New Views of the Magellanic Clouds
IAU Symposium, Vol. 190, 1999
Y.-H. Chu, N.B. Suntzeff, J.E. Hesser, and D.A. Bohlender, eds.

Deep STIS Luminosity Functions for LMC Clusters

R. Elson, N. Tanvir, G. Gilmore, R.A. Johnson, S. Beaulieu

Institute of Astronomy, Madingley Rd., Cambridge CB3 0HA, England

Abstract. We present deep luminosity functions derived from HST STIS data for three rich LMC clusters (NGC 1805, NGC 1868, and NGC 2209), and for one Galactic globular cluster (NGC 6553). All of the LMC cluster luminosity functions are roughly consistent with a Salpeter IMF or with the solar neighbourhood IMF from Kroupa, Tout & Gilmore (1993). They continue to rise at least to $0.7M_{\odot}$. NGC 1868 shows evidence for mass segregation which may be primordial. A comparison of deep luminsoisty functions for seven Galactic globulars shows that the luminosity functions are eroded at low masses by amounts that are strongly correlated with distance from the Galactic plane.

1. Introduction and Data

The LMC is an ideal laboratory for studying the formation and evolution of rich star clusters. We describe the first results from a 95-orbit Cycle 7 HST project (No. 7307) with this as its primary aim (Elson et al. 1997). Briefly, we are using WFPC2, NICMOS2 and STIS (in imaging mode with the F28X50LP filter) to obtain deep $(V-H)$ CMDs and $\sim R$-band luminosity functions for eight clusters: NGC 1805 and NGC 1818 ($\sim 10^7$ yr), NGC 1831 and NGC 1868 ($\sim 10^8$ yr), NGC 2209 and Hodge 14 ($\sim 10^9$ yr), and NGC 2210 and Hodge 11 ($\sim 10^{10}$ yr). We also have data for the Galactic globular cluster NGC 6553, primarily for calibration purposes.

These data will allow us to determine age spreads in the young clusters and identify pre-main-sequence stars (and thus investigate the timescale and sequence of star formation), to quantify the binary population and trace its evolution and the development of mass segregation. We will also be able to investigate the universality of the IMF, which is the focus of this presentation. NGC 1868 and NGC 2209 are particularly interesting in this regard. They have similar ages but very different core radii, and one possibility is that different IMFs ($x \sim 1$ as opposed to $x \sim 2$, where $x = 1.35$ is the Salpeter value) have caused their cores to expand (through mass loss due to stellar evolution) at different rates (Elson et al. 1989).

We determined magnitudes using PSF fitting, with PSFs constructed from stars in the images. Completeness was determined using artificial star tests, and background contamination using STIS images of a field near each cluster. STIS magnitudes were transformed to absolute magnitudes in the HST system using a zero-point of $K_{STIS} = 23.4$ (H. Ferguson, 1998, private communication), a distance modulus of 18.5, and an absorption $A_{STIS} = 0.18$.

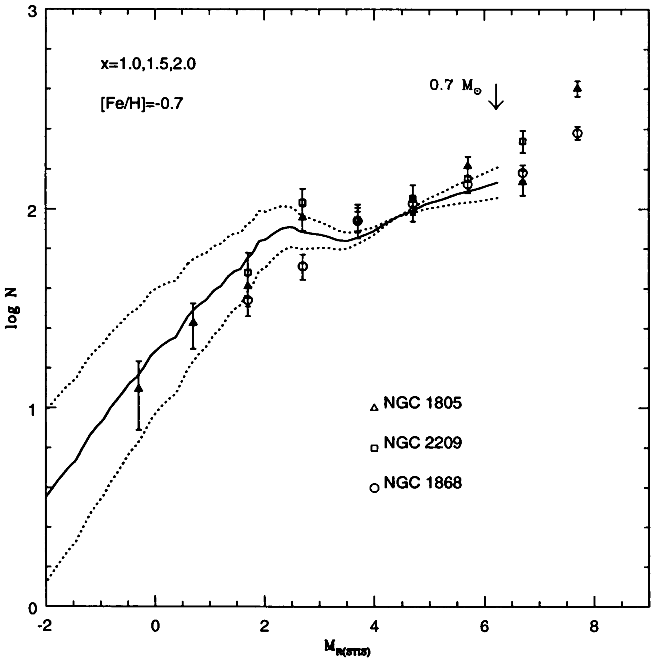

Figure 1. Luminosity functions for three LMC clusters compared to model power-law IMFs with $x = 1.0, 1.5, 2.0$. Arbitrary shifts in $\log N$ have been applied.

2. Results and Discussion

Figure 1 shows luminosity functions for NGC 1805, NGC 1868 and NGC 2209. The LFs are for stars near the half-mass radius where any dynamical evolution should not affect the mass function. All three are similar. Also shown are LFs corresponding to power-law IMFs with slopes $x = 1.0, 1.5, 2.0$. All the luminosity functions continue to rise at masses $< 0.7 M_\odot$. Variations in IMF slope do not appear to be responsible for the differences in core radii of NGC 1868 and NGC 2209. The LFs appear to be similar to those of Galactic globular clusters. The rising LF at low masses suggests that the clusters will survive disruption through evaporation, and evolve to objects like the old LMC clusters. They also suggest that 30 Doradus, which is probably a younger counterpart of these clusters, will reveal a similar population of low mass stars (cf. H. Zinnecker, this volume). This is important, as 30 Dor has often been cited as an archetypal starburst, assumed to have an IMF truncated at relatively high mass.

Figure 2 shows luminosity functions for NGC 1868 derived at three different radii. There is clear evidence for mass segregation. N-body modelling, which is an integral part of our project, will indicate to what extent this is primordial or due to dynamical evolution.

Figure 3 shows the LF for NGC 6553 and those of six other Galactic globulars from the literature (Elson et al. 1995; Santiago et al. 1996; Piotto et al. 1997).

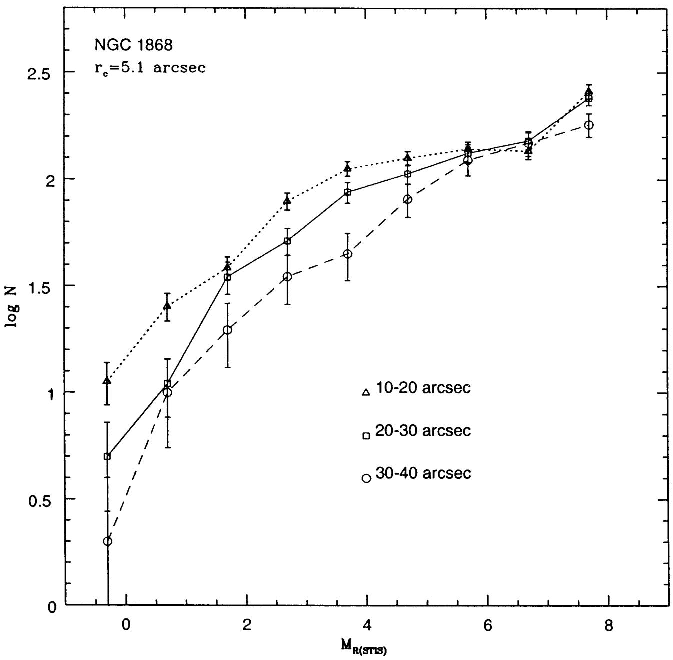

Figure 2. Luminosity functions for NGC 1868 at three different radii.

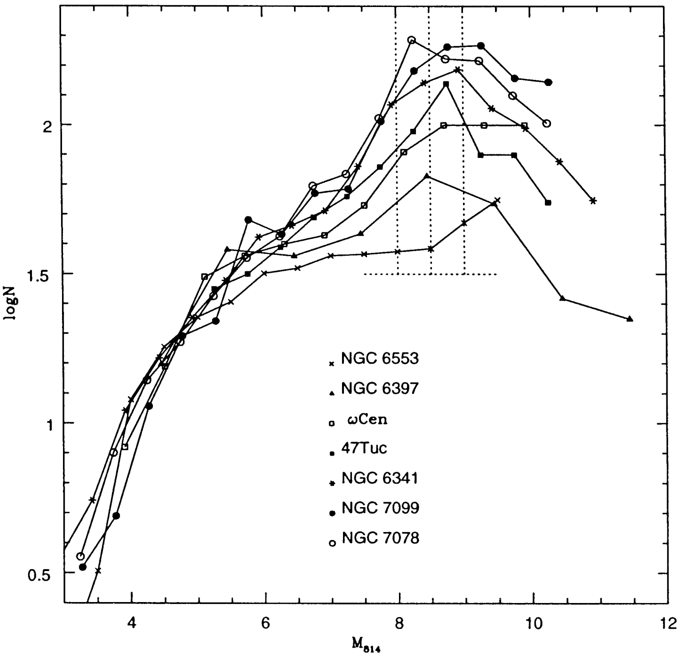

Figure 3. Luminosity functions for 7 Galactic globulars.

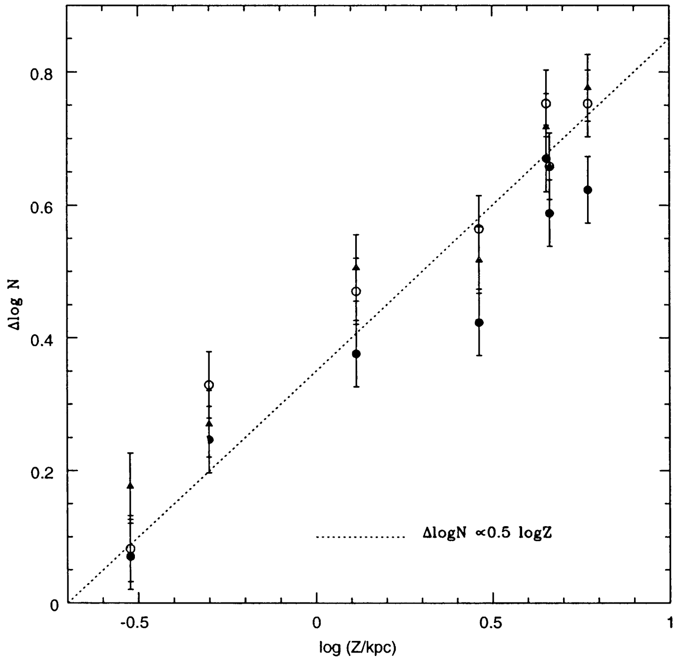

Figure 4. Relative flattening of the faint end of the luminosity functions in Fig. 3, measured at $M_{814} = 8.0, 8.5, 9.0$ (filled circles, open circles, triangles) plotted against distance above the Galactic plane.

A transformation from STIS magnitude to M_{814} was derived from the Padova isochrones (G. Worthey, 1998, private communication). While the luminosity functions agree well at brighter magnitudes, the faint ends differ markedly. Such differences have been noted before, and have been attributed to either metallicity effects, evaporation of low mass stars, or stripping of low mass stars by tidal shocking (cf. Piotto et al. 1997). We quantified the difference among the luminosity functions as the increment $\Delta \log N$ at $M_{814} = 8.0, 8.5, 9.0$. Figure 4 shows $\Delta \log N$ plotted against the distance, Z, of each cluster from the Galactic plane. There is a striking correlation, which suggests that tidal shocking is primarily responsible for the differences among the luminosity functions. A plot of $\Delta \log N$ against metallicity ($-0.3 <$ [Fe/H] < -2.5 for this sample) shows no correlation.

We are awaiting STIS images of four more clusters, NGC 1818, NGC 1831, Hodge 14, and Hodge 11. Also, background data still to be acquired, as well as improved data reduction methods, will allow us to push our luminosity functions $1-2$ mag fainter than at present (and to verify the upturn at $M_{814} > 8.5$ in the LF of NGC 6553).

References

Elson, R., Freemam, K., & Lauer, T. 1989, ApJ, 347, L69

Elson, R., Gilmore, G., Davies, M., Sigurdsson, S., Aarseth, S., & Santiago, B. 1997, STScI Newsletter, 14, 1

Elson, R., Gilmore, G., Santiago, B., & Casertano, S. 1996, AJ, 110, 682

Kroupa, P., Tout, C., & Gilmore, G. 1993, MNRAS, 262, 545

Piotto, G., Cool, A., & King, I. 1997, AJ, 113, 1345

Santiago, B., Elson, R., & Gilmore, G. 1996, MNRAS, 281, 1363

Discussion

John Pritchard: What binary star creation models are you using in your model clusters, and how did you determine the binary star fraction in NGC 1818?

Elson: Our models are N-body models, so at present do not include star formation. We input a binary frequency and distribution of mass ratios, and watch how it evolves.

The binary star frequency was determined from the CMD - there was a binary sequence that stood out clearly from the single star main sequence. We did some simple modelling to estimate the range of mass ratios of the binaries in our sample.

Hans Zinnecker: Congratulations on your very nice HST results! Just one comment: for your youngest cluster (NGC 1805) you need pre-MS tracks to deal with subsolar masses, ce n'est pas?

Elson: Merci! We will need pre-MS tracks to interpret our STIS LF's at the faint end. Also, our NICMOS and WFPC data (V-H CMD's) will allow us to identify pre-MS stars and quantify their numbers and ages.

Jan Palous: This is a comment: I assume that GCs follow radial orbits. It may imply that the individual clusters did suffer from tides to different extents since they come to the bar from various sites.

Tammy Smecker-Hanes: Since you have such striking evidence that the change in the IMF at the low mass end (loss of low mass stars) is a function of scale height, z, and hence is due to disk shocking, are there predictions for changes in cluster shape or concentration, etc., that you could look for also?

Elson: I haven't looked into other correlations, but it would certainly be an interesting thing to do.