WIYN Open Cluster Survey: Comparison of Padova and Dartmouth Isochrones Using Deep Near-Infrared Data for Key Open Clusters

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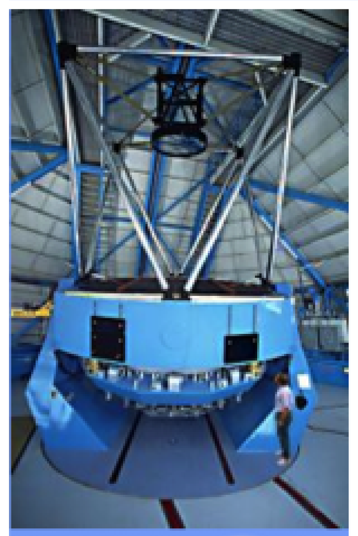


WOCS

WIYN Open Cluster Study

Abstract:

We present a comparison of results from using Padova (Marigo et al. 2008) and Dartmouth (Dotter et al. 2007) isochrones for several open clusters (M35, M37, M67) in the infrared. Using newly reduced deep near-infrared data (*J* ~ 20), we compare the validity of these isochrones at low mass, and over a wide range in cluster ages. In addition, we combine the new deep NIR data with 2MASS, mid infrared photometry (3.0-8.0 micron) and optical (*UBVRI/ugriz*) data to construct a wide photometric set for each cluster. We look for variations in isochrone-derived parameters when using different color-magnitude combinations.

Photometry:

Observations of three clusters (M67, M37, M35) were taken using the NOAO Extremely Wide Field Imager (NEWFIRM) on the Kitt Peak telescope in 2009. Near-Infrared photometry (JHK_s) was obtained down to J ~ 20 in each of the clusters and merged with existing 2MASS photometry (Skrutskie et al. 2006) to build a complete near-infrared data set for each cluster.

Mid-infrared data ([3.6][4.5][5.8][8.0]) for each of the clusters is from our own Spitzer Space Telescope study (Frinchaboy et al., in prep).

Visual data for M67 is from Deokkeun An et al. (2008) and contains photometry for the SDSS filters *ugriz*. Visual data for M37 and M35 comes from the Canada France Hawaii Telescope (CFHT) using *B* and *V* filters (Kalarai, private communication).

The M67 data set was cleaned using membership and RV information from Yadav et al. (2008)

Automated Isochrone Fitting Routine:

Given an isochrone curve with parameters Θ = (a, z, m, r), we calculate the distance in the color-magnitude plane from each cluster star to the isochrone curve. This gives us a sequence of distances $(d_0,\ldots,d_N)_\Theta$ where N is the number of cluster stars in the CMD. The isochrone parameters which minimize the average of this sequence is taken to be the best fit for the CMD. The standard errors of the fit are estimated by bootstrapping. A resampled data set is constructed by randomly selecting (with replacement) N data points from the cluster. We then fit an isochrone to this resampled data set as above. We perform 200 such resamplings, and the standard errors we quote are the standard deviations of the resulting fits.

Isochrone Fitting Trends:

M67

- Padova isochrones overestimated Z systematically, but tracked very closely with accepted values for age and distance.
- Dartmouth fittings underestimated age, especially in the visual, but this is expected since the Sloan data does not extend much above the turnoff point. Most other fits determine the correct age. Adding short observations of M67 using *ugriz* filters will help improve fittings.

M37

- Dartmouth isochrones have only been generated up to Z = 0.21, so Z is always underestimated. Padova fits are widely distributed by Z, with very few getting the correct value.
- Dartmouth isochrones all determined the correct age of M37, the lowest age available.

M35

- Z is accurately determined by all fittings and distance is correctly, but weakly, determined. Ages are widely distributed with the mode at a much older age.

Overall Trends

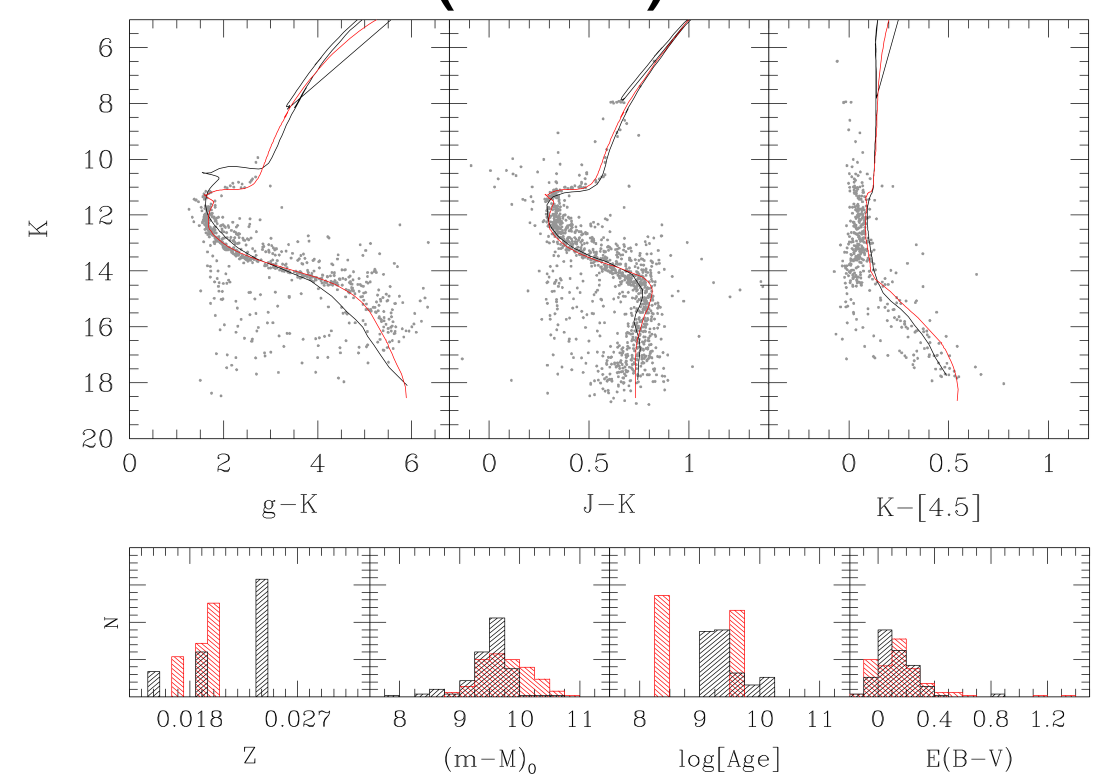
- CMDs involving *K* vs MIR or MIR vs MIR are almost completely vertical (as seen in M67 and M37 above), giving little to no information about distance or Z. Their results, while included in figures, are ignored when discussing overall trends.
- Disregarding M67's visual fittings (explained above), Dartmouth isochrones determined both Z and age much more accurately than Padova.
- There was agreement between both isochrone systems in determining distance to all clusters. Padova determined distance to M67 more accurately, while Dartmouth worked better for M37.
- Padova isochrones have some problems fitting the CMD in the lower main sequence. Padova fits diverge in Visual-NIR combination CMDs, as seen in M67 and M37. Dartmouth isochrones seem to fit well in this region, and may be more useful when comparing visual and NIR data. In other combinations (like the ones in M35), Padova isochrones fit accurately.

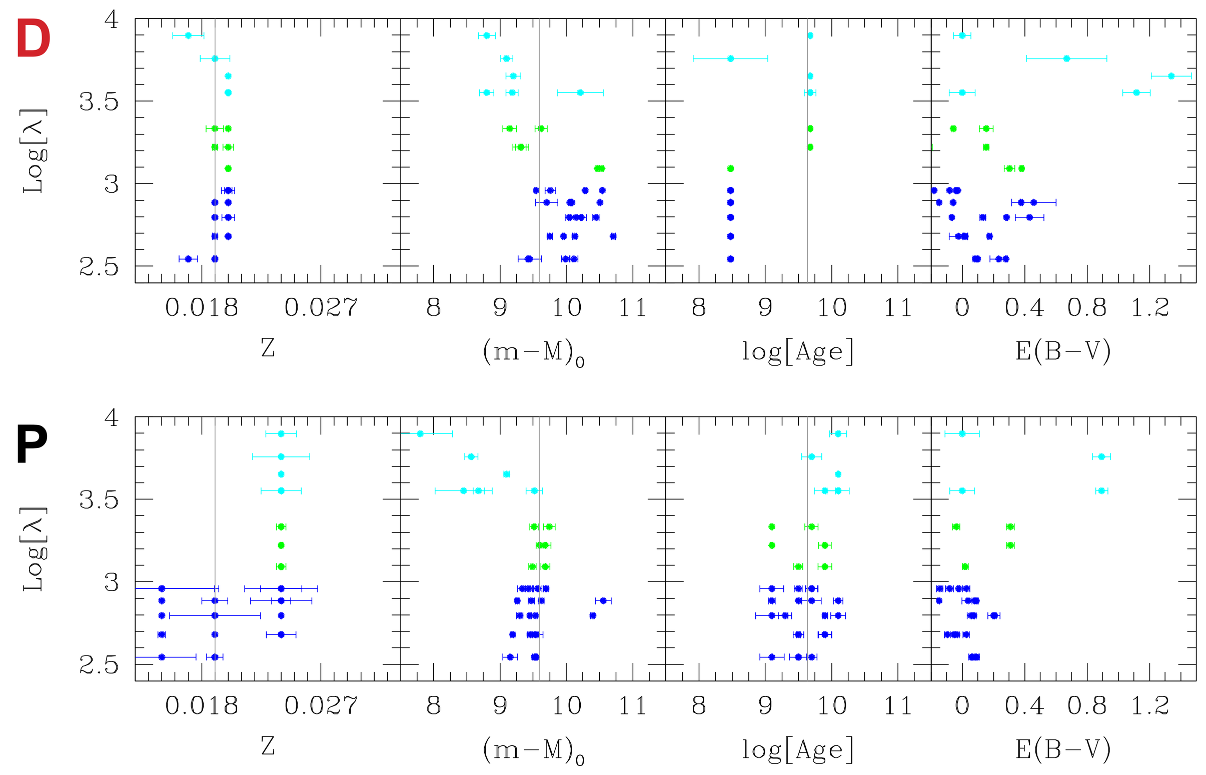
(LEFT) CMDs for given cluster with overplotted best fit isochrones. **Black**: Best-fit Padova isochrone. **Red**: Best-fit Dartmouth isochrone.

(RIGHT) Best-fit parameters plotted vs CMD wavelength. Grey lines are accepted values. **Blue**: Visual vs Visual (*V,B-V; g,g-r;* etc.). **Green**: NIR vs NIR (*J,J-H; J,J-K;* etc). **Cyan**: MIR vs MIR ([3.6],[3.6]-[8.0]; etc.). D = Dartmouth, P = Padova.

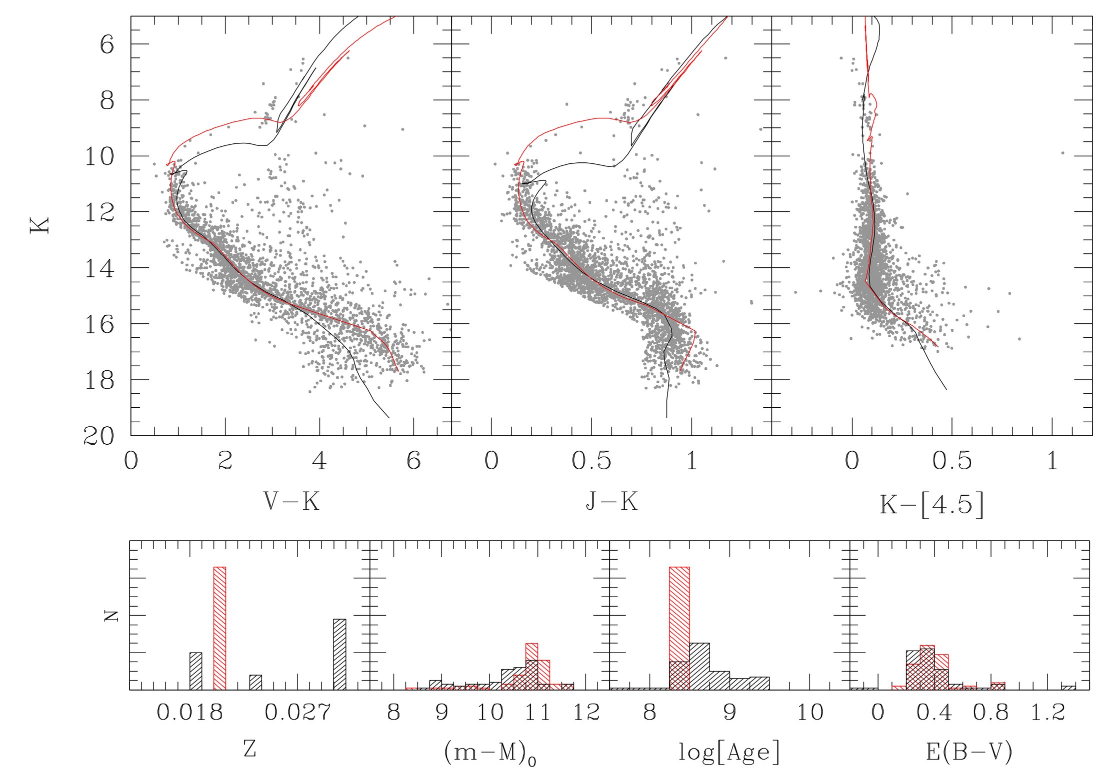
(BOTTOM) Histogram of best-fit parameter results from all CMD color-magnitude combinations (*g* vs *u-g, g-r, g-K*, etc.; *J* vs *g-J, r-J, J-H, J-K*, etc). **Black**: results from Padova isochrone fits. **Red**: results from Dartmouth isochrone fits.

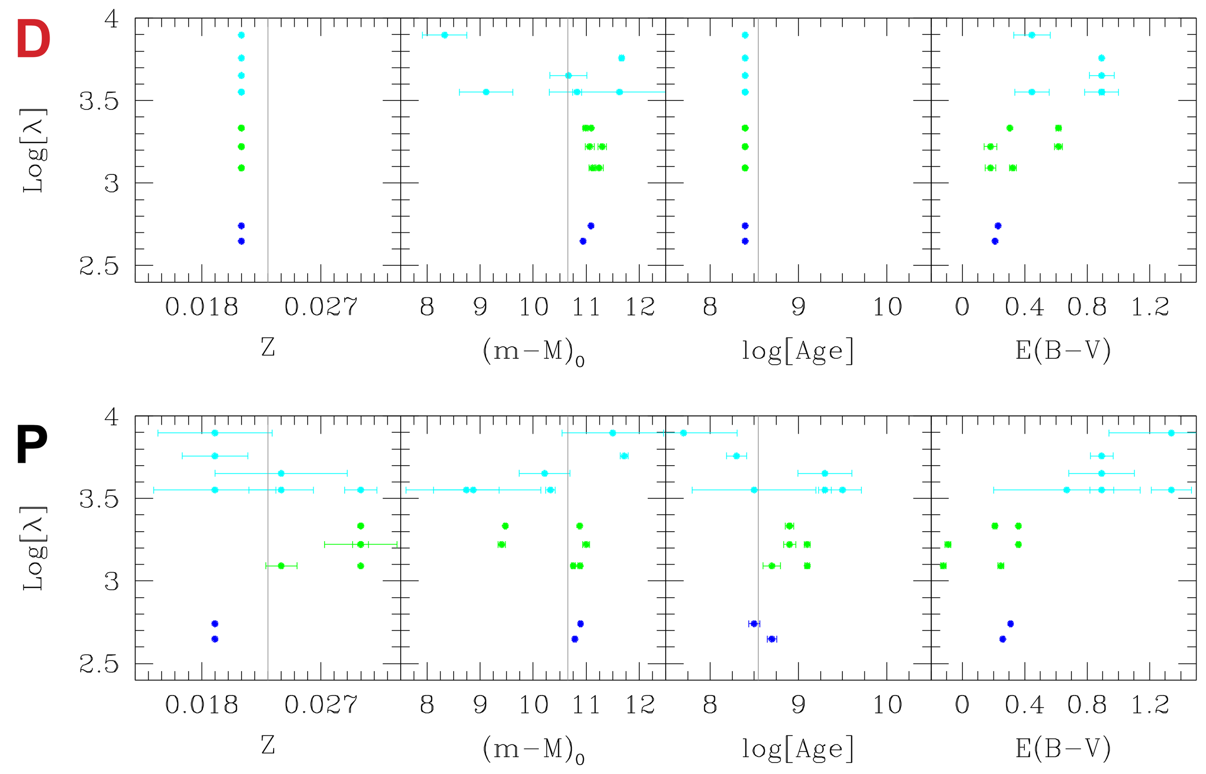
NGC2682 (M67)



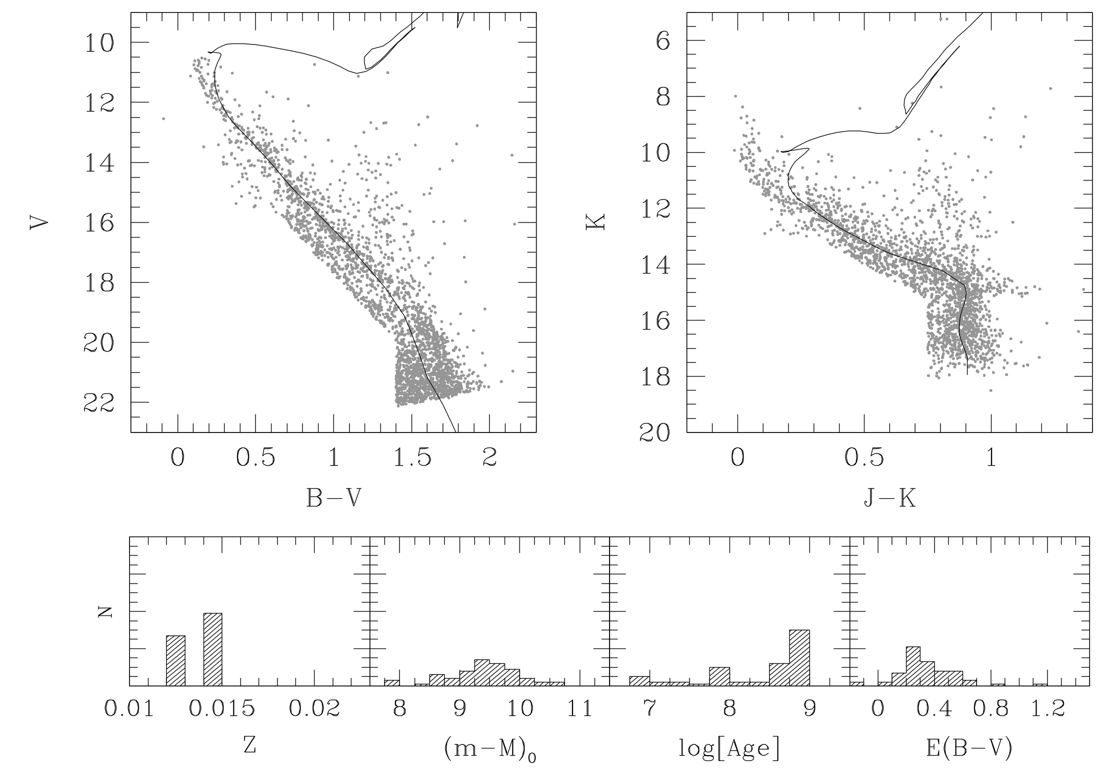


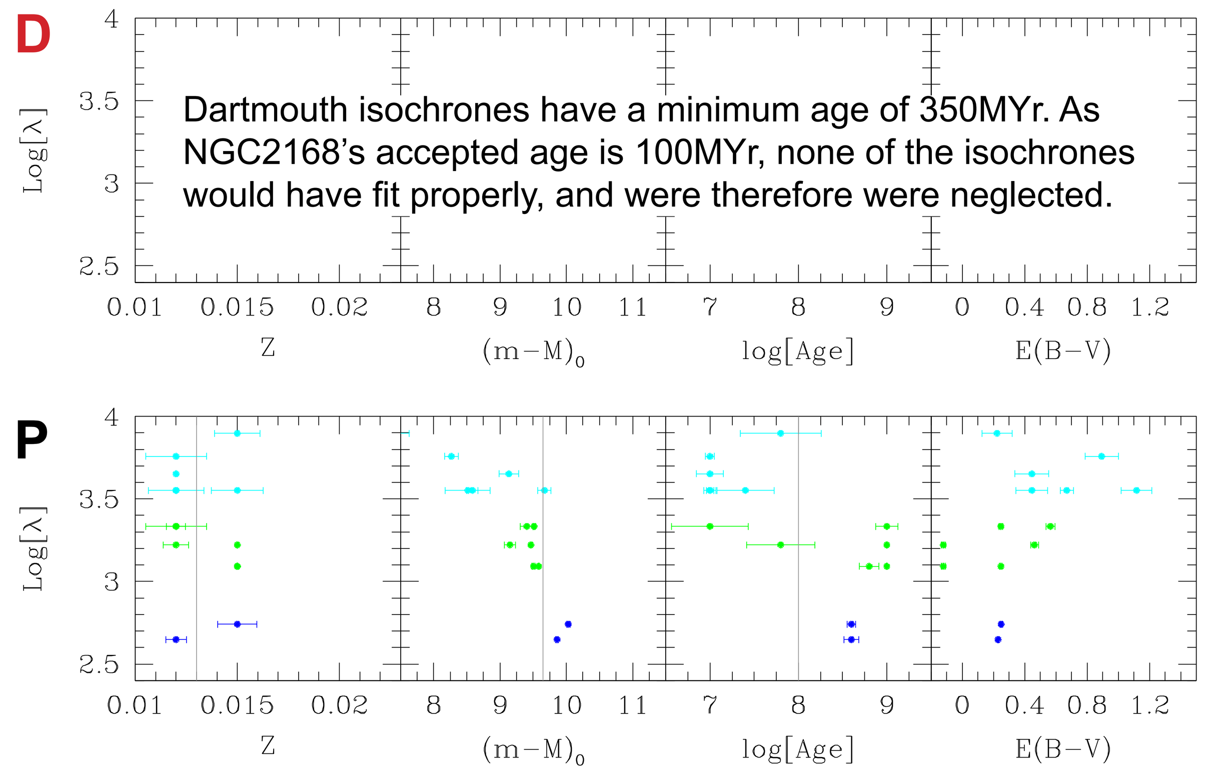
NGC2099 (M37)





NGC2168 (M35)





Future Improvements:

Isochrone fitting is only as good as the dataset. The main source of error in these fittings comes from non-member stars being included. Many (if not all) of the stars above the main sequence in the M35 and M37 CMDs are field stars, and no doubt impacted the fitting. Removing these stars via RV or proper motion measurements would greatly increase the power of this technique.

Another source of contamination is from binary stars. Binaries form a main sequence offset from the single star main sequence and therefore shift the correct fit. By fitting each star's spectral energy distribution to models of binaries and single stars, the binaries in the cluster will be filtered out, leaving us with only single star cluster members. This analysis will be completed in the near future and these fittings will be run again.

References:

Marigo, P., et al. 2008, A&A, 482, 833
Dotter, A., et al. 2007, AJ, 134, 376
Skrutskie, M., et al. 2006, AJ, 131, 1163
Deokkeun An et al. 2009. AJ, 700, 523
Yadav, R., et al. 2008, A&A, 484, 609