CAN PHYSICAL STELLAR COLLISIONS EXPLAIN THE BLUE STRAGGLERS IN THE DWARF SPHEROIDAL GALAXIES?

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ABSTRACT The hypothesis that the blue stragglers in the dwarf spheroidal galaxies have a collisional origin is considered. If all of the dark matter in these galaxies is in the form of low-mass stars and the binary frequency is $\simeq 50\%$, then it is quite possible that $\simeq 10\%$ to 20% of their blue stragglers have been produced by physical stellar collisions.

The Milky Way Galaxy's dwarf spheroidal (dSph) companions each contain $\simeq 10^2$ to 10^3 blue stragglers (Mould & Aaronson 1983, Da Costa 1984, Olszewski & Aaronson 1985, Carney & Seitzer 1986, Da Costa 1988, Mateo et al. 1991b). The central densities of these systems are known to be quite low, and thus the possibility that their blue stragglers have been produced by physical stellar collisions would seem unlikely. However, it has been shown that binary-binary collisions can produce blue stragglers in both the low-density globular clusters (Leonard & Fahlman 1991) and the old open clusters (Leonard & Linnell 1992), and so one should not dismiss the collisional hypothesis in any stellar system without carrying out a quantitative test.

In order to test the collisional hypothesis in dSph galaxies, one must know the structural parameters of these systems. Based on the recent literature (Da Costa 1988, Zaritsky et al. 1989, Pryor & Kormendy 1990, Mateo et al. 1991a), we arrive at the following observed parameters for a typical dSph galaxy: a core radius, r_c, of ~ 200 to 300 pc, and a central one dimensional velocity dispersion, σ_o, of ~ 5 to 10 km s^{-1}. The central mass density, ρ_o, can be crudely estimated from r_c and σ_o using King's formula (King 1966). For $r_c = 300$ pc and $\sigma_o = 5$ km s^{-1} one finds $\rho_o = 0.05\ M_\odot$ pc^{-3} (hereafter Case A), and for $r_c = 200$ pc and $\sigma_o = 10$ km s^{-1} one finds $\rho_o = 0.5\ M_\odot$ pc^{-3} (hereafter Case B).

The mean time between binary-binary collisions in a star cluster, t_{bb}, can be estimated using Equation (11) of Leonard (1989). This equation assumes that the binary fraction, f_b, is unity. If this is not the case, then t_{bb} must be divided by f_b^2. Also, the equation refers to only collisions in the core, and if f_b is constant throughout the system, then t_{bb} should be divided by two. We will adopt $f_b = 0.5$ throughout the system. For such a high binary frequency, binary-binary interactions dominate over binary-single as the principal source of physical stellar collisions. We will adopt a mean binary mass ratio of 0.5, and therefore the mean stellar mass is equal to 1.25 times the mean single star (and binary primary) mass, m_*. Thus, the central number density, n_o, equals $\rho_o/(1.25\ m_*)$. We will adopt $m_* = 0.5\ M_\odot$, since such a star has $M/L_V = 10$ (in solar units), which is typical for a dSph galaxy. We will adopt a mean binary semi-major axis, a, of 1 AU. We now have enough information to estimate t_{bb} corresponding to the adopted r_c, σ_o and ρ_o combinations.

The mean time between binary-binary collisions that produce merged stars, t_{ms}, equals t_{bb} divided by the fraction of strong binary-binary interactions that result in physical stellar collisions (or tidal captures), f_{ms}. For $a = 1$ AU, we will adopt $f_{ms} = 0.5$, which is based on numerical experiments.

To estimate the total number of merged stars that are expected to be present in a dSph galaxy, N_{ms}, we divide the mean lifetime of a merged star, τ_{ms}, by t_{ms}. The lifetime of a 1.0 $M_\odot$ star (which is the merged star mass that most often results from binary-binary collisions with $m_* = 0.5\ M_\odot$) is $\simeq$ 1 Gyr, which we will adopt for τ_{ms}. The result is $N_{ms} \simeq 15$ for Case A, and $N_{ms} \simeq 220$ for Case B. Most of these merged stars will be instantly observable as blue stragglers, and the lower mass ones will be eventually visible as stragglers. Therefore, if most of the dark matter in dSph galaxies is in the form of low-mass stars and the binary frequency is $\simeq 50\%$, then it is quite possible that $\sim 10\%$ to 20% of the blue stragglers in these systems are due to physical stellar collisions. Thus, dSph galaxies may be similar to the open and globular clusters in our Galaxy in that they contain a mixture of blue stragglers from binary mass transfer, slow binary coalescence, and physical stellar collisions.

It is puzzling that the fraction of blue stragglers that can be accounted for by collisions is $\simeq 10\%$ for the low density globular clusters (Leonard & Fahlman 1991), the old open clusters (Leonard & Linnell 1992), and now the dSph galaxies. If there is no connection between the structure of these stellar systems and the number of blue stragglers they contain, then one might expect to calculate quite different fractions of blue stragglers that can be accounted for in each case (e.g., 0.1%, 1% and 10%, rather than 10%, 10% and 10%). This coincidence may suggest that collisions are indeed an important contributor to the blue straggler populations of these low density stellar systems, and that something may have been incorrectly assumed or left out of the calculations on a consistent basis. For example, a binary frequency of $\sim 50\%$ has been assumed in all cases. If the true binary frequency is 75% rather than 50%, then the number of blue stragglers that can be explained increases by a factor of $(0.75/0.50)^2 \sim 2$. Also, if the main sequence lifetimes of the blue stragglers can be extended by a factor of two or three due to rapid internal rotation (see Leonard & Clement 1993, and references therein), then the number of blue stragglers that can be produced would increase by a similar factor. Such changes in the calculations would make collisions a very important source of blue stragglers in all of the stellar systems discussed.

On the other hand, the possibility that all of the dark matter in the dSph galaxies is in the form of low mass stars may be too liberal of an assumption. If we instead assume that only 1/3 of the dark matter is stellar, then the estimated number of blue stragglers produced by collisions would decrease by a factor of $(1/3)^2$ 0.1. In this case, collisions would only account for 1% of the observed blue stragglers, and thus would be a relatively unimportant mechanism.

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