SDSS/SEGUE ugriz Color-Magnitude Diagrams and Spectroscopy of Galactic Open and Globular Clusters

Young Sun Lee, N. De Lee, T.C. Beers, H. Smith (Michigan State), R. Wilhelm (Texas Tech),
C. Allende Prieto (U. Texas), B. Yanny (FNAL), C. Rockosi (UCSC), H.J. Newberg (RPI)

Abstract

The Sloan Digital Sky Survey (SDSS) and Sloan Extension for Galactic Understanding and Exploration (SEGUE) offer an unprecedented stellar database with which to explore the properties of the thin disk, thick disk, and halo of the Galaxy. To make full use of the information contained in the available spectra and photometry, we require external checks on determinations of radial velocity, effective temperature, surface gravity, and metal abundance for stars in the SDSS/SEGUE database. One useful approach is to make use of the large number of stars in open and globular clusters that have been observed in SDSS/SEGUE.

As examples, we present color-magnitude diagrams, in the SDSS *ugriz* system, for three Galactic globular clusters, M 2, M 13, M 15, and one open cluster NGC 2420, based on photometry reported in the third SDSS public data release, DR-3. These data are compared with recent isochrones. In addition, we report overall metallicities and radial velocities for the clusters, which are determined from medium-resolution (2.3 Å) spectra of likely members of each cluster. These data are used to provide an independent check on the accuracy with which we can estimate the radial velocities and atmospheric parameters (T_{eff}, log g, [Fe/H]) for SEGUE stars that will be obtained during the course of SEGUE.

SDSS/SEGUE Data

The Sloan Digital Sky Survey (SDSS) is a multi-band photometric and spectroscopic survey of a large fraction of the northern sky obtained with the 2.5m telescope at Apache Point Observatory in New Mexico (York et al. 2000). As of July, 2005, the first phase of the survey (SDSS-I) was finished and since then SDSS-II has begun. SEGUE is one of three key projects in SDSS-II: LEGACY, SEGUE, SUPERNOVA SURVEY.

SEGUE photometric data will cover 3,500 squared degrees and are processed by fitting PSFs to flattened, sky-subtracted CCD frames. The photometric accuracy is roughly 2% in *g*, *r*, and *i* and 3% in *u* and *z* for all stellar objects brighter than $g < 20$ (Stoughton et al. 2002). Spectroscopic data have a wavelength range of 3,800 – 9,000 Å at a resolution of about R ≈ 1800 (2.3 Å). For stars brighter than g ≈ 19.5, velocities are obtained by fits to a series of standard stellar templates and the accuracy is about 10 km/s.

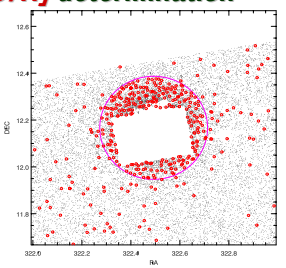
Cluster Properties

	M 15 (NGC 7078)	M 2 (NGC 7089)	M 13 (NGC 6205)	NGC 2420
RA	RA : 21:29:58.3	RA : 21:33:29.3	RA : 16:41:41.5	RA : 07:38:30.0
DEC	DEC : +12:10:01	DEC : -00:49:23	DEC : +36:27:37	DEC : +21:34:00
(l, b)	(65.01, -27.31)	(53.38, -35.78)	(59.01, 40.91)	(198.11, 19.65)
[Fe/H]	-2.26 (-2.21)	-1.62 (-1.5)	-1.54 (-1.8)	-0.38 (-0.75)
m – M	15.37 (15.14)	15.49 (15.32)	14.48 (14.48)	11.95 (11.60)
V_{HB}	15.83	16.05	15.05	N/A
RV(km/s)	-107.0 (-115.3)	-5.3 (-5.3)	-245.6 (-250.1)	+67 (+67.2)
E(B-V)	0.1 (0.095)	0.06 (0.078)	0.02 (0.042)	0.05 (0.050)

GCs from Harris (1996); NGC 2420 from Friel et al. (2002). Numbers in red are our estimates

Overall Radial Velocity and [Fe/H] determination

First we selected likely members (red dotted curve in the right top figure) of a cluster, which are defined by stars within a certain radius (magenta color in the right figure) and fit the Gaussian to the RV and [Fe/H] histograms to obtain a mean and standard deviation. And again choose stars (green color in the right top figure) within two standard deviations from the mean of RV and [Fe/H] at the same time (e.g., stars within $[Fe/H]_{mean} \pm 2\sigma$). We then fit the Gaussian (blue dashed-dotted curve) again to obtain the final overall RV and metallicity and uncertainties.



Color-Magnitude Diagrams and Isochrones

In order to make a color-magnitude diagram, we first selected stars within a certain radius (close to the tidal radius of a cluster) in RA and DEC, determined by eye. Furthermore, we eliminated stars with photometric errors greater than 0.2 magnitude in each band (*ugriz*). Then we employed the isochrones by Girardi et al. (2004), in order to estimate ages and distances of clusters. For the metallicity, we adopted [Fe/H] from the spectroscopic determination, except for NGC 2420, because we were not able to obtain a good isochrone fit with the metallicity from the spectroscopic data. Instead, [Fe/H]= -0.38 from Friel et al. (2002) was used in the fitting. First, we attempted to obtain a best fit of an isochrone in *g*, *g* - *r* plane and took into account other colors and magnitudes in fitting.

References

Friel, E. D., et al. 2002, AJ, 124, 2693

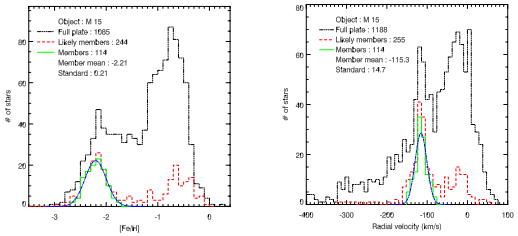
Girardi, L., Grebel, E. K., Odenkirchen, M., Chiosi, C. 2004, A&A, 422, 205

Harris, W. E. 1996, AJ, 112, 1487

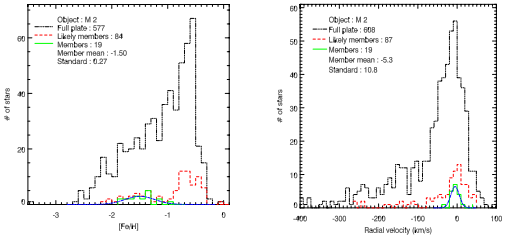
Stoughton, C., et al. 2002, AJ, 123, 485

York, D. G., et al. 2000, AJ, 120, 1579

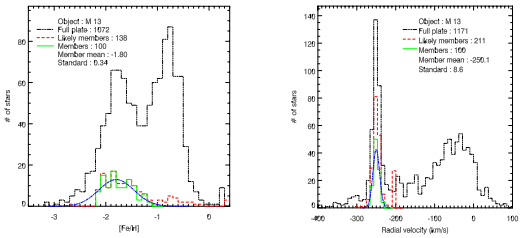
M 15 Metallicity and Velocity Distribution



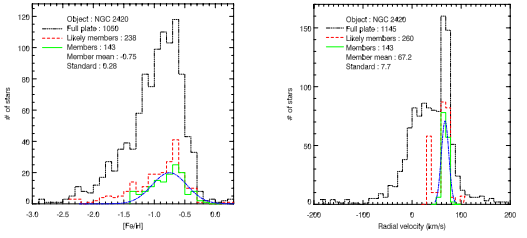
M 2 Metallicity and Velocity Distribution



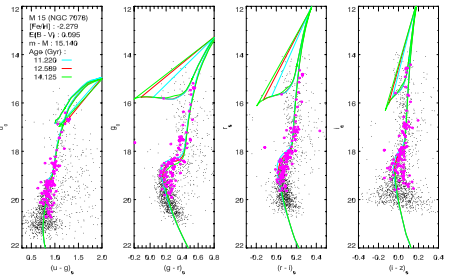
M 13 Metallicity and Velocity Distribution



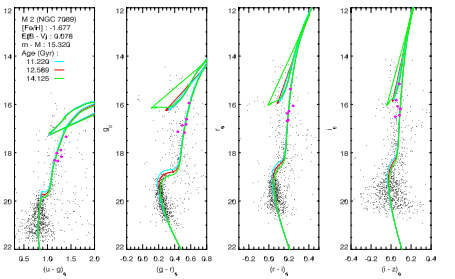
NGC 2420 Metallicity and Velocity Distribution



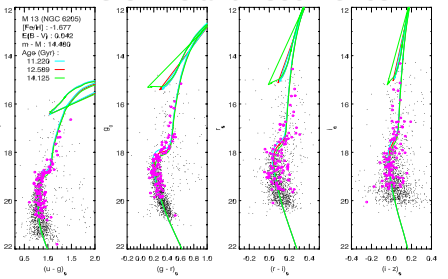
M 15 CMDs and Isochrones



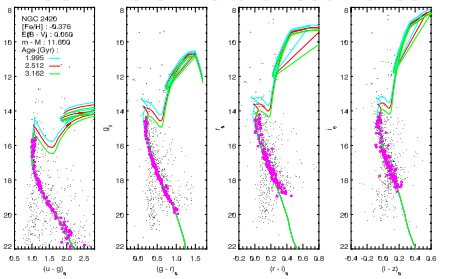
M 2 CMDs and Isochrones



M 13 CMDs and Isochrones



NGC 2420 CMDs and Isochrones



Summary

We obtained CMDs and isochrones for three galactic globular clusters, M 2, M 13, M 15, and one open cluster NGC 2420. Isochrones are generally well matched, except for the upper red giant branch regions for GCs, where the isochrones are suspect. We are seeking to improve these isochrones at present. The overall metallicity and radial velocity of each cluster are calculated based on medium-resolution (2.3 Å) spectra for likely members of the clusters by fitting Gaussians to the metallicity and radial velocity distributions of likely members. Overall averages are consistent with the values in the literature. In particular, determination of the velocity is accurate to within 10 km/s and overall metallicities deviate by no more than 0.25 - 0.3 dex among the selected cluster members.

This project is funded by the NSF through grant PHY0216783, and the Universities of JINA.