function of radius during a fifth of the age of the Sun $\sim 10^9$ years (Figures 3 and 4). From the sample of Galactic globular clusters we can see that stars suffer, a number of collisions that goes from a few thousands to one, enough to severely perturb circular stable orbits where life as we know it, could not settle down. That is, if there are planets in the central parts, and up to approximately the half mass radius (and in some cases beyond) of globular clusters, they are highly perturbed. Thus, they should be at least in very elliptical orbits, if they have survived at all. Planets in approximately circular orbits are more propitious for life since the so called *habitable zone* is circular.

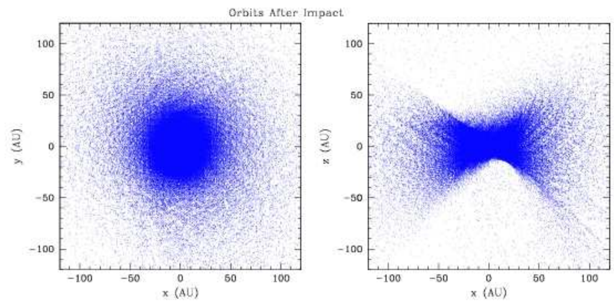

Fig. 3. Effect of a flyby stellar mass of 1 $M_\odot$ whose impact parameter and velocity are 50 AU and 10 km s^{-1}, respectively, n a disc of particles. Left frame: orbits of the particles in the x-y plane, right frame: in the x-z plane. The disc is plotted right after the maximum approach.

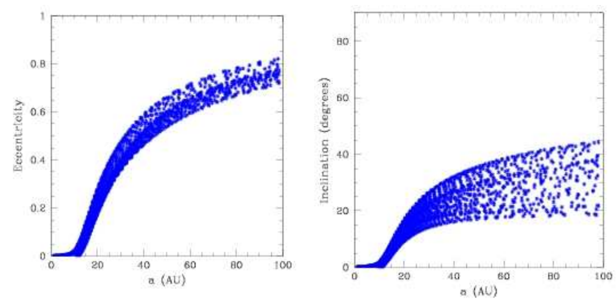

Fig. 4. Left frame: eccentricity, right frame: inclination both frames are plotted versus the semimajor axis.

If there are any non perturbed planets they would have to reside in the outskirts of the globular clusters and specifically around stars with high angular momentum, so they do not reach the central parts of globular clusters. For this example we have taken the typical velocity dispersion of 10 km s^{-1}, 1 Solar mass for the flyby, and an impact parameter of 50 AU calculated from the density law and the known observational parameters from one of the globular clusters (NGC 5272, M3).

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