Photometric survey for stellar clusters in the outer part of M33

K. Zloczewski$^1$, J. Kaluzny$^1$, J. Hartman$^2$

$^1$Nicolaus Copernicus Astronomical Center, ul. Bartycka 18, 00-716 Warsaw, Poland
e-mail: (kzlocz,jka)@camk.edu.pl

$^2$Harvard-Smithsonian Center for Astrophysics, 60 Garden St., Cambridge, MA 02138, USA
e-mail: jhartman@cfa.harvard.edu

ABSTRACT

We present a catalog of 4780 extended sources from the outer field of M33. The catalog includes 73 previously identified clusters or planetary nebulae, 1153 likely background galaxies, and 3554 new candidate stellar clusters. The survey is based on deep ground-based images obtained with the MegaCam instrument on the CFHT telescope. We provide g' r' i' photometry for detected objects as well as estimates of the FWHM and ellipticity of their profiles. The sample includes 122 new, relatively bright, likely globular clusters. Follow-up observations of fainter candidates from our list may extend the faint-end of the observed luminosity function of globular clusters in M33 by up to 3 magnitudes. The catalog includes several cluster candidates located in the outskirts of the galaxy. These objects are promising targets for deep photometry with the HST. We present a color-magnitude diagram for one detected object, showing that it is an extended and low-surface-brightness old cluster located at an angular distance of 27 arcmin from the center of M33.

catalogs– galaxies: individual (M33) – galaxies: star clusters

1 Introduction

M33 is an Scd type spiral galaxy belonging to the Local Group. Following the pioneering work of Hiltner (1960), there have been several searches for stellar clusters associated with the galaxy. A comprehensive summary and overview of this subject can be found in Sarajedini & Mancone (2007, SM hereafter). In particular, these authors presented an up-to-date catalog of star clusters and cluster candidates known in the field of M33. Over the last decade there has been a significant effort to search for faint clusters as well as for clusters located in projection near the central part of the galaxy using the imaging capability of the HST (Chandar et al. 1999, 2001; Bedin et al. 2005; Park & Lee 2007).

To date, the faintest clusters known in M33 have $V \approx 20$ or $M_V \approx -5$ (Park & Lee 2007, SM). In contrast, the least luminous globular clusters (GCs) detected in the Milky Way (MW) have $M_V \approx -1$ (Koposov et al. 2007). As pointed out by SM, the sample of clusters in the outskirts of M33 is incomplete. There is no evidence for the existence of dwarf spheroidals (dSphs) or tidal tails connected with M33 (McConnachie et al. 2006). This is in contrast to M31 and the Milky Way which both harbor sizable populations of dwarf galaxies and show extended tidal streams of stars (Ibata et al. 1994, Ibata et al. 2001, Majewski et al. 2006). Only recently fourteen faint satellites of the MW were found in the Sloan Digital Sky Survey data by looking for spatial over-densities of old, metal-poor stellar populations (e.g
Willman et al. 2002, Koposov et al. 2007). Nine of them are dSphs, two (Koposov 1 and 2) are GCs, the other three have properties intermediate between these two classes (Walsh et al. 2008, Martin et al. 2007, Belokurov et al. 2007). Sarajedini (2007) suggests that the significant age range of M33 clusters together with the lack of dwarf satellites or detectable tidal streams favors the hypothesis that the galaxy is in fact a member of the M31 'super-halo'.

The above facts together with the availability of new observations prompted us to survey the area of M33 for new stellar clusters; in particular for new GCs. In the following sections we describe the data that we used, the adopted search method, and the catalog of 4780 extended sources detected in the field of M33. The catalog includes 122 new objects which are likely globular clusters. The paper concludes with a short analysis of one particularly interesting new stellar cluster and with a brief summary.

2 The data

The imaging data used in this work were obtained using the Queue Service Observing mode at the Canada France Hawaii Telescope (CFHT) 3.6 m telescope within the programme "M33 CFHT Variability Survey" (Hartman et al. 2006, H06 hereafter). They were collected on 16 separate nights between August 2003, and November 2004. The data are available on-line from The Canadian Astronomy Data Center. Images were gathered in $g'$, $r'$ and $i'$ Sloan filters using the MegaCam instrument which is a wide-field mosaic imager consisting of 36 2048 × 4612 pixel CCDs. Exposure times of individual frames varied between 480 and 600 s (see Sec 2 H06 for details). At the MegaPrime focus the instrument provides the full field of view amounting to 1-deg$^2$ at a scale of 0.185 arcsec/pixel. The images cover most of the area occupied on the sky by M33 (see Fig. 1 in H06). Processing of the CCD frames was performed as a part of the CFHT Queue Service Observing Mode using the ELIXIR pipeline.

To facilitate the search for, and photometry of, faint extended sources we stacked a subset of the best images for each filter and CCD (field hereafter) combination. The input lists include 6-8 images in $g'$, 7-10 images in $r'$ and 6-10 images in the $i'$ filter. Median seeing values of the selected images (from all 36 fields) are 0.95, 0.88 and 0.82 arcsec for $g'$, $r'$ and $i'$ respectively. For each field/filter a "reference image" was chosen and the remaining individual images were then re-sampled to its coordinates. This was done using a modified version of the ISIS 2.1 image subtraction software (Alard and Lupton 1998, Alard 2000). The main modification of ISIS involved using a list of relatively unblended stellar sources with good S/N ratio as input for the interp task. The suitable stars were extracted using the DoPHOT program (Schechter et al. 1993). In running ISIS we divided each field into 2-8 overlapping sub-fields. This helped us cope with the spatial variability of the point spread function (PSF). For each field and filter combination the master frame was created by stacking a relevant set of re-sampled images. These master images were then used in the analysis presented below.
3 The search procedure

Huxor et al. (2008) summarize the various strategies that have been employed to search for extragalactic GCs. In our survey we used a method similar to that described by Mochejska et al. (1998). The method is based on the expectation that the profiles of GCs in M33 should be noticeably more extended than the profiles of stars. As a consequence, when a stellar PSF is subtracted from the globular cluster profile, a 'hole' or 'doughnut-shape' structure will be visible in the residual image. GCs in the MW exhibit half-light radii spanning the range 0.5-25 pc with a median value of 3.6 pc (see Table 1 in Mackey & van den Bergh 2005). At the distance of M33, such GCs would show half-light radii of 0.11-5.3 arcsec, with a median value of 0.77 arcsec. We note that our method may not be the most effective technique for identifying very extended globular clusters like those found by Huxor et al. (2005, 2008) in the halo of M31.

The search for GC candidates was performed for the 30 outer-most of the 36 observed fields. The inner-most fields, numbered by H06 as 13–15 and 22–24, contain a large number of young clusters, which are beyond the scope of this paper. We note that a successful search for clusters inside these crowded fields was conducted recently by Park & Lee (2007) using HST/WFPC2 archival images. We employed the DAOPHOT/ALLSTAR (Stetson, 1987) package to calculate the PSF and to perform profile photometry inside the analyzed sub-fields. We used this software to produce residual images which are free of all sources detected by DAOPHOT and accepted by ALLSTAR. Candidate extended, non-stellar objects were selected by visual inspection of the residual images. Preliminary centroids of these candidates were determined for each of the three filters. We then used an iterative procedure to re-build an image of each object. First, all "stars" located within 3.5 pixels of the center of each object are added back into the image. After this step we define a set of "object pixels" to consist of all pixels within the above radius that have a signal that is 4-σ above the local sky level. We then check for pixels next to the object pixels that are 5-σ below sky level. If such a dip is associated with a previously subtracted star, then the star is added back into the image. This procedure usually ends after a few iterations. The images from the 3 separate filters are aligned spatially and the master set of object pixels is formed by their combination. Finally, for each filter, the image of an extended object is reconstructed by assigning original values to all object pixels from the master set. Each re-constructed image is then inspected visually to check for bright field stars affecting the object profile. If such stars are noted they are subtracted from the image. The steps involved in the above procedure are illustrated in Fig. 1.

To derive accurate centroids of the extended objects and to estimate the FHWM of their profiles we have employed the SExtractor 2.5.0 package (Bertin & Arnouts, 1996). We set the package parameters to detect all objects having more than 10 pixels with values 3-σ above the local sky level. Refined object coordinates were calculated using the windowing option. For details on the background estimation and the source selection see the SExtractor user manual (Bertin & Arnouts, 1996; Holwerda 2005). The code was applied to frames containing only reconstructed images of the candidate extended objects. A total of 5243 objects are detected both by visual inspection of the images and by SExtractor. Of these, 4715 are detected in $g'$, 4794 are detected in $r'$ and 4971 are detected in
Some objects were counted twice as they are located on the overlapping parts of some sub-fields. After accounting for these multiple detections we are left with 4780 unique objects, the majority of which were detected in all three filters.

3.1 Photometry and astrometry

We measured the instrumental magnitudes of the extended objects using 2 circular apertures with radii of $1.0 \times FWHM$ and $2.0 \times FWHM$. When available, we used the $FWHM$ value returned by SExtractor. In cases where the source was too faint to pass the shape measurement threshold in SExtractor we used the $FWHM$ value estimated with the IRAF/imexam task. Note that for 83 faint sources imexam failed to converge as well; instrumental magnitudes are unavailable for these objects. Photometry was performed using the DAOPHOT/PHOT routine (Stetson 1987). Instrumental magnitudes were subsequently transformed to the $g'r'i'$ system of H06 by applying zero-point offsets to our measurements. The offsets were obtained by calculating the sigma-clipped median difference between the H06 catalog values and the instrumental magnitudes of stellar sources obtained by us. We used stars down to the catalog magnitudes of 23.5. Our instrumental magnitudes for stars were obtained by adding appropriate aperture corrections to profile photometry extracted with DAOPHOT/ALLSTAR (Stetson 1987). Aperture corrections were derived with the DAOGROW code (Stetson 1990). The photometry of stellar sources used in H06 is on an instrumental system which corresponds approximately to the SDSS $g'r'i'$ system. The authors applied an approximate transformation provided by the ELIXIR pipeline which was used for processing the MegaCam data. While implementing the ELIXIR calibration H06 used only the zero-point terms and ignored the color terms of the transformations. It is expected that a more accurate calibration of the stellar photometry used in H06 will be available in the near future. For the moment the photometry of extended objects presented here is on the same instrumental system as the catalog of H06. One may, however, use the transformation provided in Sec. 4.1 of H06 to get approximate $R$ magnitudes of objects in our list.

The astrometric frame solution was derived for each field using the equatorial coordinates of stellar sources included in the catalog of H06. The median difference between matched stars was 0.04 arcsec. The astrometric system of H06 is tied to the USNO-B1.0 catalog (Monet et al. 2003), however, for most of MegaCam CCDs the calibration was obtained indirectly using astrometry from Massey et al. (2006). We estimate that the accuracy of the equatorial coordinates obtained for our objects is about 0.25 arcsec.

4 The catalog and selection of GC candidates

Table 1 lists photometric and astrometric data for a total 4780 non-stellar objects. We show here only a few rows from the catalog which is available in full on the

*IRAF is distributed by the National Optical Astronomy Observatory, which is operated by the Association of Universities for Research in Astronomy, Inc., under a cooperative agreement with the National Science Foundation.
The ID’s listed in the first column of Table 1 include the MegaCam field number (see H06), the number of our subfield and the number of the object on a given subfield. The equatorial coordinates listed in columns 2-3 are followed by photometry listed in columns 4-15. As described above we provide aperture magnitudes measured for radii of $1.0 \times FWHM$ and $2.0 \times FWHM$. Columns 16 and 17 give $FWHM$ and ellipticity $ell$ measured in the $g'$ filter with SExtractor. The flags returned by SExtractor for the $g'$, $r'$ and $i'$ filters are listed in the next 3 columns. The flags returned by SExtractor for the $g'$, $r'$ and $i'$ filters are listed in columns 18-20. Column 21 gives the $FWHM$ value estimated with IRAF/imexam. The last column provides our proposed classification of the object: $-1$ galaxy (1155 objects); 0 unclassified (3462 objects); 1 likely stellar cluster (122 objects); 2 an already known high confidence clusters included in the SM catalog (41 objects). Our classification is based on visual inspection of the images. Most background galaxies show either structures resembling spiral arms or an elongated "bulge/bar" surrounded by an ellipsoidal halo. Images of most candidate stellar clusters show some "clumpiness" which presumably reflects the presence of some unresolved but noticeable stars within the limits of the object. It should be stressed that the catalog includes only objects which are unresolved or only partially resolved into stars on the MegaCam images. We did not attempt to include resolved objects such as stellar associations or relatively extended young open clusters.

One may expect that the sample of unclassified objects is dominated by background galaxies. This is particularly true for faint objects which were difficult to classify by visual inspection. Nonetheless, detecting and studying the faint population of GCs in M33 would be worth the effort. One way to distinguish between stellar clusters in M33 and background galaxies would be to use HST images. However, only a small fraction of the outer field of the galaxy has been imaged with either WFPC2 or ACS. Another way to select genuine clusters would be to measure their radial velocities.

The sample of targets for spectroscopic follow-up can be narrowed by applying two filters. First, one may exclude candidates with ellipticity $e > 0.3$. All known globular clusters in the Local Group have $e < 0.3$. Harris et al. (2006) note also a lack of clusters with $e > 0.3$ in a large sample of NGC 5128 clusters. Applying the ellipticity criterion to our list reduces the number of objects of type 1 and 0 from 3584 to 2544. Out of the 1040 rejected objects, 179 do not have an ellipticity measurement, 840 are of type 0 and have $e \geq 0.3$, and 21 are of type 1 and have $e \geq 0.3$.

The second possible filter uses the fact that stellar clusters show either blue or

---

†See AAA archive described at [http://www.astrouw.edu.pl/~acta/acta.html](http://www.astrouw.edu.pl/~acta/acta.html); the data are available also at [http://www.camk.edu.pl/case/results/index.html](http://www.camk.edu.pl/case/results/index.html).

‡Object’s flags meaning: $-1$ FW and elipticity was not measured, 0 no comment, 1 has neighbors bright and close or bad pixels, 2 was originally blended with another one, 4 at least one pixel is saturated, 8 too close to image boundary, 16 aperture data are incomplete or corrupted, 32 isophotal data are incomplete or corrupted, 64 a memory overflow occurred during deblending, 99 SExtractor have not detected the object, 128 a memory overflow occurred during extraction. Positive flags but 99 are returned by SExtractor. Please refer to package manual for details.
only moderately red colors. In Fig. 2 we show a color-color diagram of all objects of type 0 and 1 that have $e < 0.3$. The confirmed clusters included in the catalog of SM are marked with bold symbols on the diagram. As one can see, the confirmed clusters occupy a well defined region in the color-color space. The area inside the quadrilateral marked in Fig. 2 contains a total of 758 objects with ellipticity $e < 0.3$. Forty nine of them are classified as likely clusters. Of the remaining 50 objects with such classification, 38 are located outside of the quadrilateral region and 11 do not have magnitude measurements in all three bands. The color-magnitude diagrams presented in Figs. 3-4 show that the sample of objects with $g' - r' < 0.7$ or $r' - i' < 0.5$, which can be considered candidate stellar clusters, extends about 3 mag below the faint end of the currently confirmed sample.

In Figs. 5-7 we present images of 122 objects of type 1 included in our catalog. They can be compared with images of 41 "high confidence clusters" from the SM catalogue which are shown in Fig. 8. As one can see, many objects from our sample look similar to the already known clusters. Spectroscopic follow-up of the whole sample of new cluster candidates would be challenging, but feasible, with currently available instrumentation.

A total of 45 clusters from the SM catalog are located on images of M33 analyzed in our survey. Table 2 gives their cross-identification with our numbering system. We have recovered 41 of them. The bright cluster SM-420 is saturated on our images. The compact cluster SM-419 was identified on HST/WFPC images by Chandar et al. (2001), on our images its profile is hardly different from profiles of nearby stars. Moreover, the object is located only 2.7 arcsec from a star of comparable magnitude. The clusters SM-034 and SM-426 did not pass our visual selection.

Ten objects (#03-1-017, #03-3-014, #03-3-023, #04-6-015, #05-6-018, #16-6-008, #21-8-004, #25-4-009, #26-1-013 and #33-4-018) match to planetary nebulae candidates listed in Magrini et al. (2001). Only #33-4-018 was classified by us as a likely cluster.

5 Cluster 34-5-022

Some of the newly detected cluster candidates can be seen in archival HST/ACS images. We are planning to discuss these objects further in a separate contribution. However, it is possible to obtain resolved stellar photometry using the MegaCam data for at least one of the new objects that we have detected: the cluster candidate #34-5-022. As there are no HST data for this object we present here a short discussion of its properties. As can be seen in Fig. 7 #34-5-022 is a relatively extended object of low central concentration and low surface brightness. Its profile has a FWHM of 4.3 arcsec, and the half-light radius can be estimated at 1.2 arcsec, which at the distance of M33 corresponds to 5.5 pc. For comparison, in the sample of 41 high confidence clusters from the SM list which are included in our catalog, the most extended object is #12-1-008 with FWHM=3.34 arcsec. From a visual inspection of available images the total radius of cluster #34-5-022 can be estimated conservatively at 7.4 arcsec or 36 pc. Several stars located inside the limits of the object can be resolved on the MegaCam images. In Fig. 9 we present color-magnitude diagrams for these stars along with photometry of nearby stars.
from the galaxy field. The stars located within the cluster limits primarily occupy the left side of the red giant branch defined by the M33 field stars. This indicates that #34-5-022 is most likely an old or intermediate age object of metallicity lower than the average metallicity of the surrounding M33 population.

We have measured $BV$ magnitudes for #34-5-022 using public images of M33 collected with the CFHT telescope and the CFHT12K mosaic. Specifically we have used the images 2002BF02-674528 and 2002BF02-674529 for $B$ and $V$, respectively. The zero points of the photometry were derived using a few nearby stars with $BV$ photometry published by Massey et al. (2006). For the aperture of radius 4.7 arcsec we obtained for #34-5-022 $B = 20.00$ and $V = 19.38$. Recent direct determinations of the distance modulus to M33 cover the range of 24.32-24.92 (Bonanos et al. 2006). Adopting $(m-M)_0 = 24.6$ and $A_V = 0.3$ we obtain an absolute magnitude of the cluster $M_V = -5.2$. This luminosity places the object in the domain of globular clusters in the $M_V$ versus half-luminosity-radius plane. According to the empirical formula proposed by Mackey & van den Bergh (2005), at $M_V = -5.2$ the division between dwarf galaxies and globular clusters occurs near $R_h = 45pc$. We conclude that #34-5-022 is a very good candidate for one of the faintest and at the same time one of the most extended old stellar clusters detected so far in M33. It is located in the outskirts of the galaxy disk at a projected angular distance from the center of $d = 26.8$ arcmin. Of a total of 264 high confidence clusters included in the SM catalog, only 3 objects have larger values of distance with $27.3 < d < 28.2$ arcmin. Moreover, Stonkute et al. (2008) recently reported the detection of an extended cluster, M33-EC1, located at a projected distance of 48.4 arcmin from the galaxy center. This cluster as well as cluster #34-5-022 deserve detailed photometric study using $HST$ images.

6 Discussion

The presented catalog of extended objects located in the outer field of M33 contains 122 probable globular clusters. They are first class candidates for spectroscopic follow-up. The catalog also includes a few hundred fainter objects that are diffuse and roughly spherical. Studying this sub-sample may allow one to extend the faint end of the currently known luminosity function of M33 clusters by 2-3 magnitudes. Our list includes 33 likely clusters (objects of type 1) which are located at a distance of $25 < d < 33$ arcmin from the center of M33. The SM catalog includes only 3 clusters and 1 unclassified object which are located in this distance range. The clusters located in the outer part of the galaxy are attractive targets for obtaining deep color-magnitude diagrams with the $HST$. The diagrams of clusters projected onto the inner part of the disk are strongly dominated by field stars (Sarajedini et al. 1998, 2000) making it difficult to distinguish their red giant branches and nearly impossible to identify their main sequence stars. This problem should be greatly reduced for the outer-most clusters. Moreover, studying these objects will provide insight on the puzzling paucity of blue horizontal branch clusters in M33. The color-magnitude diagrams of 3 outer M33 disk fields presented by (Barker et al. 2007) include stars located about 3.5 mag below the level of the red giant clump. These diagrams are based on relatively shallow images obtained with the $HST$/ACS. Hence, one may expect that deeper exposures of the outer-most clusters should
allow clear identification of the upper main sequence stars in these objects.

Acknowledgements. Research of JK and KZ is supported by the Foundation for the Polish Science through grant MISTRZ. This research used the facilities of the Canadian Astronomy Data Centre operated by the National Research Council of Canada with the support of the Canadian Space Agency. Based on observations made with the NASA/ESA Hubble Space Telescope, and obtained from the Hubble Legacy Archive, which is a collaboration between the Space Telescope Science Institute (STScI/NASA), the Space Telescope European Coordinating Facility (ST-ECF/ESA) and the Canadian Astronomy Data Centre (CADC/NRC/CSA). Based on observations obtained with MegaPrime/MegaCam, a joint project of CFHT and CEA/DAPNIA, at the Canada-France-Hawaii Telescope (CFHT) which is operated by the National Research Council (NRC) of Canada, the Institut National des Science de l'Univers of the Centre National de la Recherche Scientifique (CNRS) of France, and the University of Hawaii.

REFERENCES

Alard, C., & Lupton, R.H. 1998, Astrophys. J., 503, 325.
Alard, C. 2000, Astrophys. J. Suppl. Ser., 144, 363.
Barker, M.K., Sarajedini, A., Geisler, D., Harding, P. & Schommer, R. 2007, Astron. J., 133, 1138.
Bedin, L.R. et al. 2005, Astron. Astrophys., 444, 831.
Bertin, E., & Arnouts, S. 1996, Astron. Astrophys. Suppl. Ser., 117, 393.
Bonanos, A.Z. et al. 2006, Astrophys. J., 652, 333.
Belokurov, V. et al. 2007, Astrophys. J., 654, 897.
Chandar, R., Bianchi, L., & Ford, H.C. 1999, Astrophys. J. Suppl. Ser., 122, 431.
Chandar, R., Bianchi, L., & Ford, H.C. 2001, Astron. Astrophys., 366, 498.
Ibata, R.A., Gilmore, G., & Irwin, M.J. 1994, Nature, 370, 194.
Ibata, R.A., Irwin, M.J., Ferguson, A.M.N., Lewis, G., & Tanvir, N. 2001, Nature, 412, 49.
Hartman J.D. et al. 2006, MNRAS, 371, 1405 (H06).
Hiltner, W.A. 1960, Astrophys. J., 131, 163.
Holwerda, B.W. 2005, Source Extractor for Dummies v5, preprint, astro-ph/0512139.
Harris, W.E., Harris, G.L.H., Barmby, P., McLaughlin, D.E., & Forbes, D.A. 2006, Astron. J., 132, 2187.
Huxor, A.P., Tanvir, N.R., Irwin, M.J., Ibata, R., Collett, J.L., Ferguson, A.M.N., Bridges, T., & Lewis, G.F. 2005, MNRAS, 360, 1007.
Huxor, A.P., Tanvir, N.R., Ferguson, A.M., Irwin M.J, Ibata, R., Bridges, T., & Lewis, G.F. 2008, MNRAS, in print, arXiv:0801.0002v1.
Koposov, S. et al. 2007, Astrophys. J., 669, 337.
Mackey, A.D., & van den Bergh 2005, MNRAS, 360, 631.
Magrini, L., Cardwell, A., Corradi, R.L.M., Mampaso, A. & Perinotto, M. 2001, Astron. Astrophys., 367, 498.
Majewski, S.R., Law, D.R., Polak, A.A., & Patterson R.J. Astrophys. J. Letters, 2006, 637, 25.
Martin, N.F., Ibata, R.A., Chapman, S.C., Irwin, M., and Lewis, G.F. 2007, MNRAS, 380, 281.
Massey, P., Olsen, K.A.G., Hodge, P.W., Strong, S.B., Jacoby, G.H., Schlining, W., & Smith, R.C. 2006, Astron. J., 131, 2478.
McConnachie, A.W., Chapman, S.C., Ibata, R.A., Ferguson, A.M., Irwin, M., Lewis, G.F., Tanvir, N.R., & Martin, N. 2006, Astrophys. J. Letters, 647, 25.
Mochejska, B.J., Kaluzny, J., Kroonenberger, M., Sasselov, D.D. & Stanek, K. Z. 1998, Acta Astron., 48, 455.
Monet, D.G. et al. 2003, Astron. J., 125, 984.
Park, W.-K., & Lee, M.G. 2007, Astron. J., 134, 2168.
Sarajedini, A. 2007, First light science with the GTC eds. Guzman, R., Packham, C., and Rodriguez Espinosa, R.M. (RMAA Conf. Ser.), 29, 48.
Sarajdini, A., & Mancone, C.L. 2007, Astrophys. J. Suppl. Ser., 134, 447 (SM).
Schechter, P.L., Mateo, M., & Saha, A. 1993, *P.A.S.P.*, **105**, 1342.
Stetson, P.B. 1987, *P.A.S.P.*, **99**, 191.
Stetson, P.B. 1990, *P.A.S.P.*, **102**, 932.
Stonkute, R. et al. 2008, *Astron. J.*, *in print*, arXiv:0802.0501.
Walsh, S.M., Willman, B., Sand, D., Harris, J., Seth, A., Zaritsky, D. & Jerjen, H. 2008, *Astrophys. J.*, *submitted*, arXiv:0712.3054v1.
Willman, B. et al. 2002, *Astron. J.*, **123**, 848.
$$\alpha_{2000} \ [^\circ] \quad \delta_{2000} \ [^\circ] \quad g' \ (1) \quad g'_{\text{err}} \ (1) \quad r' \ (1) \quad r'_{\text{err}} \ (1) \quad i' \ (1) \quad i'_{\text{err}} \ (1)$$

| ID   | $\alpha_{2000}$ | $\delta_{2000}$ | $g'$     | $g'_{\text{err}}$ | $r'$     | $r'_{\text{err}}$ | $i'$     | $i'_{\text{err}}$ |
|------|-----------------|-----------------|----------|------------------|----------|------------------|----------|------------------|
| 01-1-001 | 23.90952        | +31.10885       | 24.051   | 0.069            | 23.258   | 0.034            | 22.676   | 0.035            |
| 01-1-002 | 23.91051        | -31.12007       | 23.760   | 0.036            | 22.596   | 0.014            | 21.508   | 0.008            |
| 01-1-003 | 23.91083        | +31.08312       | 99.999   | 9.999            | 99.999   | 9.999            | 99.999   | 9.999            |
| 01-1-004 | 23.91130        | -31.09520       | 23.292   | 0.026            | 22.160   | 0.010            | 21.368   | 0.008            |
| 01-1-005 | 23.91165        | +31.05102       | 23.345   | 0.045            | 22.159   | 0.013            | 21.548   | 0.012            |
| 01-1-006 | 23.91170        | +31.10112       | 23.140   | 0.025            | 22.011   | 0.010            | 20.954   | 0.006            |

Table 1: Catalogue of candidate clusters in the outer part of M33.

| ID   | $\alpha_{2000}$ | $\delta_{2000}$ | $g'$     | $g'_{\text{err}}$ | $r'$     | $r'_{\text{err}}$ | $i'$     | $i'_{\text{err}}$ |
|------|-----------------|-----------------|----------|------------------|----------|------------------|----------|------------------|
| 003  | 25 8 024        | 035             | 25 3 001 | 327              | 31 6 020 | 436              | 12 2 015 |
| 006  | 25 8 015        | 041             | 33 4 016 | 345              | 31 6 012 | 438              | 30 6 013 |
| 009  | 25 7 008        | 053             | 33 6 006 | 393              | 04 6 011 | 439              | 12 3 011 |
| 010  | 16 4 016        | 090             | 33 3 008 | 401              | 04 6 014 | 441              | 12 6 003 |
| 015  | 25 2 017        | 091             | 06 6 015 | 421              | 12 2 005 | 443              | 12 5 006 |
| 016  | 34 1 026        | 102             | 33 3 005 | 422              | 12 1 006 | 446              | 12 5 016 |
| 023  | 25 2 014        | 115             | 06 6 018 | 425              | 12 2 008 | 447              | 12 7 022 |
| 026  | 34 2 006        | 149             | 05 3 005 | 427              | 12 2 010 | 449              | 11 1 024 |
| 028  | 07 6 018        | 155             | 32 6 016 | 428              | 12 1 008 | 449              | 11 1 024 |
| 029  | 16 6 013        | 194             | 05 6 005 | 429              | 12 2 014 | 449              | 11 1 024 |
| 032  | 16 7 016        | 216             | 32 3 019 | 432              | 12 1 011 | 449              | 11 1 024 |

Table 2: Cross-identification of high confidence clusters from the SM catalog with objects from our list.
Figure 1: Illustration of a procedure to construct clean images of extended objects. Rows from top to bottom show: a background galaxy (# 02-01-022), a new cluster candidate (# 12-07-007), a known cluster (# 34-02-006) and a background galaxy with an extended halo. Columns from left to right show: input image, star subtracted image, object pixels map, cleaned object image and cleaned object image with marked contours of 2-σ, 3-σ and 4-σ counts above sky level. Each stamp has a size of $25'' \times 25''$. 
Figure 2: Colour-colour diagram for objects of type 0 or 1 and with ellipticity $e < 0.3$. Filled squares are high confidence clusters from the SM catalog. The parallelogram shows a color selection that may be applied to choose candidate clusters for spectroscopic follow-up.
Figure 3: $g' - r'$ vs. $i'$ diagram for objects of type 0 or 1 and $e < 0.3$. Filled boxes are high confidence clusters from the SM catalog.
Figure 4: $r' - i'$ vs. $i'$ diagram for objects of type 0 or 1 and $e < 0.3$. Filled boxes are high confidence clusters from the SM catalog.
Figure 8: High confidence clusters from the SM catalogue included in our list. Each stamp has 25 arcsec on a side. North is up and east is to the left.
Figure 9: Color-magnitude diagrams for the 90×90 arcsec$^2$ region of M33 centered on the stellar cluster #34-5-022. Stars located at a projected distance $d<4.8$ arcsec from the cluster center are marked with large symbols.