Blue Stragglers in NGC 5053

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We present photometry for blue straggler stars (BSS) in the globular cluster NGC 5053. A total of 25 stars were confirmed as blue stragglers. We find the blue stragglers to be centrally concentrated. In addition, NGC 5053 is compared with other globular clusters to identify trends among clusters and dominant processes in blue straggler formation. There is a clear trend of decreasing BSS frequency with increasing luminosity. Also seen is a trend of BSS frequency to approach that of the Galaxy as cluster density approaches the density of the Galaxy.

Introduction

Blue straggler stars in globular clusters are found to be stars that appear bluer and brighter than the cluster turn off. Because all stars in clusters are roughly the same age, one would expect stars above the turnoff to have evolved beyond the main sequence. However, blue stragglers seem to remain on the main sequence longer than the typical star.

Blue stragglers are thought to form mainly from binary systems. Primordial binary stars (binaries which form at the creation time of the cluster) may coalesce and form a star that is more massive and brighter than the two parent stars. The resulting star then appears as a blue straggler. Alternatively binary systems which collide with other stars (singles or binaries) may produce a blue straggler if two or more of the interacting stars merge. Binaries separated by less than a few AU tend to form BSS in collisions with other stars. However, binaries which are separated by more than a few AU tend to get ripped apart by colliding stars.

Previous color magnitude diagrams have been created and blue stragglers studied from NGC 5053. This was done by Nemec and Cohen in 1989 (hereafter NC89) and by Sarajedini et al. 1995 (hereafter S95). Nemec did a follow up study, also in 1995. Among these, 28 blue straggler stars have previously been identified. NC89 used g and r filters in their study, and S95 used B and V filters. This project used B and V filters and will verify previously identified BSS, as well as study the radial distribution of BSS and compare NGC 5053 to other clusters.

NGC 5053 is known as one of the least metal-rich clusters in the Milky Way, but interestingly is also a fairly low density cluster. The cluster's luminosity is unusually high for its density. Previous studies performed by Sandquist (2004) and Piotto et al. (2004) on the comparison of globular clusters and their blue straggler populations show a gap in studied clusters. The gap appears between about log $\varrho = 0.5$ and log $\varrho = 1.5$. The logarithm of the density of NGC 5053 is 0.53, and its integrated V magnitude is -6.72. The goal of this project is to see how NGC 5053 compares to the previously studied clusters and identify some of the trends in blue straggler formation.

Observations and Reduction

Observations were made on 3 May 2005 with the 40" telescope at Mt. Laguna Observatory. A 2048x2048 pixel CCD camera was used with 0.4 arcsec/pixel, providing a field roughly 400 arcsec in radius around the center of NGC 5053. Along with sky flats and bias images, a total of 37 images were taken in B and V filters. Of these, only the best seeing frames were finally used to create the color magnitude diagram and measure blue straggler and other star populations. The frames were reduced using IRAF. Images were then aligned and combined according to exposure time to increase the contrast between the stars and the background.

Find and phot were then used from DAOPHOT II to obtain initial lists of stars and initial photometry. Selected stars from across the frame were used to define a point spread function, which characterizes the shapes of the stars as they appear on the frame. The PSF and the initial star lists were then run through three iterations of ALLSTAR to create lists of all the stars in each frame. These lists were then combined to create a master star list.

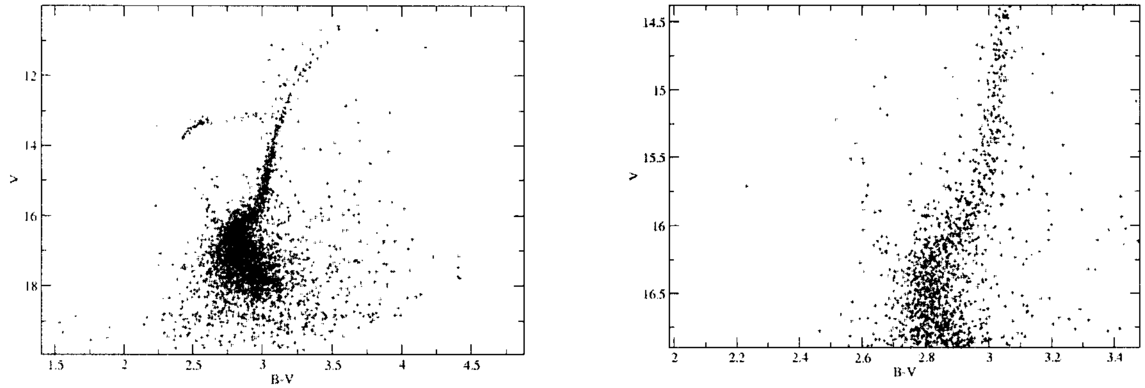

Fig. 1 : The color magnitude diagram is presented on the left. On the right, the blue straggler region is shown.

Analysis

CMD

The color magnitude diagram (Fig. 1) shows the V magnitude vs. B-V color for all the stars found in the cluster. One can see the defined structures of the main sequence, the turnoff, giant and horizontal branches. Above the main sequence are the stars identified as BSS. First all the BSS which were previously found by NC89 and S95 were identified in this study. Then any stars appearing to be BSS, but not previously listed as BSS, were identified. Of these candidates, several had been previously rejected as blue stragglers by NC89 and S95. However, at the time of this writing several stars are still under consideration. These candidates may or may not be accepted as blue straggler stars.

It should be noted that several BSS previously identified have been rejected as blue stragglers. First Nemec (1995) stated that BSS # 24 was originally misclassified as a blue straggler in NC89 and should be a subgiant star. This star appears in the subgiant branch on our color magnitude diagram and was therefore rejected as a BSS. Also, BSS # 20 originally identified in NC89 does not appear within our viewing frame, so we could not retrieve photometry for it. Lastly, two BSS were located well within the main sequence of our color magnitude diagram, numbers 16 and 12. These stars have also been rejected as BSS. This leaves 25 stars which have currently been identified as BSS.

To measure the frequency of blue stragglers, a reference population is required. The horizontal branch was chosen because of its previous use as a reference population for blue stragglers and because these bright stars are usually easy to identify. 53 horizontal branch stars were found. Another reference population was measured which included giants and subgiants. These stars number 323. The frequency of BSS is then $F_{BSS} = N_{BSS} / N_{HB}$. This value was measured to be $F_{BSS} = 0.47 +/- 0.12$. The error is derived from Poisson error statistics.

Radial Distribution

To explore the radial distribution of the BSS, plots were made comparing BSS to the reference populations. The cumulative radial distributions show that the BSS tend to have more stars located toward the center of the cluster than the horizontal branch or giant star populations. The probability that the BSS distribution could be found from the same radial distribution as the HB and giant branch is 0.23 and 0.28 respectively, calculated by a Kolmogorov-Smirnov test. These numbers are inconclusive, most likely because there are an inadequate number of blue stragglers.

To further investigate the radial distribution of NGC 5053 blue stragglers, we examined the frequency of BSS as a function of radius. Other clusters that were compared were Pal 13, M3, and 47 Tuc. Pal 13 most closely resembles NGC 5053, because they share a similar density, but NGC 5053 is brighter by ~3 magnitudes. Both M3 and 47 Tuc are considerably denser and are also brighter than NGC 5053. The plot shows how the frequency of BSS changes with radius. Both M3 and 47 Tuc show a distinct dip in BSS frequency with a rise in the outer regions of the cluster. NGC 5053 does not show this feature but our study does not reach the outer limits of the cluster.

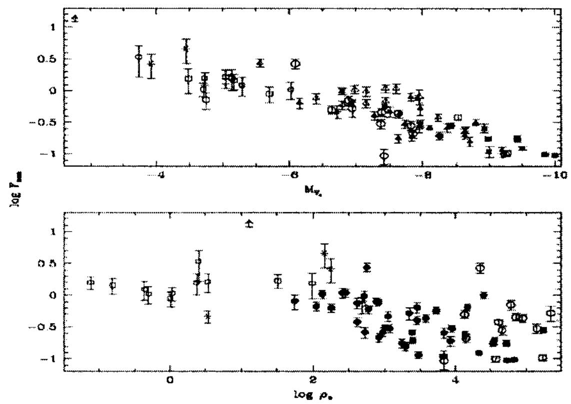

Fig. 2: Logarithm of BSS frequency vs. integrated V magnitude and logarithm of density for high and low density clusters.

Density and Magnitude

The main purpose of this study was to include NGC 5053 on two plots of BSS frequency versus density and magnitude. These plots appear here as Fig. 2. The other clusters on this plot were taken from previous studies. Piotto et al. (2004) studied some of the higher density clusters, while Sandquist (2004) studied the lower density clusters. NGC 5053 is located to the right of the low density clusters previously studied. The magnitude plot shows a clear trend of increasing BSS frequency with decreasing luminosity. NGC 5053 appears to abide by this trend. The density trend is not so clear. Indeed there is much scatter showing evidence of there being little trend of BSS frequency according to density.

Conclusions

We note that NGC 5053 agrees with the trend of BSS frequency to magnitude and provides evidence that there is only a small trend of BSS frequency according to density. In addition, BSS tend to be more centrally concentrated than evolved stars, with some clusters having an increase in BSS population far away from the core.

Looking at the density of the clusters studied, one can see a small trend of increasing BSS frequency with decreasing density. One may expect that this would be the case by noting that the BSS frequency of the Galaxy is 4.0, measured by Preston & Sneden (2000) and quoted by Piotto et al. (2004). This value would place the Galaxy higher on the plot of Fig. 2 than most of the clusters. Then as the cluster density approaches that of the Galaxy, so does the frequency of BSS. While this trend is logical, it is only slightly seen in the plot. It should be noted that the two open clusters appearing on the plot have values close to that of the Galaxy, but are denser than some of the globular clusters.

The clearer trend lies in the luminosity plot of Fig. 2. This shows a decreasing BSS frequency with increasing luminosity or mass. These F_{bss} values are also lower than that of the Galaxy. While in the Galaxy the dominant process of BSS formation is most likely binary coalescence, some mechanism in the clusters must subdue that process. Since binary collisions are much more likely in clusters than the open galaxy, it is probable that they may cause this drop in BSS frequency. Binary collisions that produce blue stragglers would likely have done so far in the past and those BSS would then have evolved beyond detection, thus decreasing the number of blue stragglers in a cluster, as proposed by Piotto et al. (2004).

In conclusion, more massive clusters have likely produced BSS far in the past and have run out of primordial binaries, evidenced by low BSS frequency compared to the Galaxy. In addition, the mass of the cluster appears to have more of an impact on BSS formation than the density of the cluster, since clusters with similar densities tend to have a range of BSS frequency. It makes sense that the more mass a cluster has, the more possible collisions can produce either BSS or single stars by destroying binaries. Lower luminosity clusters and lower density clusters tend to have BSS frequencies closer to that of the Galaxy, as expected.

More work is needed to fully understand the mechanisms leading to blue straggler formation. Future studies may measure the frequency of BSS and binary stars, especially as a function of radius. Also, more studies of open clusters are needed to investigate the trend of BSS frequency to density. Studying the apparent rise in BSS frequency at outer regions of clusters would provide a more detailed look at the distribution and possible formation features of BSS within clusters. Some attempt could be made also to find the lifetime of BSS, using computer models. While a good idea of the processes by which blue stragglers form has taken shape, more work is needed to discern the details of BSS formation and evolution.

References:

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