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Orbital Trends of Binary Pulsars

Tapan Chatterjee

University of Puebla (FCC), Apartado Postal 1316, Puebla, Mexico

Abstract. We try to understand the eccentricity of high-mass binary pulsars using some methods of statistical mechanics.

1. Introduction

There is a high abundance of binaries among pulsars characterized by short spin periods and low magnetic fields, such that binarity seems to be a characteristic of their formation and birth properties (e.g., see Verbunt 1990). High mass binary pulsars (HMBPs) are believed to originate from massive binary systems; during the violent formation epoch some combinations of recoil velocities and masses can leave two neutron stars, of comparable mass, bound in a relative orbit. An analysis of orbital parameters on the basis of statistical mechanics and energy minimization should be conducted to determine the expected eccentricity; further, on the basis of the same characteristics, the orbital evolution should be studied. This will throw light on the formation of such systems. Observations indicate younger HMBPs (e.g., B2303+46 with an age $\sim 3 \times 10^7$ yr) have very eccentric orbits ($e \approx 0.7$; Thorsett et al. 1993), while older ones (e.g., B1543+12 with an age $\sim 2 \times 10^8$ yr) have less eccentric orbits ($e \approx 0.3$; Wolszczan 1991). This is indicative of a circularization process in progress to minimize the energy of the system.

2. Orbital Dynamics and Distribution of Eccentricity

Chatterjee & Magalinsky (2000) consider the problem of the dynamics of two compact bodies (which in this context can be considered as a binary pulsar) with two degrees of freedom, corresponding to their separation and effective size using a condition which favors energy minimization and implies gravity softening. On the basis of statistical mechanics, considering the bound binary to be a subsystem in a microcanonical ensemble, we determine the equilibrium distribution of system parameters. The distribution of the eccentricity, for a given energy, has the form

$$W(\epsilon; \epsilon_m) = Q^{-1}\epsilon^2(1-\epsilon^2)^{-1}(\epsilon_m^2-\epsilon^2)^{-1/2}, \tag{1}$$

with $Q = (\pi/2)[(1-\epsilon_m^2)^{-1/2} - 1]$, ϵ being the eccentricity and ϵ_m its maximum value for a given energy. Thus the equilibrium distribution function is a monotonically increasing function of eccentricity, limited by its maximum value for a given energy. This is such that (after the initial violent phase) binary pulsars are

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expected to have eccentric orbits. A point to be noted is that the distribution is almost insensitive to the orbital and spin angular momentum.

Analytical results on the basis of statistical mechanics (Magalinsky & Chatterjee, in preparation) indicate that the orbit will circularize in the adiabatic regime on a large timescale; ultimately, circularization will take place in an effort to minimize the energy of the system (e.g., Lynden-Bell & Pringle 1974).

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