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The Radial Distribution of Millisecond Pulsars in 47 Tuc

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Abstract. Recent observations of 47 Tuc have revealed a large population of compact objects. Spectral analysis suggests that most of the soft X-ray sources observed by *Chandra* are millisecond pulsars. However, the observed radio millisecond pulsars are much more centrally concentrated, and the probability of this happening by chance is very low. Using our Monte Carlo code "StarFokker" to simulate the dynamical evolution of the cluster, we show that the diffusion time out of the core is very long, and this could explain the observed distribution if the formation of millisecond pulsars took place in the core $\sim 10^9$ years ago.[5]

1. Distribution of Soft X-ray Sources and Millisecond Pulsars

Recent observations (Camilo et al. 2000; Freire et al. 2001; Grindlay et al. 2002) have revealed a population of point X-ray sources and radio millisecond pulsars (MSPs) in 47 Tuc. 17 radio MSPs have known positions, all of which coincide with point X-ray sources. Most of these sources are soft. This suggests that the radio MSPs and the soft point X-ray sources are the same population.

However, there are 44 soft X-ray sources extending to $\sim 10\, r_c$, whereas all radio MSPs with known positions fall within $\sim 3 r_c$. The probability of randomly choosing 17 sources from the known soft X-ray source distribution and finding all of them within $3\, r_c$ is only $\sim$2%.

2. Analysis and Results

Using our Monte Carlo code (Joshi, Rasio, & Portegies Zwart 2000; Watters, Joshi, & Rasio 2000; Joshi, Nave, & Rasio 2001; Fregeau et al. 2002), we computed the evolution of a simple 2-component system containing 3×10^5 stars, 2000 of which were heavier (1.4 $M_\odot$) than the rest (0.9 $M_\odot$). The heavier stars represent the neutron stars and lighter ones represent the cluster background. We started the simulation with a $W_0 = 5$ King model, and evolved the system to core collapse. For comparison with 47 Tuc, we evolved our cluster until the ratio of half-mass to core radii reached $r_h/r_c = 6.3$, which is the value observed for 47 Tuc, today. The age of the radio MSPs in 47 Tuc is $\sim 10^9$ yr. Using the results

[5] Our full poster paper can be found at:
`http://norte.phys.northwestern.edu/~ato/padova2002poster.pdf`

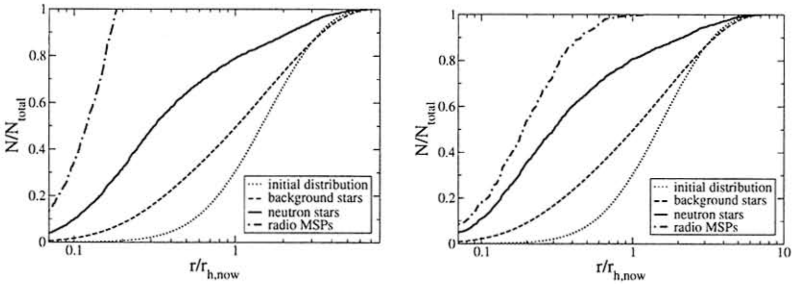

Figure 1. Distribution of stars in the cluster 10^9 years ago (left) and at the present (right). The radius is in units of current half-mass radius. The dotted line is a $W_0 = 5$ King model which is used as the initial condition.

of our simulation, we determined which neutron stars were in the core $\sim 10^9$ yr ago and called these radio MSPs. Then, we checked if the current distribution of these stars is consistent with the observed radio MSP distribution. In Figure 1 we show the distributions of stars in the cluster 10^9 years ago and at present.

Using the predicted radial profile for the MSPs, we find that the probability of finding 17 inside 3 r_c out of a population of 44 is now increased to $\sim 25\%$. Since the diffusion timescale for the outer edge of the distribution through 2-body relaxation is comparable to radio MSP ages in 47 Tuc, the restriction of the radio MSP to this region can be produced naturally. This would require the production of all radio MSPs inside the core of the cluster $\sim 10^9$ yr ago, through a mechanism that does not lead to significant kicks or recoils. One such mechanism is the binary-merger-induced collapse of a white dwarf to form a MSP directly without a kick (Chen & Leonard 1993).

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