Empirical Isochrones and relative ages – is IC348 really that young?

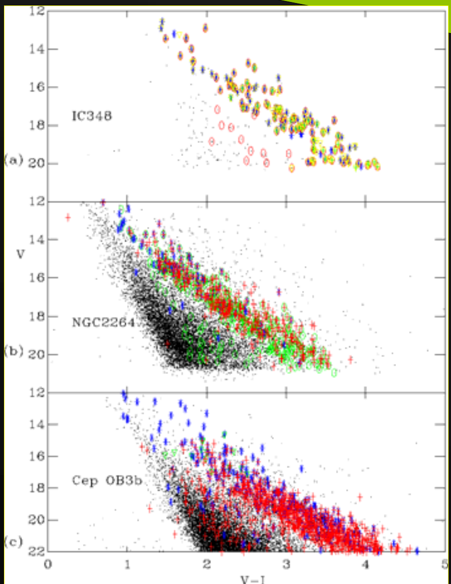
Nathan Mayne & Tim Naylor School Physics, University of Exeter (n.j.mayne@ex.ac.uk)

Abstract

Interpreting observational studies of rotational evolution of stars relies on the determinations of the ages of the groups studied. In the past this has been done predominantly using isochronal theory. We have constructed observed sequences for several OB associations and young clusters, allowing us to derive relative ages. We apply this method to several groups with rotational studies; The ONC, NGC2264, CepOB3b and IC348. The relative age of Cep OB3b is found to be approximately equal to that of NGC2264 (i.e. about half the age given in the literature). The relative age for IC348 was found to fall between that of NGC2264 and σ Orionis (i.e. somewhat older than that in the literature). We discuss the implications of this re-ordering of the groups for rotational evolution of pre-main-sequence (PMS) stars.

Introduction

Most ages for stellar groups, sub-groups, clusters or associations are derived from fitting observations to theoretical isochrones. In many instances an isochrone fits part of a sequence but systematically deviates from the observed sequence in other sections. In addition if a sequence is fitted to an isochrone in one colour, the derived age may be different to that derived in another. For the field of rotational period evolution of star populations, the distribution of periods has been charted for several clusters. The working hypothesis is that a bi-modal distribution (the ONC) evolves into a unimodal distribution (NGC2264). IC348 with a bi-modal distribution similar to the ONC at an age of around NGC2264 challenges this view. It is clear that to maintain this line of argument robust relative ages with well defined uncertainties are crucial.

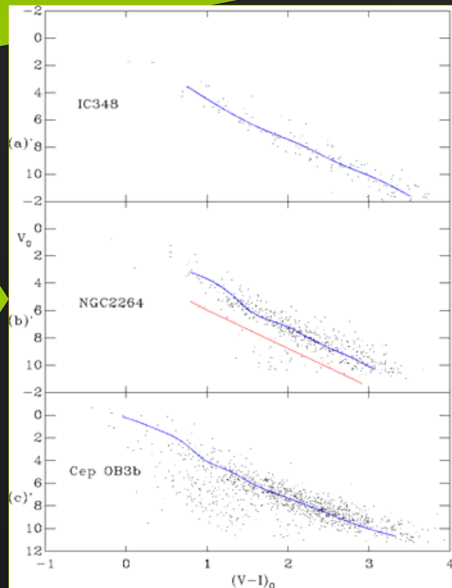


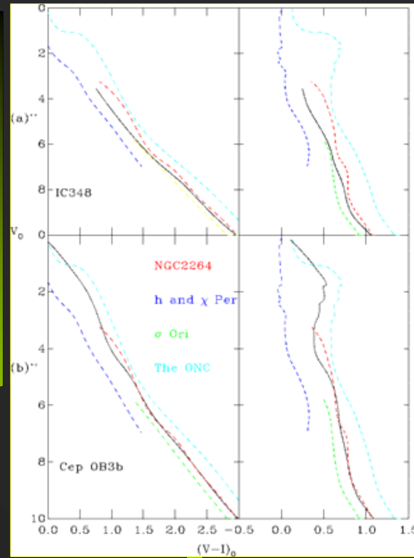
Method

Isolation First the sequence is isolated from the background and foreground populations using literature memberships (left panel). An additional colour-magnitude selection is then applied (e.g. the red line in the right panel for NGC2264).

Fitting Median stars were then selected from the sequence by binning in *V*-band intervals and selecting the median star in *V-I*, with a minimum number of stars in each bin required. A cubic spline was then fitted through the median stars, with the gradients at the ends tied to a quadratic (right panel, blue lines).

Comparison To derive relative ages we convert to absolute magnitudes and colours. The order in which the fitting and conversion to absolute magnitude is done is crucial. Global average values simply translate a sequence in a CMD, retaining the relative positions of stars within the sequence, this is not the case for individual extinctions and distances. For IC348 the extinctions have therefore necessarily been applied before fitting.





Method 2

Relative age plots are shown on the panel above (solid lines) with fiducial sequences for comparison. The ONC (~1 Myr), NGC2264 (~3 Myrs), σ Ori (~4-5 Myrs) and h and χ Per (~13 Myrs). To aid analysis we also created a ZAMS subtracted CMD (right graph), using the ZAMS relation of Siess & Dufour (2000). Here each point on the spline has the corresponding (in *V)* ZAMS colour subtracted from it's own *V-I*, separating the sequences significantly.

In the ZAMS subtracted space at V_0 ~ 3 mag many of the sequences show a "wave" effect. This is due to a failure of the spline interpolation to follow the features of the sequence.

Figure (a)'' reveals an age for IC348 as slightly older than that of NGC2264. This is older than the literature age.

Figure (b)'' shows Cep OB3b as being coincident with NGC2264; younger than the literature ages.

The largest uncertainty is due to the distance modulus (typically ~0.2 mags).

Members

(a) IC348 - Asterisk (blue) are X-ray sources from Preibisch& Zinnecker (2002). Circles (red) are periodic variables from Cohen et al. (2004) and Littlefair et al. (2005). Crosses (green) are Hα sources from Herbig (1998). Triangles (yellow) are spectroscopic members from Luhmen et al. (2003) and Herbig (1998).

(b) NGC2264 - Circles (green) are periodic variables from Lamm et al. (2004). Asterisks (blue) are X-ray sources from Flaccomio et al. (1999). Crosses (red) are Hα sources from Dahm & Simon (2005).

(c) Cep OB3b - Asterisk (blue) are X-ray sources from Naylor & Fabian (1999) and Getman et al. (2006). Triangles (green) are spectroscopic members from Pozzo et al (2003). Circles (black) are Hα sources from Ogura et al. (2002). Crosses (red) are periodic variables from Littlefair et al. (in prep)

Conclusion

We have developed a method of deriving robust relative ages for young PMS sequences in CMD space. We have derived relative ages for several young star-forming regions. The relative age derived for IC348 is of particular interest. We conclude that the correct age order for the three clusters with extensive rotational studies is the ONC, NGC2264 and finally IC348. This appears to proclude the current evolutionary models, that of a bi-modal rotational period distribution to a unimodal distribution, unless the local environment has a dominant affect on the time scales.

Uncertainties in the distance modulus would not allow us to reverse this order, particularly given that IC348 cannot be placed behind the molecular cloud.

Relative ages for the following clusters have been determined by this method. We place them in similar age groups, (in increasing age); the ONC, NGC6530 and IC5146 (~1Myr); Cep OB3b, NGC2362, λ Ori and NGC2264 (~3Myrs); σ Ori and IC348 (~4-5Myrs); NGC7160 (~10Myrs), h and χ Per (~13Myrs); and finally NGC2547 (~30Myrs).

To add your favourite PMS to the age ladder just e-mail us!