CONF-9210324--3

LA-UR- 93-472

Title: **WHY BLUE STRAGGLERS FORMED VIA COLLISIONS MAY NOT BE RAPID ROTATORS**

LA-UR--93-472

DE93 008708

Author(s): Peter J. T. Leonard, T-6
Maurice J. Clement, Univ. of Toronto

Submitted to: Proceedings of Conference "Blue Stragglers"
Space Telescope Science Institute (STSI)
Baltimore, Maryland, Oct. 12-13, 1992

Los Alamos
NATIONAL LABORATORY

WHY BLUE STRAGGLERS FORMED VIA COLLISIONS MAY NOT BE RAPID ROTATORS

PETER J.T. LEONARD
Theoretical Division, Los Alamos National Laboratory, Los Alamos, NM 87545, USA

MAURICE J. CLEMENT
Department of Astronomy, University of Toronto, Toronto, Ontario M5S 1A1, Canada

ABSTRACT We propose that the blue stragglers formed via collisions may not be rapid rotators due to magnetic braking during a Hayashi phase as they approach the main sequence. It is conceivable that just the envelopes of the blue stragglers are spun down, while their cores remain rapidly rotating. This would greatly extend the main-sequence lifetimes of the blue stragglers produced by collisions.

Blue stragglers formed via physical stellar collisions and mergers are expected to be initially rapid rotators (Hills & Day 1976, Benz & Hills 1987), while the blue stragglers in the old low-density star clusters appear not to be rapid rotators (Peterson, Carney & Latham 1984, Mathys 1991). This is one of the few remaining problems faced by the collisional hypothesis (Leonard & Linnell 1992), and must be overcome before this hypothesis can be considered to be a major source of blue stragglers in the old low density star clusters.

The solution is unlikely to be magnetic braking after the blue stragglers reach the main-sequence. For example, the 11 brightest blue stragglers in M67 (which show no evidence of rapid rotation) all have spectral types earlier than F5 (see Table 1 of Mathys 1991), and thus they lack convective envelopes, and therefore magnetic braking should not be important.

We propose that blue stragglers produced by collisions lose most of their angular momentum via material that is either lost during the collision or goes into a disk, and that most of the remaining angular momentum is lost during a Hayashi phase as the stragglers approach the main sequence. The first stage of angular momentum loss is fairly well understood (Benz & Hills 1987, Goodman & Hernquist 1991), and it is the second stage of angular momentum loss that we propose here in the context of the blue straggler problem for the first time. The merged object produced by a collision between two stars should possess an amount of internal energy well in excess of that corresponding to a main sequence star of similar mass. Consequently, the merged star will swell up to look like a luminous pre main sequence star. It will radiate away its internal energy on the Kelvin Helmholtz timescale ($\sim 10^7$ yr for Solar type stars), as it follows a Hayashi track down to the main sequence. During this time, angular momentum can be lost via a wind from the star's surface, which would be very efficient if a magnetic field can be generated due to convection in the star's envelope. Regardless of the exact details, it is clear that there is some way to spin down pre-main-sequence stars, since it is well known that T Tauri stars are not rapid rotators, in spite of the fact that there should have been a lot of angular momentum present in the early stages of their formation. In summary, we propose that the processes that slow down the rotations of T Tauri stars also slow down the rotations of blue stragglers produced by collisions.

It is conceivable that the cores of blue stragglers produced by collisions will still be rapidly rotating even after their envelopes have slowed down. Certainly, a collision will spin-up the entire merged star, and the processes that slow down the star's rotation probably operate at or near its surface (e.g., magnetic braking due to a convective envelope). Thus, the physical processes to set up the situation of a rapidly rotating core and a slowly rotating envelope exist, and if the transport of angular momentum within the star (which is poorly understood) is inefficient, then this condition might persist for some time.

If the condition of a rapidly rotating core and a slowly rotating envelope can be set up and persist, then this might solve some other problems. It is believed that rapid rotation (especially in the core) can extend the main-sequence lifetime of a star considerably, perhaps by a factor of two or three (Wheeler 1979, Saio & Wheeler 1980, Maeder 1987, Sreenivasan 1992). A factor of two or three increase in the lifetimes of the blue stragglers produced by collisions would go a long way towards explaining the observed number of stragglers in the old low-density clusters, since estimates using standard lifetimes have come up a bit short (Leonard & Fahlman 1991, Leonard & Linnell 1992).

It has been noted by Hills & Day (1976) and Benz & Hills (1987) that blue stragglers produced by collisions should have enhanced helium abundances in their envelopes compared with stragglers formed via other mechanisms, and thus the stragglers with a collisional origin will be bluer than those produced by the other mechanisms, and perhaps so much so that UBV photometry might be able to tell the difference (Bailyn 1992). However, it was found by Deupree (1990) that stars with rapid rotation in the core and slow rotation in the envelope will be somewhat fainter and redder than non rotating or uniformly rotating stars. This effect must be taken into account before strong conclusions are drawn regarding the origin of blue stragglers based on their colors.

We note that blue stragglers produced by binary mass transfer (McCrea 1964) and slow binary coalescence (Zinn & Searle 1976, Renzini, Mengel & Sweigart 1977) are also expected to be initially rapid rotators. It is unlikely that such stragglers will go through a Hayashi phase on their way to the main sequence, and thus the spin down mechanism proposed in this paper is probably irrelevant in these scenarios. Some other way of slowing the rotations of mass transfer and slow binary coalescence stragglers must be found. It is conceivable that these stragglers might also have rapidly rotating cores, which would extend their lifetimes, and make them fainter and redder than normal.

ACKNOWLEDGMENTS

The authors gratefully acknowledge useful comments from Charles Bailyn, Bob Deupree, Jack Hills and Ranga Sreenivasan. This research was supported by the

U.S. Department of Energy and the Natural Sciences and Engineering Research Council of Canada.

REFERENCES

Bailyn, C.D. 1992, ApJ, **392**, 519

Benz, W. & Hills, J.G. 1987, ApJ, **323**, 614

Deupree, R.G. 1990, ApJ, **357**, 175

Goodman, J. & Hernquist, L. 1991, ApJ, **378**, 637

Hills, J.G. & Day, C.A. 1976, Astrophysical Letters, **17**, 87

Leonard, P.J.T. & Fahlman, G.G. 1991, AJ, **102**, 994

Leonard, P.J.T. & Linnell, A.P. 1992, AJ, **103**, 1928

Maeder, A. 1987, A&A, **178**, 159

Mathys, G. 1991, A&A, **245**, 467

McCrea, W.H. 1964, MNRAS, **128**, 147

Peterson, R.C., Carney, B.W. & Latham, D.W. 1984, ApJ, **279**, 237

Saio, H. & Wheeler, J.C. 1980, ApJ, **242**, 1176

Sreenivasan, S.R. 1992, unpublished

Renzini, A., Mengel, J.G. & Sweigart, A.V. 1977, A&A, **56**, 369

Wheeler, J.C. 1979, ApJ, **234**, 569

Zinn, R. & Searle, L. 1976, ApJ, **209**, 734