Relative Age Dating of Young Star Clusters from YSOVAR

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Abstract

The YSOVAR (Young Stellar Object VARiability; Rebull et al. 2014) Spitzer Space Telescope observing program monitored a dozen star forming cores in the mid-infrared (3.6 and 4.5 microns). Rebull et al. (2014) placed these cores in relative age order based on numbers of YSO candidates in SED class bins (I, flat, II, III), which are based on the slope of the SED between 2 and 25 microns. Pan-STARRS data have recently been released (Chambers et al. 2016); deep optical data are now available over all the YSOVAR clusters. We worked with eight of the YSOVAR targets (IC 1396A, AFGL 490, NGC 1333, Mon R2, GGD 12-15, L 1688, IRAS 20050+2720, and Ceph C) and the YSO candidates identified therein as part of YSOVAR (through their infrared colors, variability, and/or X-ray detections plus a star-like SED; see Rebull et al. 2014). We created and examined optical and NIR color-magnitude diagrams and color-color diagrams of these YSO candidates to determine if the addition of optical data contradicted or reinforced the relative age dating of the clusters obtained with SED class ratios.

This project is a collaborative effort of high school students and teachers from three states. They analyzed data individually and later collaborated online to compare results. This project is the result of many years of work with the NASA/IPAC Teacher Archive Research Program (NITARP).

Methods

Sources

Our subset of the YSOVAR star clusters in relative age order from youngest to oldest as ranked by Rebull et al. (2014) based on SED class count ratios (that is, primarily using information from 2-25 μm): **L1688, IRAS 20050+2720, Ceph-C, AFGL 490, NGC 1333, GGD 12-15, Mon R2, IC 1396A**

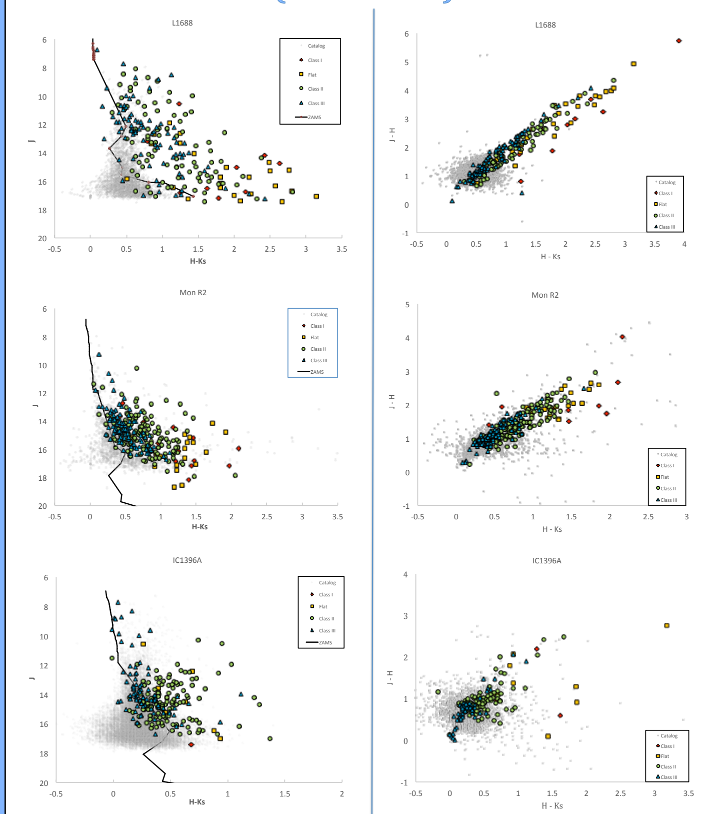
Archival Datasets

Pan-STARRS (grizy; AB mags)
2MASS (JHKs; Vega mags)

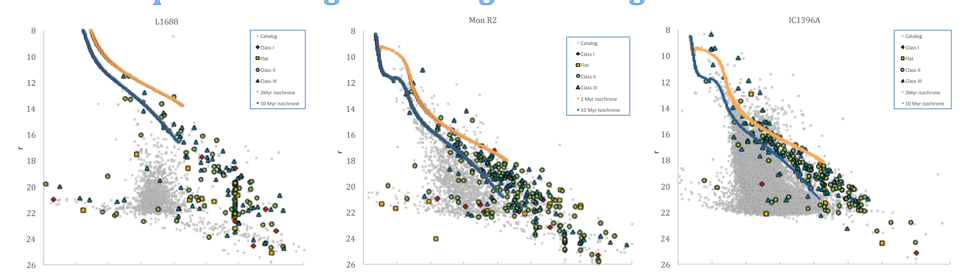
Our Process

- Through color-color and color magnitude diagrams, we strove to check and/or refine the relative age rankings in Rebull et al. (2014).
- Pan-STARRS data recently released (Chambers et al. 2016); could provide new insight into relative age ranking.
- Used 2 and 10 Myr isochrones from TA-DA (Da Rio & Robberto 2012, using NextGen +AMES atmospheric models).
- Used intrinsic disk-free YSO colors from Pecaut and Mamajek (2013) and distances as in Rebull et al. (2014).
- Expected to be able to place clusters in relative age order by comparing source distribution for each cluster in relation to the isochrones/disk-free stars. **Did not work as expected!**

Sample Color-Magnitude and Color-Color Diagrams (2MASS data)



Sample Color-Magnitude Diagrams Using Pan-STARRS data



Results and Conclusions

- We expected the Pan-STARRS data to complement the relative age ordering suggested based on SED classes from the IR data. However, it was not at all clear what the relative age ordering of the clusters based on our graphs should be. (L1688 should be among the youngest and IC1396A among the oldest clusters.) We tried many combinations and the results were still inconclusive.
- Reddening should push late-type stars ~parallel to the isochrones, which is partly why we thought looking at the distributions with respect to the two isochrones might work.
- We have an intrinsic bias in that we only have optical data for the less-embedded sources; we explored the distributions of just the Class III stars (least embedded), which also did not work as we expected.
- After optical CMD attempts failed on the assumption that the NIR data should reach down to more embedded (and reddened) sources, we explored 2MASS CMDs. (L1688 should be ~youngest and IC1396A ~oldest.) Reddening very obvious in L1688, less so in Mon R2; this clearly complicates interpretations of source distributions, even in the NIR. Looking just at the locations of Class III sources doesn't seem to help. So this, too, did not work as we expected!

Future Work

- Obtain and apply isochrones using Pan-STARRS y-band data (not available in TA-DA).
- Explore the use of binning to quantify ratios of objects between isochrones; perhaps simply looking at the distributions to compare them is not enough. (Excel may not be amenable.)
- Consider what kinds of dereddening we can plausibly do. (Excel may not be amenable.)
- Create CMDs/CCDs that combine Pan-STARRS and 2MASS to determine if this larger wavelength baseline provides insight into the relative ages of the clusters. (Will need to be careful combining AB and Vega mags.)
- Apply this approach to the other clusters in the YSOVAR dataset.
- Provide more collaborative opportunities between the students of our four schools.

Chambers, K., Magnier, E., Metcalf, N., etal, 2016, arXiv:1612.05560.
DARIO & ROBBERTO 2012 *AJ* 141: 176-186.
Pecaut and Mamajek 2013 *ApJS* 208: 9-31.
Rebull 2014 *AJ* 148: 92-119.