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Deriving the Low-Mass IMF in Young Clusters: Which Evolutionary Tracks to Use?

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1. Introduction

The initial mass functions (IMFs) derived in embedded clusters are strongly dependent on the adopted temperature scale and set of evolutionary tracks. In Luhman & Rieke (in preparation) we justify the adoption of the temperature scale of Leggett et al. (1996). Over the last several years, evolutionary tracks by D'Antona & Mazzitelli (1994) (DM94), Burrows et al. (1993), and Swenson (FJS93) have been used widely in the analysis of embedded clusters. Only very recently have model interiors been coupled with sophisticated model atmospheres. New evolutionary tracks using Allard's latest NextGen atmospheres have been produced by both Burrows (private communication) and Baraffe et al. (1997) (BCAH97). We test these various tracks against the two low-mass eclipsing binaries (YY Gem, CM Dra), the Pleiades, and globular clusters.

2. CM Dra and YY Gem

In Figure 1 we present the observed properties of YY Gem and CM Dra with the theoretical predictions. For YY Gem, the stellar radii and ratio of component luminosities are from Budding et al. (1996) and the system L_{bol} is from Leung & Schneider (1978). For CM Dra, we repeated the calculation by Lacy (1976) of the component luminosities using new parallax data; the radii were taken from Metcalf et al. (1996). We then used the radii and luminosities for each system to calculate T_{eff}.

Chabrier & Baraffe (1995) found good agreement between the data on CM Dra and YY Gem and their evolutionary tracks using Allard's Base atmospheres. These tracks are not shown, but are similar to the Base tracks of Burrows. However, more recent interiors combined with Allard's latest NextGen atmospheres do not fit the binary data as well as the Base models and are only marginally better than the older tracks of DM94 and FJS93. The fit actually worsens for CM Dra if its low metallicity (implied by kinematics) is included. The possible youth of YY Gem does not change the fits substantially. It is interesting to note that all three generations of models by Burrows (Model X, Base, NextGen) produce identical mass-radius relationships which fit perfectly with the data for CM Dra.

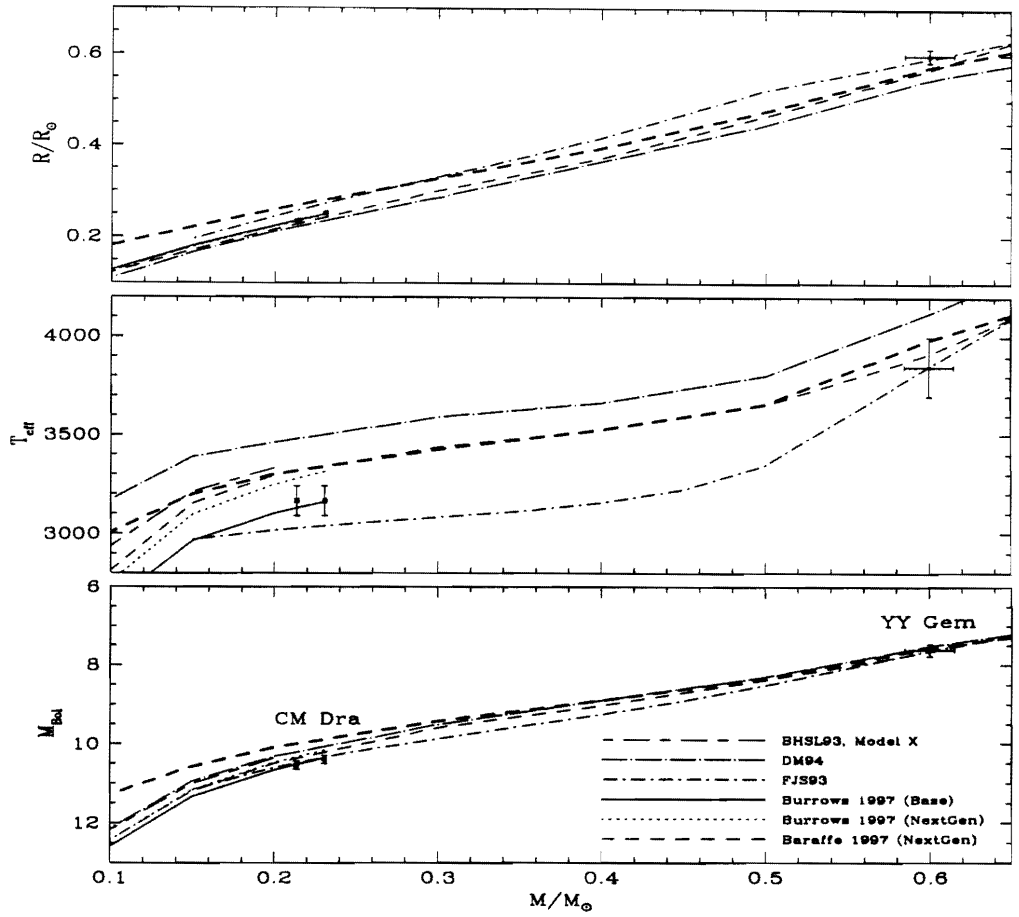

Figure 1. Comparison of stellar properties derived for YY Gem and CM Dra to the predictions of model interiors (solar metallicities). The bold dashed line represents 100 Myr as given by BCAH97.

3. Pleiades and Globular Clusters

We have transformed the Pleiades $(V\text{-}I)_C$ colors of Stauffer (private communication) to spectral type using Bessell (1979) for <M0V and Bessell (1990) for ≥M0V. We converted from spectral type to T_{eff} using both Kirkpatrick et al. (1993) and Leggett et al. (1996). Visual magnitudes were converted to L_{bol} using the bolometric corrections compiled by Kenyon & Hartmann (1995). In Figure 2, we have plotted the Pleiades with tracks of DM94, FJS93, and BCAH97. Both DM94 and BCAH97 imply a mass-dependent age for the empirical Pleiades isochrone (~100 Myr), where lower mass sources appear progressively younger. If we use the synthetic colors produced by BCAH97 to transform between the theoretical and observation planes, we find that this trend is enhanced (i.e, the synthetic temperature scale is cooler). The FJS93 isochrones, on the other hand, are parallel to the Pleiades locus, but these stars then fall below the FJS93 main sequence.

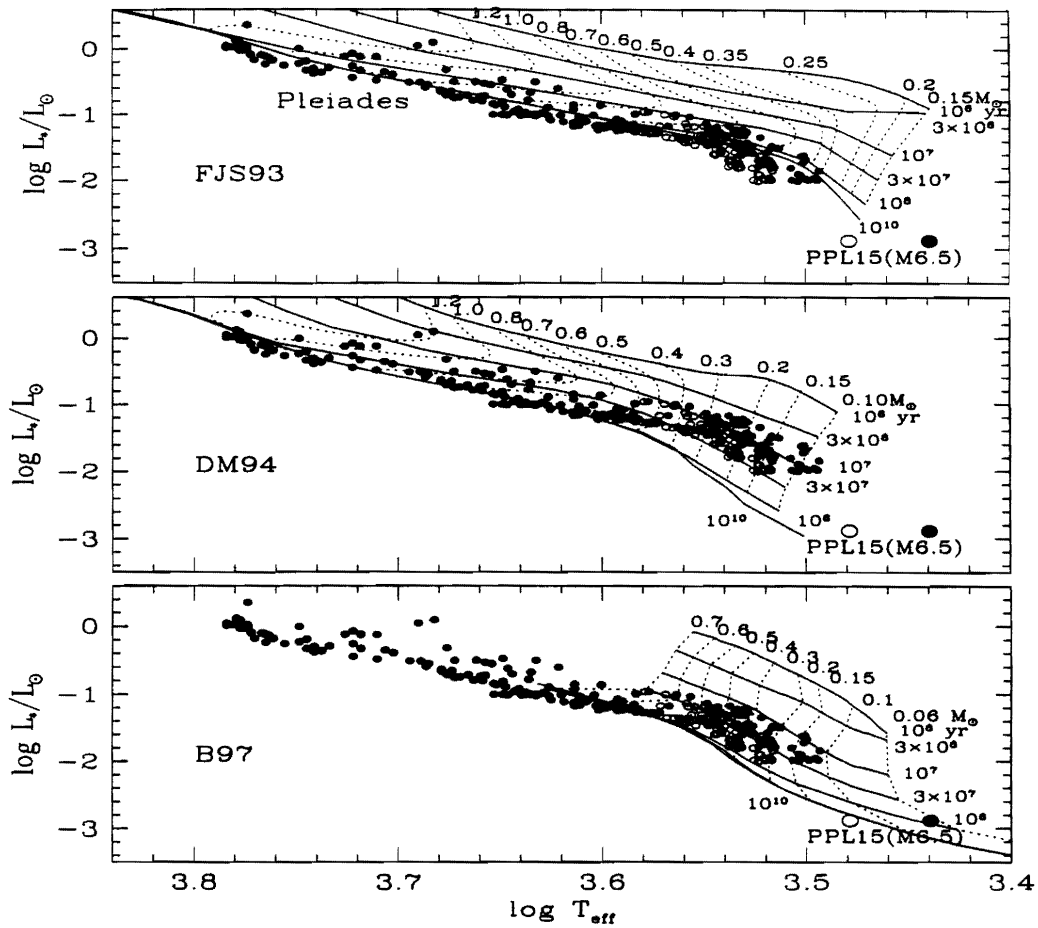

Figure 2. The Pleiades with evolutionary tracks of FJS93, DM94, and BCAH97. Solid and open circles were transformed with the Leggett et. al. (1996) and Kirkpatrick et al. (1993) temperature scales, respectively.

Baraffe et al. (1997) find excellent agreement between their latest tracks and the main sequence down to 0.1 $M_\odot$ in the globular cluster NGC 6397. The higher temperatures and reduced metallicities ([Fe/H] = −1.9) of such stars make them easier to model, whereas the solar abundance calculations do not match well with observations. For instance, the predicted solar metallicity main sequence falls equidistant between the NGC 6397 sequence and the Leggett et al. (1996) young disk sequence.

4. Which Tracks Are Appropriate for Young, Embedded Clusters?

Since the BCAH97 tracks only extend up to 0.7 $M_\odot$, it is not possible to derive an IMF for the entire population. However, we can make the simple calculation of $N(>0.7\ M_\odot)/N(<0.7\ M_\odot)$ using each set of tracks. This ratio is 0.18, 0.18, and 1 using the DM94, FJS93, and BCAH97 tracks, respectively, whereas Scalo (1986)

predicts a value of 0.22. The strange IMF produced by BCAH97 may be due to the limitations of the NextGen atmospheres. The lowest gravity available in the atmospheric models (log(g) = 3.5) is near that expected for low-mass stars at 1 Myr. New model interiors by D'Antona & Mazzitelli (DM97) which treat convection in a more sophisticated manner produce a cooler main sequence than found in DM94, bringing it into better agreement with observations. Since model atmospheres are not used in DM97, the surface gravity constraints of the NextGen models are avoided and DM97 may be useful for studying young stars. The DM97 tracks must be tested with the binary and Pleiades data as well, but they may prove to be the most promising set of tracks for deriving IMFs in very young clusters.

New instrumental capabilities, particularly near-IR spectroscopy, now permit placement of hundreds of embedded cluster members on the H-R diagram. The uncertainties in evolutionary tracks, especially at young ages, loom as perhaps the largest obstacle in interpreting these new data to derive fundamental cluster properties such as the IMF. Further progress on interior models is essential in addition to more observational tests of the tracks at young ages.

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References

Baraffe, I., Chabrier, G., Allard, F., & Hauschildt, P. H. 1997, ApJ, in press (BCAH97)

Bessell, M. S. 1979, PASP, 91, 589

Bessell, M. S. 1990, A&AS, 83, 357

Bessell, M. S., & Brett, J. M. 1988, PASP, 100, 1134

Budding, E., Butler, C. J., Doyle, J. G., Etzel, P. B., Oláh, K., Zeilik, M, & Brown, D. 1996, Ap&SS, 236, 215

Burrows, A., Hubbard, W. B., Saumon, D., & Lunine, J. I. 1993, ApJ, 406, 158

Chabrier, G., & Baraffe, I. 1995, ApJ, 451, L29

D'Antona, F., & Mazzitelli, I. 1994, ApJS, 90, 467 (DM94)

Kenyon, S. J., & Hartmann, L. 1995, ApJS, 101, 117

Kirkpatrick, J. D., Kelly, D. M., Rieke, G. H., & Liebert, J. 1993, ApJ, 402, 643

Lacy, C. H. 1977, ApJ, 218 444

Leggett, S. K., Allard, F., Berriman, G., Dahn, C. C., & Hauschildt, P. H. 1996, ApJS, 104, 117

Leung, K.-C., & Schneider, D. P. 1978, AJ, 83, 618

Luhman, K. L., & Rieke, G. H. in preparation

Metcalfe, T. S., Mathieu, R. D., Latham, D. W., & Torres, G. 1996, ApJ, 456, 356

Scalo, J. 1986, Fund. Cosmic Phys., 11, 1

Swenson, F. J. private communication (FJS93)