

# WIYN Open Cluster Study: Photometry of Star Cluster M41

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## INTRODUCTION

We present a five-color photometric analysis of the open star cluster Messier 41 using 84 images taken by the WIYN (Wisconsin, Indiana, Yale, NOAO) 0.9m telescope and a determination of the age, metallicity, reddening, and distance of M41. The point spread function of the stellar light profile was found for every star in each frame, and was used to measure each star's apparent magnitude. Stellar magnitudes were averaged within the five filters in order to create a master catalog of cluster stars.

## OBSERVATION AND COLLECTION

Data were collected at the Kitt Peak National Observatory located near Tucson, Arizona using the WIYN 0.9m telescope. Images of the clusters and standards were taken using the Johnson/Cousins U, B, V, R, and I filters. Exposure times of 1, 5, 25, 125, and 625 seconds were used on the collection dates of February 7-8th, 2018. Photometric Landolt Standards were taken throughout the night for calibration. Within these 84 images of M41 (see Table 2), a range of 1,794 to 14,969 stars were found in each image.

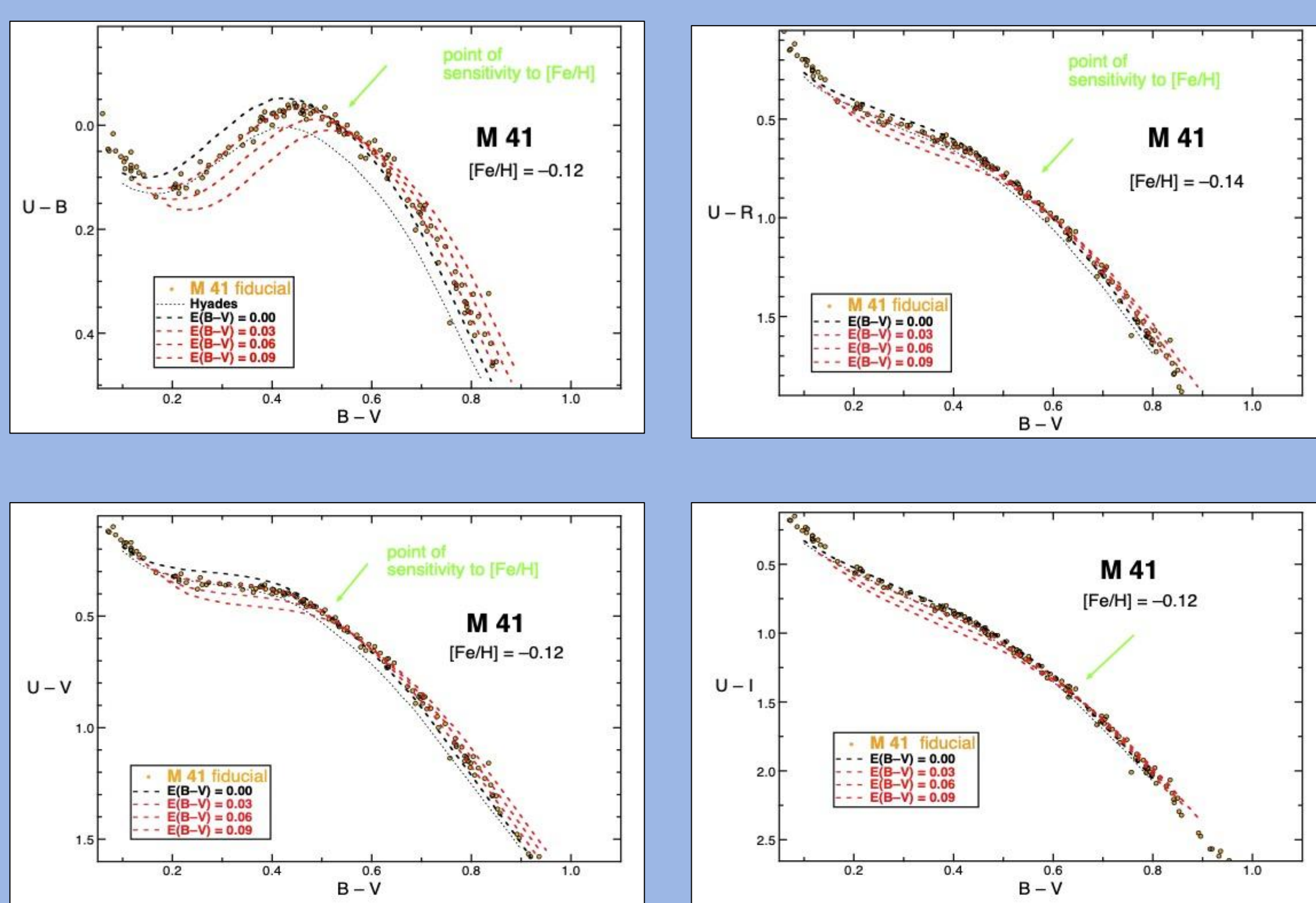


Fig. 1. Selected color-color diagrams that determine metallicity and reddening

Table 1

Reddening E(B-V)	Metallicity [Fe/H]	Age (Myr)	Distance (pc)
0.025 ± 0.004	-0.125 ± 0.006	255 ± 45	671 ± 17

## DATA REDUCTION AND STANDARDIZATION

In order to process each image, important programming software for astronomical research were used including: DAOPHOT, IRAF, and ds9. A point spread function (PSF) was calculated for individual images by defining the best measured isolated stars in that frame, and applied to every star in the frame. Once every star was fitted and magnitudes were determined, aperture correction was applied in order to account light falling outside the PSF radius. This maximized accuracy before matching frames and filters. Averaged catalogs of all images in each filter were created and then combined into one complete master catalog. The next process of this study was the standardization of our master catalog of stars with the use of Arlo Landolt's catalog (L92). We adjusted our data to correspond to that of Landolt's, thus putting our photometric analysis on the standard system.

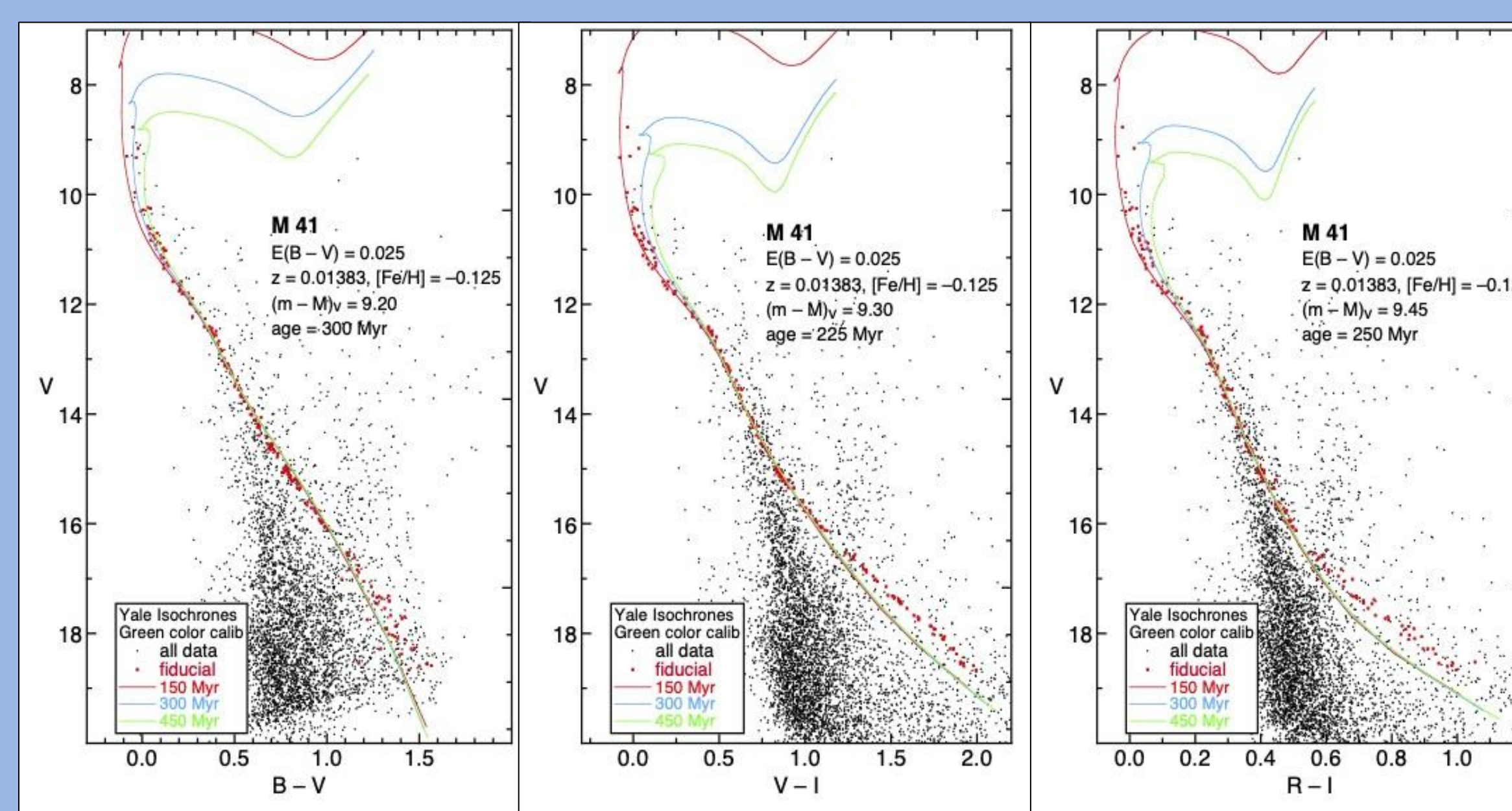


Fig. 2. Color-magnitude diagrams plotting the fiducials with the Y2 Isochrones to match with the appropriate reddening and metallicity. Here, distance and age can be determined.

Table 2

Filter Type	Total # Images Used	# 1s Exposures	# 5s Exposures	# 25s Exposures	# 125s Exposures	# 625s Exposures
U	16	0	4	4	5	3
B	18	4	4	4	5	1
V	16	4	4	3	5	0
R	17	4	5	4	4	0
I	17	4	4	4	5	0

Table 2. Out of the 92 images taken, 84 were used in calculation.

## ANALYSIS

Using the Gaia Catalog, cluster members defining a set of fiducial stars was determined and then refined by eye to those that appear to lie on the single-star main sequence of M41 (Fig. 1, red stars in Fig. 2). These stars were then compared to the single-star sequence of the Hyades, an unreddened cluster, in multiple color-color diagrams (Fig. 1) resulting in the determination of reddening and metallicity of the cluster. The chosen fiducial star set was plotted amongst several different reddening curves; the metallicity could then be confirmed at the point that the fiducial trend was parallel to a reddening curve. To estimate the distance and age of the cluster, Yale Yonsei (Y2) Isochrones of the reddening and metallicity previously calculated were used to be matched with the fiducial set (Fig. 2), and adjusted in distance until the main sequence was fit. The age of M41 is determined by the Y2 Isochrone from matching the main sequence turn off point.

## RESULTS

Between colors, the reddening values are very consistent. When averaged, the final calculated reddening is  $E(B-V) = 0.025 \pm 0.004$  and the metallicity is  $[Fe/H] = -0.125 \pm 0.006$ . When calculating the age, there was a slight discrepancy between one of the six color diagrams vs. the other five. The age was consistent, however there was a larger difference in distance of the cluster. With the outlier, the age is shown to be  $254 \pm 40$  Myr with a distance of  $684 \pm 35$  pc, but without the outlier the age is concluded to be  $255 \pm 45$  Myr with a distance of  $671 \pm 17$  pc. Final results of reddening, metallicity, age and distance, reported without the outlier, are presented in Table 1.

## REFERENCES

- Gaia Collaboration *et al.*, 2018, *A&A*, 616, 1  
 L92 Landolt A., 1992, *AJ*, 104, 340  
 Y2 Demarque, Woo, Kim, & Yi 2004, *ApJS*, 155, 667

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