Are pre-main-sequence stars older than we thought?

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Outline

• **Distances and Extinctions** (Mayne & Naylor 2008, MNRAS 386 261)


• $\tau^2$ (Naylor & Jeffries 2006, MNRAS 373 1251)

• **Nuclear (not quite turn-off) ages** (Naylor, submitted)
The Ideal Sequence

- Upper MS (weakly age sensitive)
- MS (distance sensitive)
- PMS (age sensitive)
Use Model Isochrones?

• Different models give different ages.
• Even if you use the same model…
  – different colours give different ages
  – different mass ranges give different ages.
• But given consistent data we can obtain an age ordering.
The Ages

• 1Myr – IC5146
• 2Myr – ONC, NGC 6530
• 3Myr – λOri, σ Ori, NGC 2264
• 4-5Myr – IC348, Cep OB3b¹, NGC 2362
• 5-10Myr – γ Vel²
• 10Myr – NGC 7160
• 13Myr – h and χ Per
• 40Myr – NGC 2547

The Ideal Sequence

Upper MS (weakly age sensitive)

MS (distance sensitive)

PMS (age sensitive)
The problem

- Binary sequence
- By eye fitting
  - objectivity
  - Parameter uncertainties

From Meynet, Mermilliod & Maeder 1993.
• A good fit is when many of the data points lie in the high probability regions.
• Take the product of the values of $\rho$ at each datapoint.
• Better still product of the integrals of $\rho$ over $U_i$ => $\tau^2$
• Derivable from Bayes’ Theorem.
• $\chi^2$ fitting is a special case.
• Frequentist-style
  – Goodness of fit ($\chi_v^2 = 1$)
  – Parameter uncertainties.
Nuclear Ages

- NGC 6530
- 0.25 Myr (Geneva-Bessell)
- $Pr(\tau^2)=0.03$
• NGC 6530
• 5.50 Myr (Geneva-Bessell)
• $Pr(\tau^2)=0.67$
• *c.f.* 2 Myr PMS isochronal (contraction) age

Nuclear Ages
Can we change the age scale?

- Suggesting PMS ages are factor 1.5-2.0 longer than “conventional” PMS ages.

- The “new” ages match (though are more precise than) previous upper MS measures.
  - NGC2547 45Myr vs 57Myr (Claria 1982)
  - IC2602 42Myr vs 35Myr (Mermilliod 1981)
  - ONC 5Myr vs 4Myr (Meynet et al 1993)

- Explains shortage of clusters 5-20Myr

- Resolves conflict between planet formation and disc dissipation timescales.
Conclusions

- PMS contraction ages are rubbish.
- Probably because the cool atmospheres of the stars used are not good models.
- Far better to rely on hot atmospheres and nuclear physics.
- The resulting ages allow planet formation and give a more even age distribution.
- BUT cannot be used on a cluster-by-cluster basis as uncertainties are large.