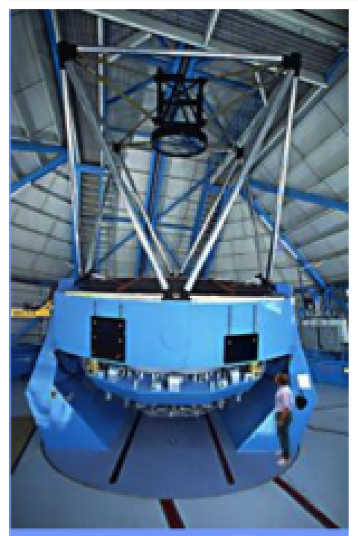
Comparison of Stellar Evolution Models using Newly-Acquired Infrared Data



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WOCS

WIYN Open Cluster Study

Background:

Characterizing a star requires knowing five values: the star's **distance** from Earth, the star's **age**, **reddening** (amount of interstellar gas between Earth and the star), **metallicity** (percentage of atoms that aren't Hydrogen or Helium), and the star's **mass.**

Determining these five parameters is hard for an individual star, but is made easier when studying star clusters. Clusters are assumed to have formed from the same gas cloud at roughly the same time, making four of the five parameters constant.

Isochrones:

To determine the four constant cluster parameters, cluster data is fit to stellar evolution models called isochrones: sets of synthetic stars that have a certain distance, age, metallicity and reddening, but vary in mass. When plotted on a color-magnitude diagram (CMD), as seen in figure 1 below, they form a ridgeline.

Ridgelines are generated for every possible combination of distance, age, metallicity and reddening, then run through a computer program that fits those ridgelines to the actual data.

Using a simple χ^2 fitting, the "best" ridgeline is chosen. The parameters associated with that ridgeline are taken to be the parameters of the cluster itself.

Why do this?

Stellar evolution models are calibrated using visual-wavelength filters (for a long time, these were the only filters that were used in astronomy), thus there is no guarantee that they are completely accurate in infrared bands.

This is a problem, as many newly discovered open clusters are obscured by interstellar gas and dust, which can only been penetrated by infrared wavelengths.

The question we attempt to answer is this:

If we only have infrared data on a cluster, can we be confident that the derived parameters are correct?

To answer this, several methods are employed:

Compare derived parameters for visual filters and infrared filters to see if there are systematic differences.

Compare different stellar evolution models (the Padova and Dartmouth systems) to see whether one has better accuracy than the other.

Plot ridgelines over the cluster data in various bands to see where fits deviate and problems arise.

Data:

Previous work on this project showed that the largest deviations in ischrone fits occured for dim, low-mass stars. Therefore we needed data that covered this low-mass range before any interesting results could follow. The final data set combined information from various sources:

Infrared Data:

New infrared data from the NOAO Extremely Wide Field Imager (NEWFIRM) on the Kitt Peak telescope was analyzed at TCU for several open clusters, two of which were used in this project (M67, M37). This data was deep, meaning that it measured very faint sources, allowing us to probe low-mass stars.

The deep data from NEWFIRM was combined with shallow (only bright stars) infrared data from the 2-Micron All Sky Survey (2MASS).

Visual Data:

Visual data for M67 was obtained from a literature source, Deokkeun An et al. (2008).

Visual data for M37, taken on the Canada-France-Hawaii telescope, was obtained via private communication with J Kalirai.

Figure 1

Isochrone ridgelines overplotted on M67 CMDs.

Left: Visual, *Right:* Infrared. **Black**: Padova, **Red**: Dartmouth

Parameters for isochrone fits are the same for both filter systems, taken from the infrared isochrone fitting. Parameters different between Padova + Dartmouth

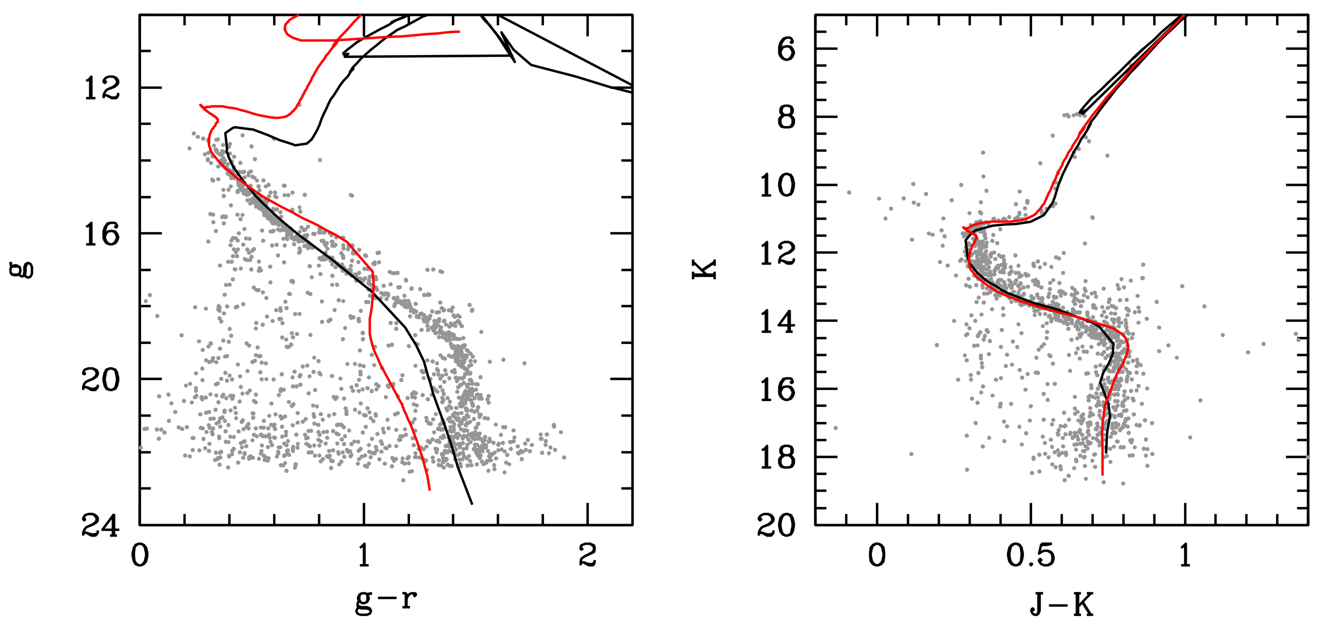
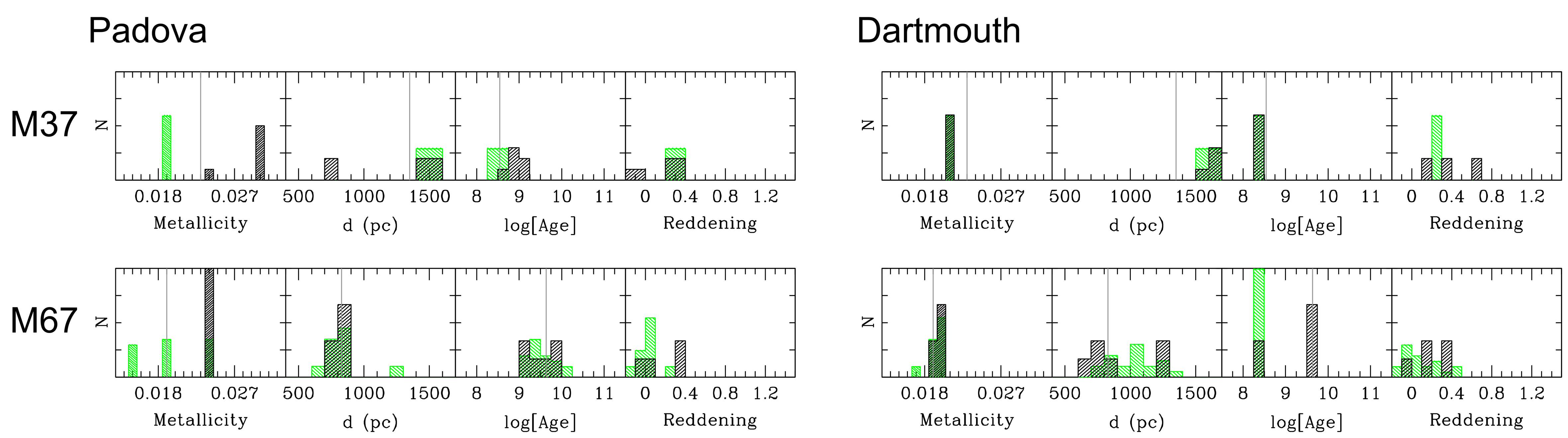


Figure 2

Histogram of isochrone-derived parameters using different filter combinations.

Green: Parameters from Visual-only fittings. **Black**: Parameters from Infrared-only fittings.
Grey lines: "accepted" values for parameters.

Total number of fittings normalized between Visual and Infrared.



Observations:

Figure 1:

The fact that ridgelines with the same parameters do not fit visual and infrared data the same is readily apparent. If we are to get consistent results when we only have IR data, the same ridgeline must fit both sets of data equally well.

The ridgeline strongly deviates from the visual data for dimmer stars (bottom of the CMD), while brighter ones seem to fit fairly well. This means there is probably something wrong with the evolutionary models when it comes to low mass stars in the infrared.

The Dartmouth system fails miserably here, but in other filter combinations (and in M37), the dartmouth ridgeline compares more favorable in the visual bands. There is still some deviation in low mass, but much less than the Padova system. Dartmouth stellar evolution models much more accurately model low mass star evolution.

Figure 2:

In most parameters, the visual and IR fits trend toward the same value. We may not be able to accurately determine parameters from a single fitting, but may need multiple filters in the IR to get the right answer.

Combining the visual and IR results, the Dartmouth system much more accurately (and consistently) predicts certain values, such as metallicity and age. Distance and reddening determinations show similar amounts of spread between the two systems.

Note that the visual data for M67 does not have anything brighter than ~13. This is near a critical point in the CMD, called the *turn-off*, which is directly related to the age of the cluster. The turn-off's absence explains the spike in low age for Dartmouth system fits in the visual, as the fitting routine cannot find it. Removing the green bar in the histogram shows accurate determination of age for M67.

Future Work:

One thing that affects the isochrone fits is the presence of binary stars. Ridgelines are based off of single star evolutionary models, and therefore don't take into account the fact that binaries make up a significant fraction of the stars in the cluster.

Because binaries are brighter than single stars (extra light from the 2nd star), they will appear above the single star ridgeline, shifting the best-fit model up from where it really should be. Because binaries are positioned differently on a CMD depending on what filters are used, this could contribute to the scatter in parameters when using different filter systems.

My PhD research focuses on detecting binary stars within open clusters, and as a by-product will clean the CMD of all binary stars, leaving only singles. Fitting isochrones to this cleaned set should produce more accurate results (at least within the same filter systems).