BLUE STRAGGLERS AS LONG-LIVED STARS

J. Craig Wheeler
Department of Astronomy, University of Texas at Austin
Hideyuki Saio
Joint Institute for Laboratory Astrophysics
Michel Breger
Department of Astronomy, University of Texas at Austin

The existence of blue stragglers in old open clusters with apparent mass more than twice the mass of the turnoff argues against simple binary mass transfer as the mechanism of their origin. The excess of blue stragglers to the red of the termination of the core hydrogen burning main sequence suggests that blue stragglers are not evolving normally. Stellar evolution models invoking mixing in an extended core region can account for the distribution of blue stragglers in the H-R diagram. Such models live longer, brightening and evolving further to the red before core hydrogen exhaustion than do normal stars. The distribution of blue stragglers in NGC 7789 is consistent with a range of mixed core mass fraction ~30-90 per cent and a narrow range in mass ~1.7-2.1 $M_\odot$. Such evolution will result in a class of helium rich stars which have lived longer than normal and whose total mass exceeds the Chandrasekhar limit.

DISCUSSION

Vilhu: Your mass of ~2$M_\odot$ is about the same as that found for W UMa-stars of the W-type. There exists one scenario (Webbink) according to which these contact binaries may evolve by gradual mixing of the primary, while the system evolves towards a more extreme mass ratio.

Wheeler: Such coalescence may be relevant to blue stragglers, but I would expect it to produce a basically normal star. Once the mixing ceases, the star should evolve normally and it is then subject to the constraint that its luminosity should not be greater than that of a normally evolving star with twice the turnoff mass, and it should evolve very rapidly after central hydrogen exhaustion. As I have said, some blue stragglers in NGC7789 violate both of these restrictions. Bear in mind that the ~2$M_\odot$ I derived here followed from continuous mixing. A single mixing episode followed by inhomogeneous evolution is a different case, and one which apparently disagrees with observation.

Sugimoto: If the mixing is common and if the amount of the mixing depends

D. Sugimoto, D. Q. Lamb, and D. N. Schramm (eds.), Fundamental Problems in the Theory of Stellar Evolution, 187–189.

https://doi.org/10.1017/S0074180900073915 Published online by Cambridge University Press

sensitively on various parameters, why aren't all stars blue stragglers?

Wheeler: All I can say is that, if the present hypothesis of evolution with a large mixing core of fixed mass is relevant, then results say that only a narrow mass range is involved. Any theory which accounts for this mixing should explain the narrow mass range or should give an alternative mass distribution which accounts self-consistently for the observations.

Mouschovias: As a non-expert on the subject, I understand that the evolution of a star is determined by a small number of physical parameters. Can any expert in this room point to anything funny happening to stars with mass $2M_\odot$? If so, can that possible physical effect cause the required mixing?

Wheeler: There is a whole zoo of possible mixing mechanisms. Depending on the circumstances, rotation, magnetic fields, and composition gradients can either help or hinder mixing. The difficulties in starting from first principles to study mixing encouraged me to take the alternate approach of searching for an empirical justification for mixing and then looking for hints of the physical process. If the narrow mass range we have derived is valid, it is a very important clue. For instance, Press has suggested that an outer convective zone could generate inwardly propagating sonic waves whose energy could perturb the central stellar regions. Press was interested in the solar neutrino problem but, for my purpose, I can imagine that as one goes up in mass a narrow range is selected by the competition between the growing inner CNO burning core and the decreasing outer convective envelope such that the inner region which mixes is amplified. Alternatively, Ian Roxburgh reminds me that the ^{3}He instability discussed by Gough et al. and others could play a role. Quantitatively, either of these very different physical processes would, a priori, be expected to operate more efficiently at a somewhat lower stellar mass than we have formally derived here.

Schatzman: What do we know about the rotational velocity of blue stragglers?

Wheeler: Little. Blue stragglers should be systematically restudied with modern instruments. Several open cluster blue stragglers are apparently slow rotators. Alternatively, Rogers has reported some relatively rapid rotators among field blue stragglers, which are selected by their blue colors and low metallicity.

Tayler: Is there a significant difference between your minimum blue-straggler mass and the turnoff mass? If not, continuing in your completely ad hoc manner, could we not suggest that your stars have mixed shortly after reaching the turnoff so that lower mass stars have not yet had time to become blue stragglers?

Wheeler: I will not try to defend the difference between the minimum blue straggler mass and the turnoff mass. I do think the average blue straggler mass we have derived is significantly larger than the turnoff. I am not certain whether the spread I showed is real. If stars of

$M \sim 1.5M_{\odot}$ underwent mixing just after turnoff, their subsequent evolution would depend on whether the extensive mixing continued or whether "standard" helium-rich central hydrogen burning ensued. If extensive mixing continued, the result would be similar to the present models but the timescale would be changed a little. A given value of X_c would be reached somewhat sooner. The present results should then follow and they are apparently inconsistent with $M \sim 1.5M_{\odot}$. If the mixing is transient and the star begins central hydrogen burning with a higher helium mass fraction in an ordinary small convective core, it will evolve fairly quickly but more or less normally off the main sequence. I would guess the result would not reproduce the observed distribution of the blue stragglers satisfactorily. If such stars mix again upon central hydrogen exhaustion, and continue to do so repeatedly, the outcome is difficult to intuit. Each time the star regains the main sequence, it will be brighter. Perhaps such repeated mixing at central hydrogen exhaustion would reproduce the observed blue stragglers. I can not say.