The Age of Taurus – Environmental Effects on Disc Lifetimes?

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Abstract

We have derived the age of the Taurus star-forming region to be 3-4Myr, significantly older than the typically quoted 1-2Myr. We find that Taurus shows an excess of discs for its age, suggesting low density stellar environments lead to longer disc lifetimes. As part of this study, we have also developed a method of Bayesian extinction fitting.

Are Class II objects isochronally older than Class III?

Class II objects, broadly corresponding to classical T Tauri stars, and Class III objects, broadly corresponding to weak-line T Tauri stars, are thought to represent an evolutionary sequence, and thus Class II objects are usually assumed to be younger than Class III sources.

By dividing our sample of Taurus members based on infrared evidence of discs we find that the Class II sources either lie together with the Class III sources, or sit far below the Class III sequence (see Figure 1), i.e. if we naively fit isochrones to the groups, we would find the Class II sources to be older.

This appears to be largely due to accretion changing the luminosity of the star, and thus we measure the age using only the Class III sources.

Previous work – A robust PMS age scale

It is well known that model isochrones do not simultaneously fit both the high-mass sequence and the low-mass members (see e.g Stauffer et al. 2007).

In Bell et al. (2013) we showed that by adopting a semi-empirical bolometric correction (BC)-colour-$T_{\rm eff}$ relation we were able to correct for this discrepancy and derive pre-main sequence ages that agreed with the ages derived from upper-main sequence fitting and the lithium depletion boundary technique.

The resulting age scale showed that young clusters were older than previously believed, by around a factor two.

Extinction fitting

Our previous work has used clusters with uniform reddenings, but many low-density star-forming regions have extinction that varies significantly across the field. We have developed a method of extinction fitting using solely photometry. In an *i-Z*, *J-H* colour-colour diagram the reddening vectors are almost perpendicular to the majority of the sequence (see Figure 2) and so we can deredden each star individually. This filter choice also minimises the effect of discs.

We adopt a Bayesian method, which allows us to account for uncertainties due to age and binarity by marginalising over these parameters.

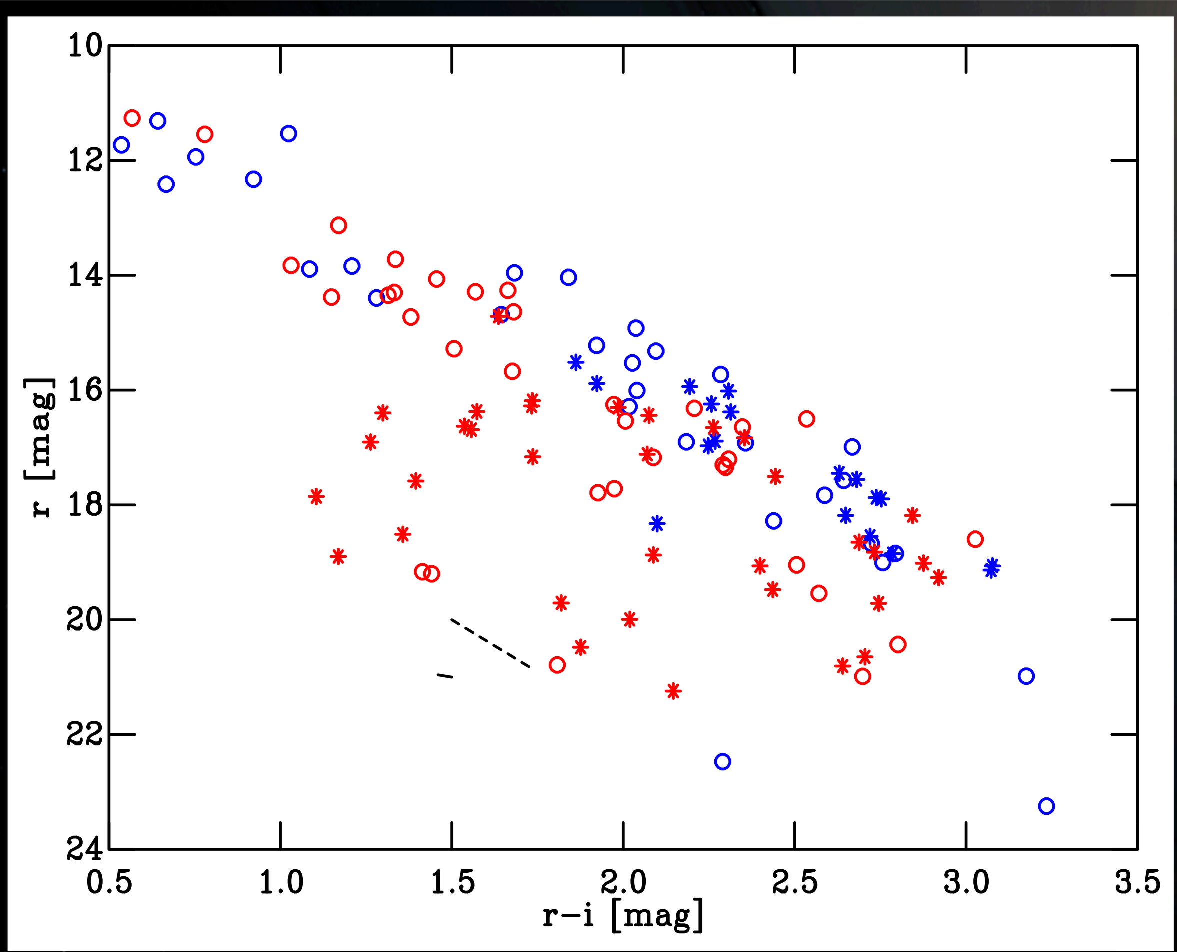
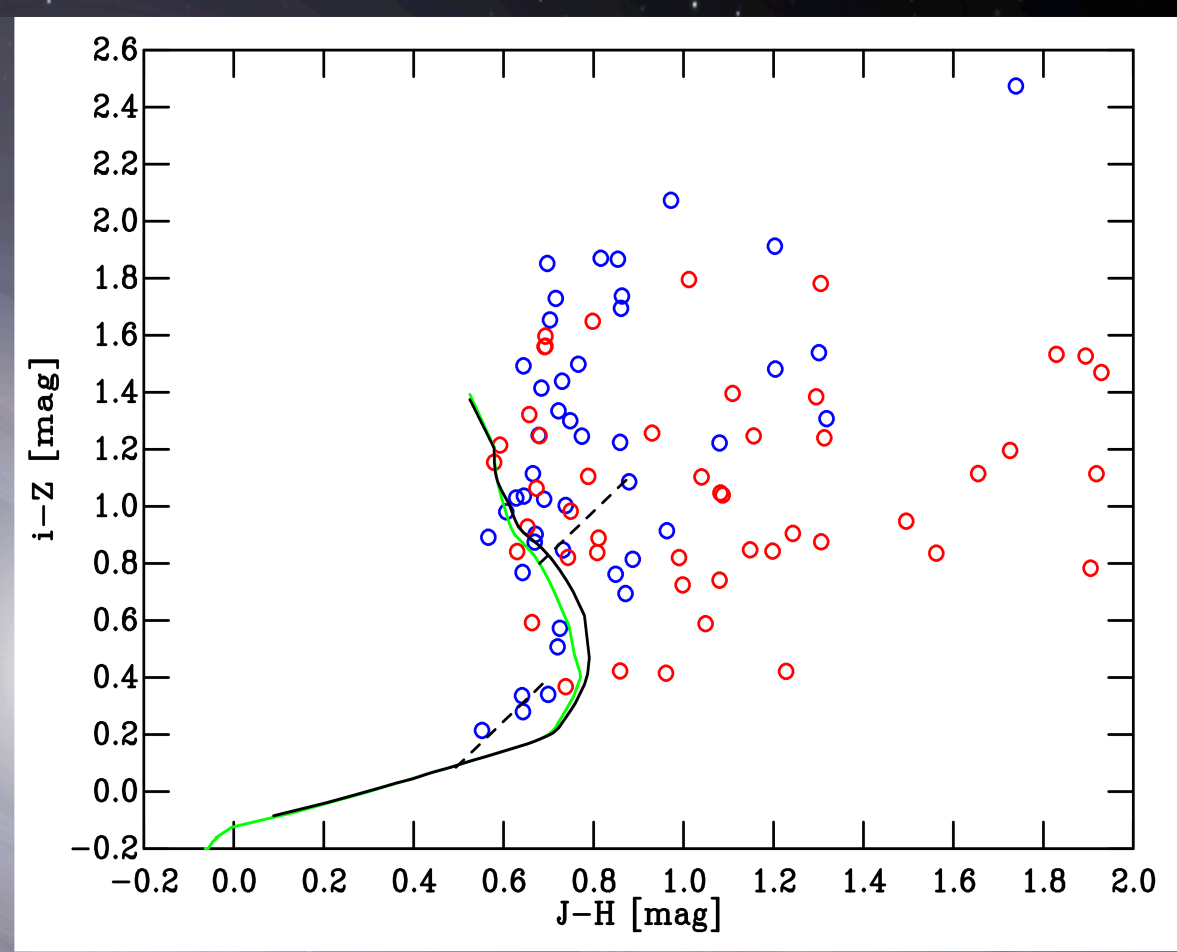


Figure 1. *r*, *r-i* diagram for Taurus members in the SDSS and a sample observed with the Isaac Newton Telescope Wide-Field Camera (WFC). Open circles show WFC photometry, asterisks show SDSS (transformed to the WFC system). Blue symbols denote Class III sources, red denotes Class II sources. The solid black line shows the effect of 50Å of Hα flux, the dashed black line shows the reddening vector for A_V= 1. Note that we are plotting *observed* colour/magnitude, i.e. no dereddening has been applied to these objects.

Figure 2. *i-Z*, *J-H* diagram for Taurus members in the WFC sample. Blue circles denote Class III sources, red denotes Class II sources. Overlaid are composite Baraffe et al. (1998) and Dotter et al. (2008) isochrones with the Allard et al. (2012) bolometric corrections and additional empirical corrections discussed in Bell et al. (2014). The black solid line is a 2Myr isochrone, the green solid line is a 4Myr isochrone. The black dashed lines show the reddening vectors in this space, for A_V= 2 mag.



The Age of Taurus

We find that Taurus is 3-4Myr old (see Figure 3), significantly older than previous estimates.

In Bell et al. (2013), we determined ages for a number of massive clusters. To avoid biasing our ages due to probing different mass regimes in different clusters we determined the nominal age by comparing the location of a $0.75M_{\odot}$ star to the centre of the sequence.

We have repeated this process for Taurus, and thus the derived age is on the same age scale as the other clusters in Bell et al. (2013), though we note that unlike our previous work, there is a sparsity of higher mass members, making the comparison difficult for the youngest models.

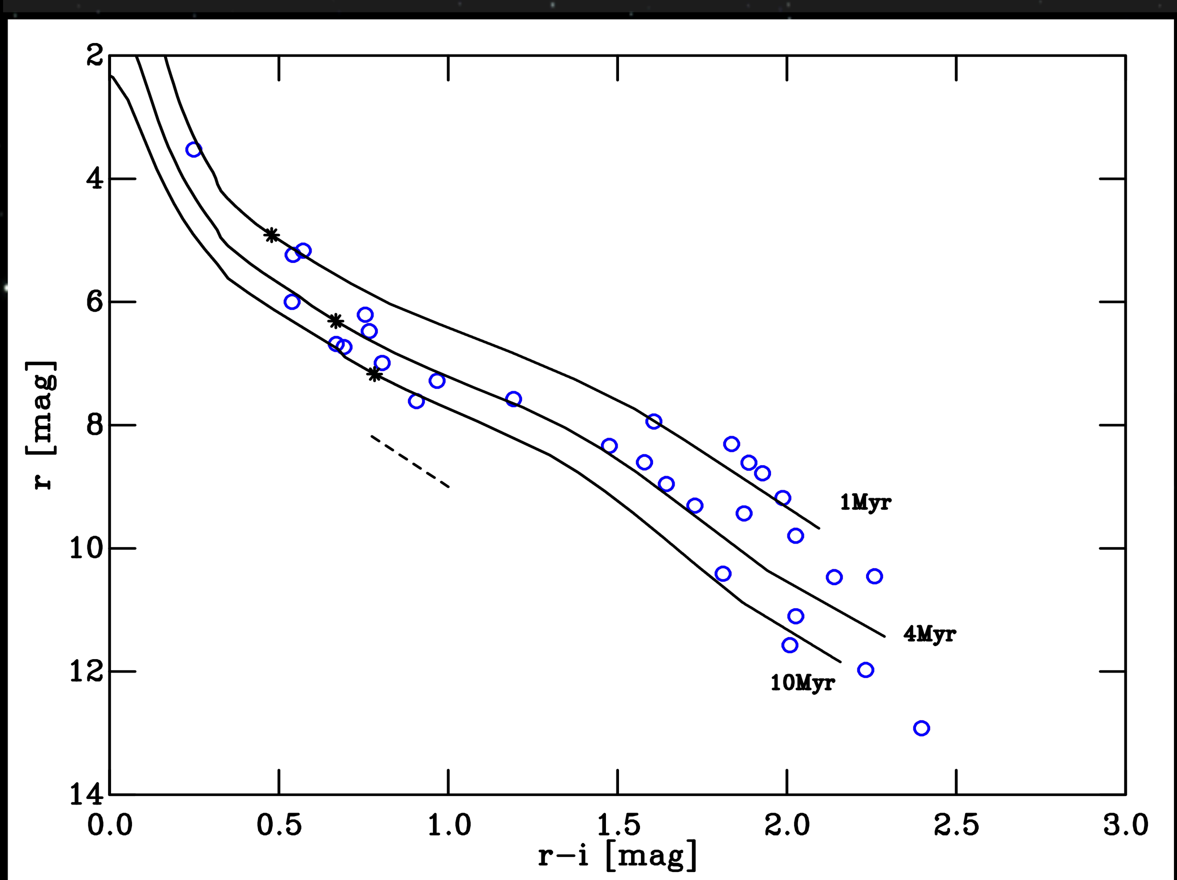


Figure 3. *r*, *r-i* diagram for Taurus members identified as Class III. Overlaid are 1, 4 and 10Myr isochrones based on the Dotter et al. (2008) interior models with the Allard et al. (2012) bolometric corrections and additional empirical corrections discussed in Bell et al. (2014). Asterisks indicate the position of a theoretical star with mass $0.75M_{\odot}$. The black dashed line shows a reddening vector for A_V= 1 mag.

Implications – Disc Fraction

The circumstellar discs around young stars are believed to be the birthplaces of planets. How long these discs last is a crucial input into the models of planet formation. It has long been argued that these discs will last longer in low stellar density environments because stellar encounters and UV radiation both erode discs.

In Bell et al. (2013) we produced a plot of disc fraction against age for a group of massive clusters. We adopted disc fractions based on spectral types of mid-K to early-M, to ensure we are probing similar regimes in each cluster.

Taurus has a measured mid-K to early-M disc fraction of 69% (Luhman et al. 2010). This disc fraction is based on the XMM-Newton Extended Survey(XEST) fields (Güdel et al. 2007), though we note that the disc fraction based on the entirety of Taurus is also consistent with this value.

We now add Taurus to the disc diagram (see Figure 4), and find that it has the highest disc fraction of any cluster in our sample, despite being noticeably older than the youngest group.

This suggests discs survive longer in the low stellar density environment in Taurus.

Potential Bias

The work presented here is still in progress, thus there are a number of potential biases we still must consider.

There is a clear bias in the age fit towards older ages if we include the Class II sources. By choosing only the Class III sourcess we remove this bias.

The members used to determine the age are those with clean *r*, *i*, *Z*, *J*, *H* photometry, and so there exists a possibility that we have biased our fit by including only optically visible members. This is unlikely however, as there is no evidence of a population detected in the infrared data that drop out in the optical.

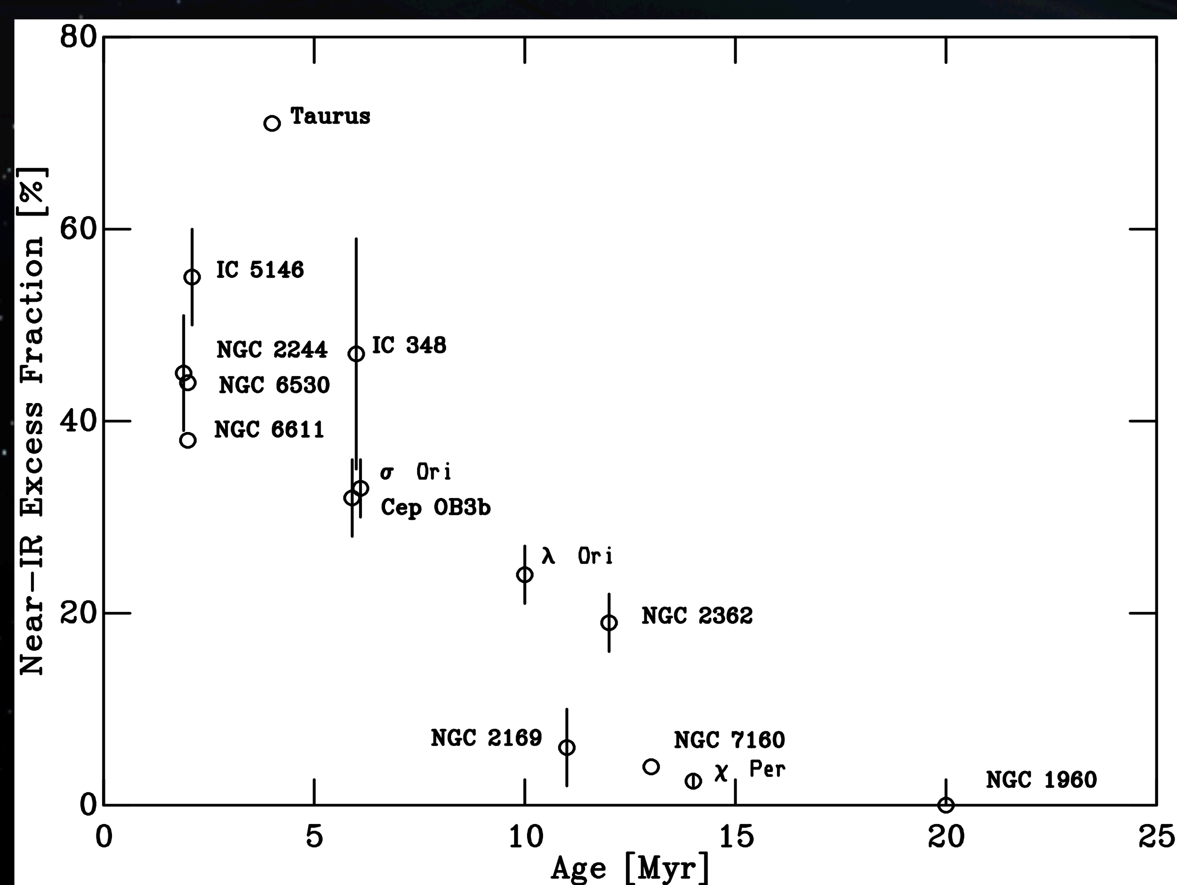


Figure 4. Disc fraction vs age for the cluster sample from Bell et al. (2013), with Taurus added.

Background Image Credit: NASA, ESA and G. Bacon (STScI)

Allard et al., 2011, ASPCS, Vol. 488, p. 91
Baraffe et al., 1998, A&A, 337, 403
Bell et al., 2013, MNRAS, 434, 806
Bell et al., 2014, MNRAS, 445, 3496
Dotter et al., 2008, APJS, 178, 89
Güdel et al., 2007, A&A, 468, 353
Luhman et al., 2010, APJS, 186, 111
Stauffer et al., 2007, APJS, 172, 663