Final Technical Report

to

National Aeronautics

and

Space Administration

Title: AGES OF EXTRAGALACTIC INTERMEDIATE-AGE STAR CLUSTERS

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Research Summary:

   The main emphasis of my research proposal, NAGW-441, was the development
of a cluster dating technique for faint, distant star clusters observable in
the Local Group of galaxies with the Space Telescope. This dating technique
relied on the variation with age in the luminosity of cluster giants; they,
like the brightest cluster main sequence stars, become fainter with increasing
cluster age (see Flower 1984, Ap.J., 278:582). For very distant clusters to
be observed with the Space Telescope, only the red giants, and perhaps the
very brightest main sequence stars in metal rich clusters, will be observable.
[For moderately metal poor clusters, the faintest cluster red giants are
brighter than the brightest cluster main sequence stars (Flower 1984 B.A.A.S.,
15, 912).] Hence, for distant extragalactic clusters, like those in M31, for
instance, the only available way to accurately date the metal poor clusters
will be through the cluster red giants.

   My dating technique is described and applied to Magellanic Cloud star
clusters in Flower (1984 Ap.J. 278:582). The published color-magnitude
diagrams of intermediate-age Magellanic Cloud star clusters generally exhibit
all of the cluster red giants plus the brightest main sequence stars. For the
metal poor clusters, the brightest main sequence stars are at magnitude levels
where observational uncertainty and scatter dominate. I have dated in the
above paper six clusters and in Flower (1984 IAU Symp. No. 108, pg 31; 1984
IAU Symp. No. 105, pg 79) one other cluster, NGC 1978. Although the quality
of current photographic cluster color-magnitude diagrams for Magellanic Cloud
clusters is perhaps what we can expect in the future with Space Telescope
color-magnitude diagrams of star clusters in the most distant galaxies, soon
very deep earth-based CCD color-magnitude diagrams of Magellanic Cloud clusters
will become available. Because I will be able to use the entire upper end of
the main sequence as well as the faintest cluster red giants for cluster
dating, these data will provide a very important calibration for my dating
technique.

   The models that I have computed for dating intermediate-age clusters
range from 3.25 M_θ to $\sim$ 2 M_θ. At $\sim$ 2 M_θ the models become degenerate and I
did not compute models beyond core-helium ignition below this mass. Thus I am
able to date clusters younger than $\sim 10^9$ years. To date older clusters,
either in distant galaxies using the faintest red giants or in nearby galaxies
using both main sequence stars and red giants, core-helium burning phases for
masses < 2 M_θ must be generated.

   A very interesting recent development in Magellanic Cloud research is the
suggestion that the Magellanic Clouds are closer than previously thought. If
so, this would increase current cluster age estimates due to the reduction in
the assumed intrinsic luminosities of the member stars. Most of the inter-
mediate-age Magellanic Cloud star clusters that have been dated using their
color-magnitude diagram morphology have ages $\leq 10^9$ yr; this is also the age
limit for evolved 2 M_θ models. A new distance scale would necessarily increase
derived cluster ages to over 10^9 yr – out of range of the present grids of
models.

I have stressed cluster dating using as much of the color-magnitude diagram morphology as possible becasue there appears to be a fundamental uncertainty in the mapping of assumed model metallicity, Z, and observed metallicity, [Fe/H]. Currently, it is difficult to obtain satisfactory synthetic color-magnitude diagrams (generated from the evolutionary tracks) based on a one-to-one correspondence between Z and [Fe/H]. In general, the observed [Fe/H] is much lower than the value of Z necessary to reproduce the observed cluster color-magnitude diagram morphologies.

One possible solution to this mapping problem may lie with stellar opacities (Carney, Janes, and Flower 1984, Ap.J., submitted). It is not clear yet exactly what changes are needed; for low mass models, comparisons with observed color-magnitude diagrams suggest increases in the envelope opacities, while for high mass models, comparisons indicate opacity decreases above 10^7 K are needed. Another solution may involve stellar mass loss. Some preliminary mass loss calcualtions being done at Clemson indicate that moderate amounts of mass loss may improve the comparisons between observed color-magnitude diagrams and the synthetic color-magnitude diagrams generated from grids of evolutionary tracks.

Publications:

1. The models computed and an application of the dating technique is given in "Ages of Intermediate-Age Magellanic Cloud Star Clusters", 1984, Ap.J. 278:582.

2. The above results plus the dating of one more cluster were reported at two international meetings: IAU Symposium No. 105, "Observational Tests of the Stellar Evolution Theory" page 79 (1984) and IAU Symposium No. 108, "Structure and Evolution of the Magellanic Clouds" page 31 (1984). Both are in press.

3. The abstract in the Bulletin of the American Astronomical Society 15:912 (1983) presents a qualitative relationship between cluster metallicity and color-magnitude diagram morphology.

4. The problem with the mapping of assumed model metallicity Z and observed metallicity [Fe/H] is discussed in "The Young SMC Cluster NGC 330 (1984 Ap.J., submitted).

The Young SMC Cluster NGC 330

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Abstract

We report the results obtained from deep photoelectric and photographic UBV photometry, low-resolution spectroscopy, and DDO and infrared photometry for stars in and around the young SMC cluster NGC 330. We also compare synthetic color-magnitude diagrams to that obtained for the cluster, finding it to have an age of 12 x 10^6 years, whereas the young surrounding field population is about 50% older. Photometric metallicity indicators suggest the cluster is very metal-poor, but we discuss reasons why they may be misleading.