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

Tim Naylor

Nathan Mayne

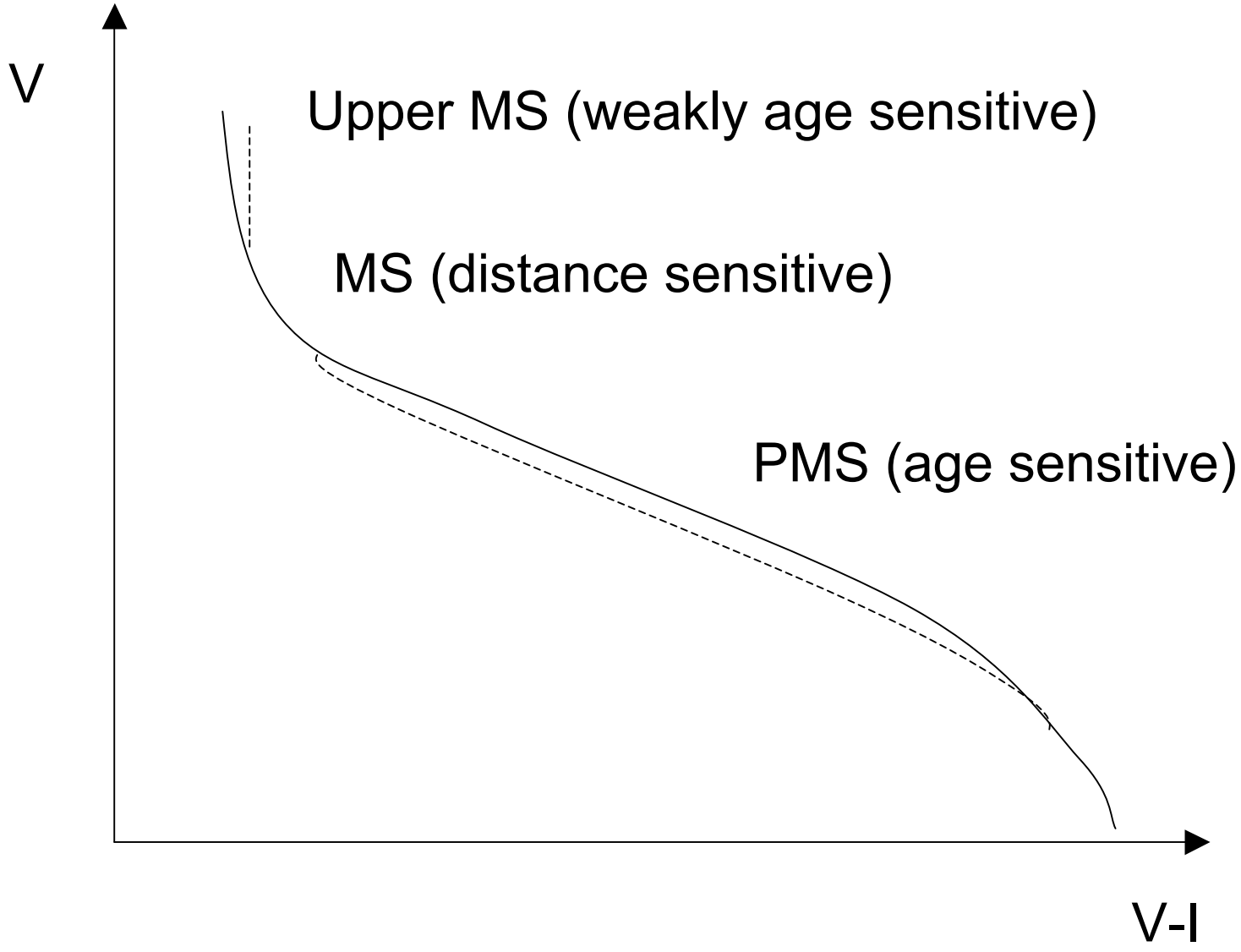
Rob Jeffries, Stuart Littlefair

UNIVERSITY OF EXETER

Outline

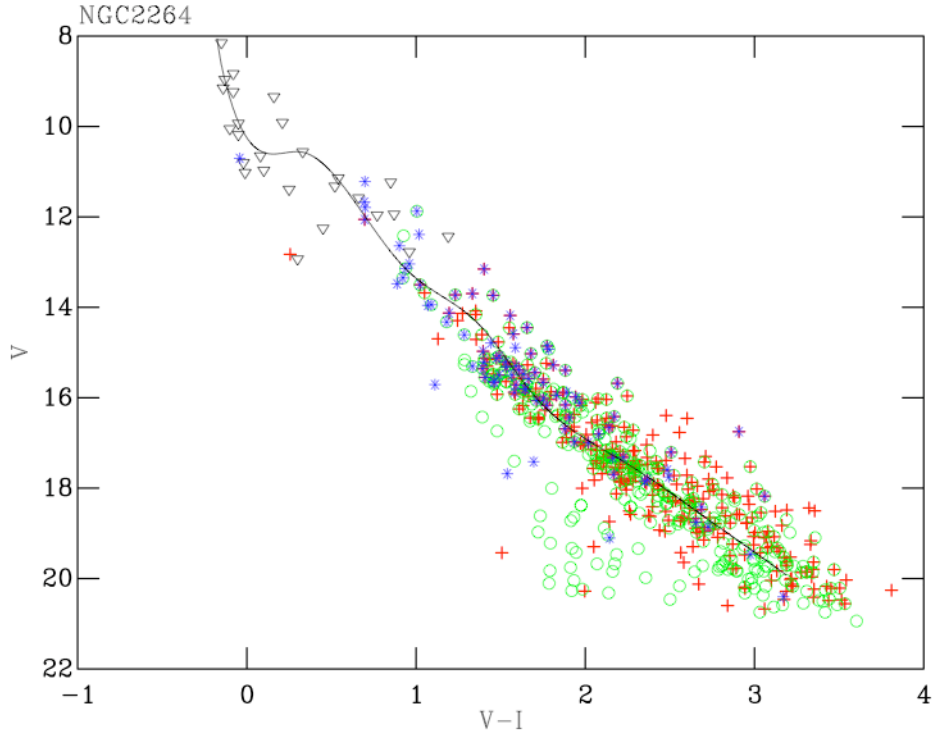
- Distances and Extinctions (Mayne & Naylor 2008, MNRAS 386 261)
- Relative PMS ages (Mayne et al 2007, MNRAS 375 1220; Mayne & Naylor 2008, MNRAS 386 261)
- τ^2 (Naylor & Jeffries 2006, MNRAS 373 1251)
- Nuclear (not quite turn-off) ages (Naylor, submitted)

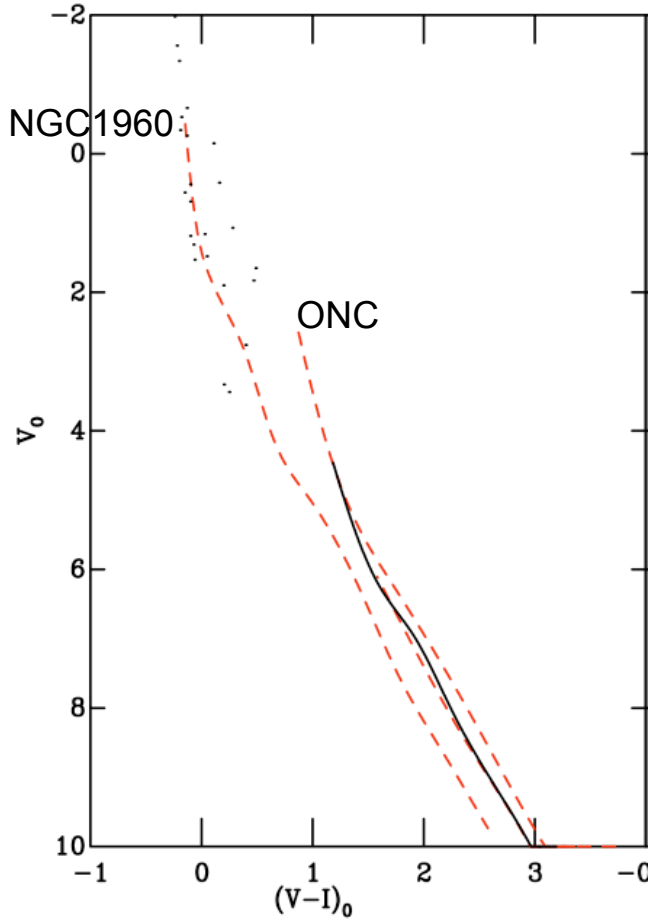
The Ideal Sequence



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.


NGC2264
V
V−I

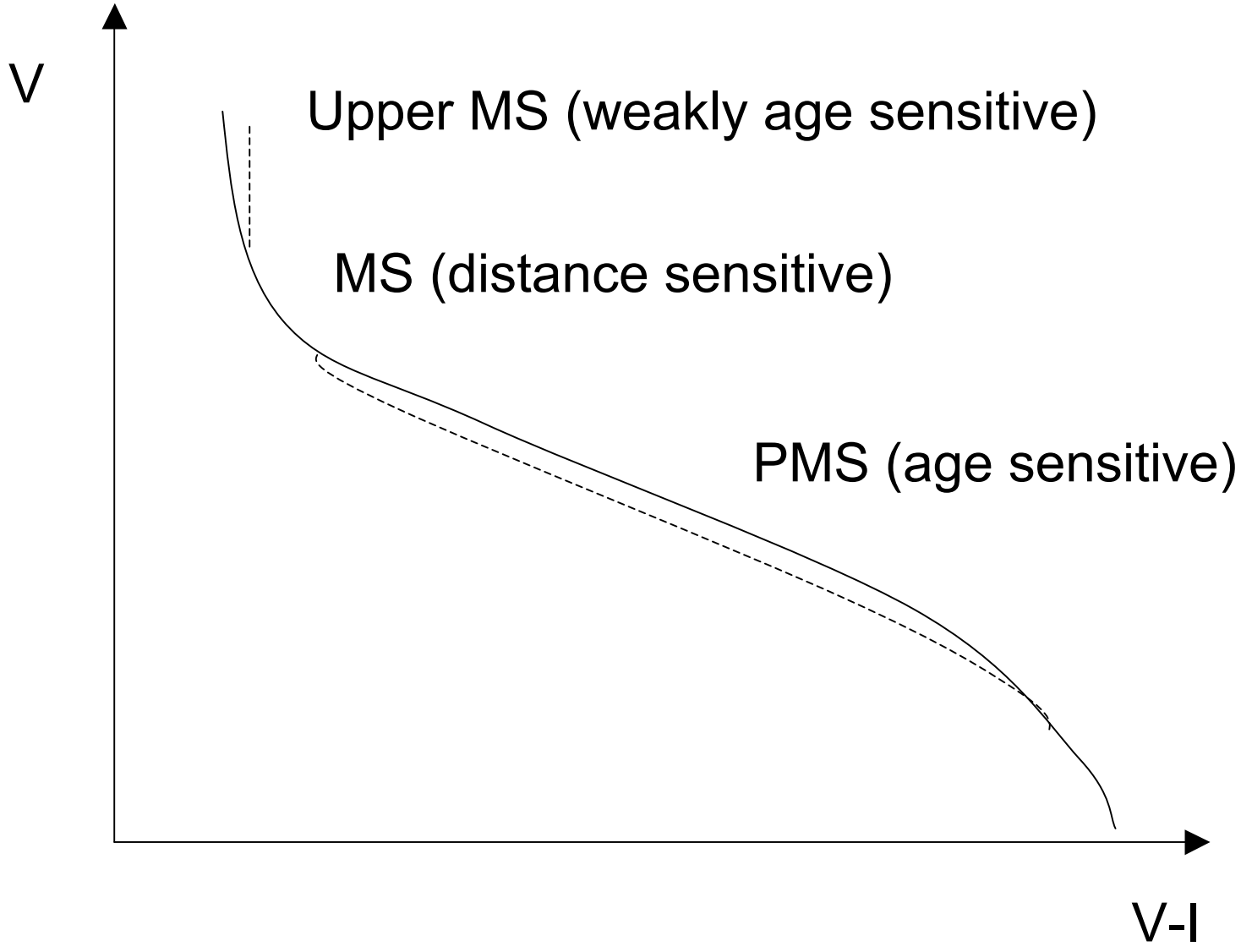

NGC1960
ONC
V_0
$(V-I)_0$

The Ages

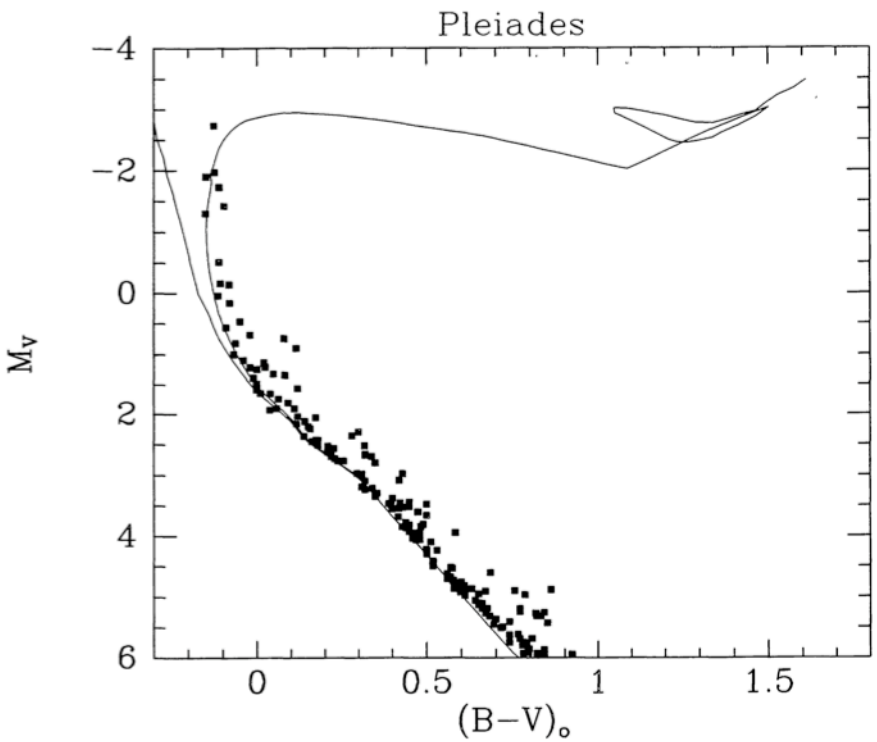
- 1Myr – IC5146
- 2Myr – ONC, NGC 6530
- 3Myr – λOri, σ Ori, NGC 2264
- 4-5Myr – IC348, Cep OB3b[1], NGC 2362
- 5-10Myr – γ Vel[2]
- 10Myr – NGC 7160
- 13Myr – h and χ Per
- 40Myr – NGC 2547

Mayne & Naylor (2008), except [1]Littlefair (in prep) and [2]Jeffries et al (2009).

The Ideal Sequence

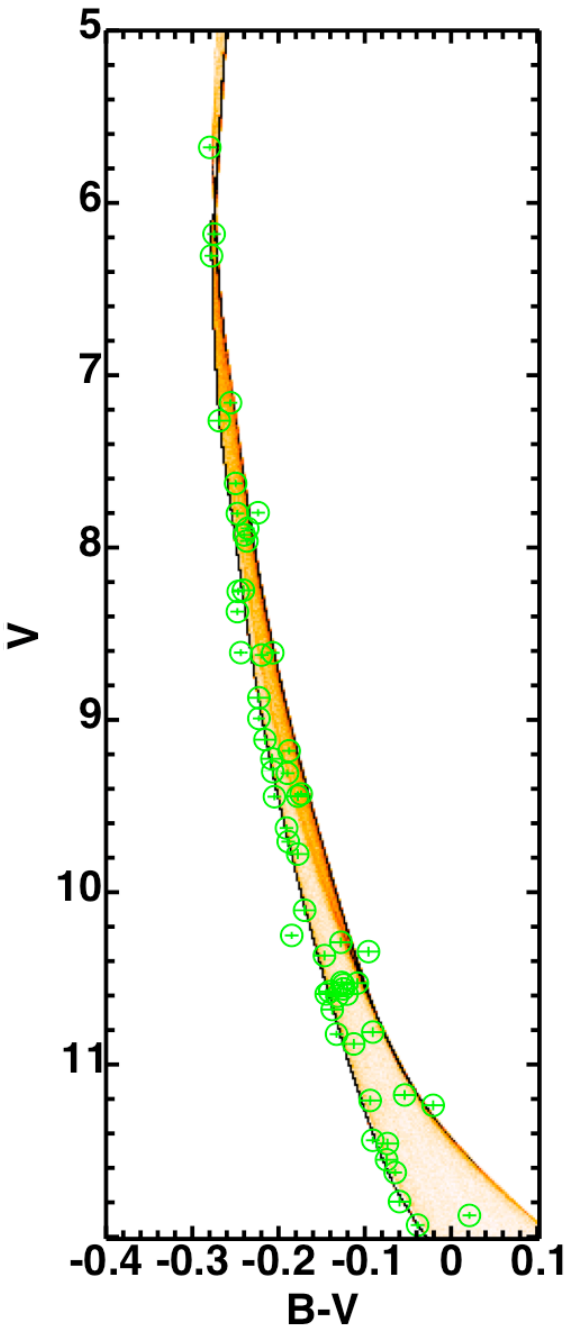


The problem

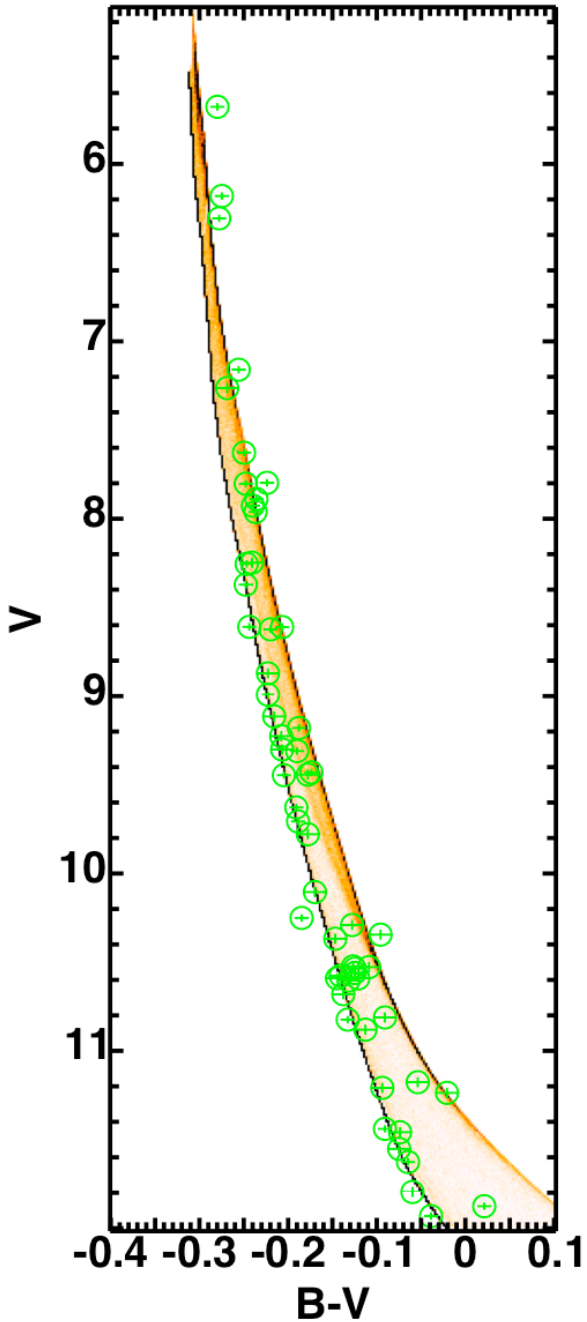


- Binary sequence
- By eye fitting
  - objectivity
  - Parameter uncertainties

From Meynet, Mermilliod & Maeder 1993.

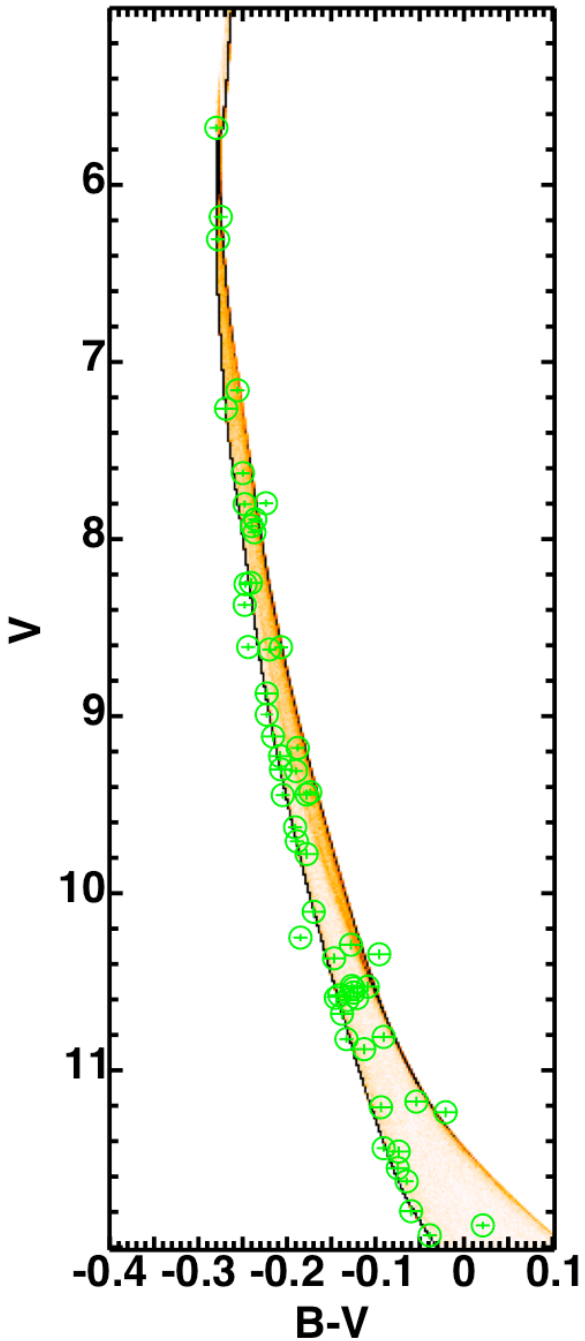


- A good fit is when many of the data points lie in the high probability regions.
- Take the product of the values of ρ at each datapoint.
- Better still product of the integrals of ρ over U_i => τ^2
- Derivable from Bayes' Theorem.
- χ^2 fitting is a special case.
- Frequentist-style
  - Goodness of fit ($\chi_\nu^2 = 1$)
  - Parameter uncertainties.



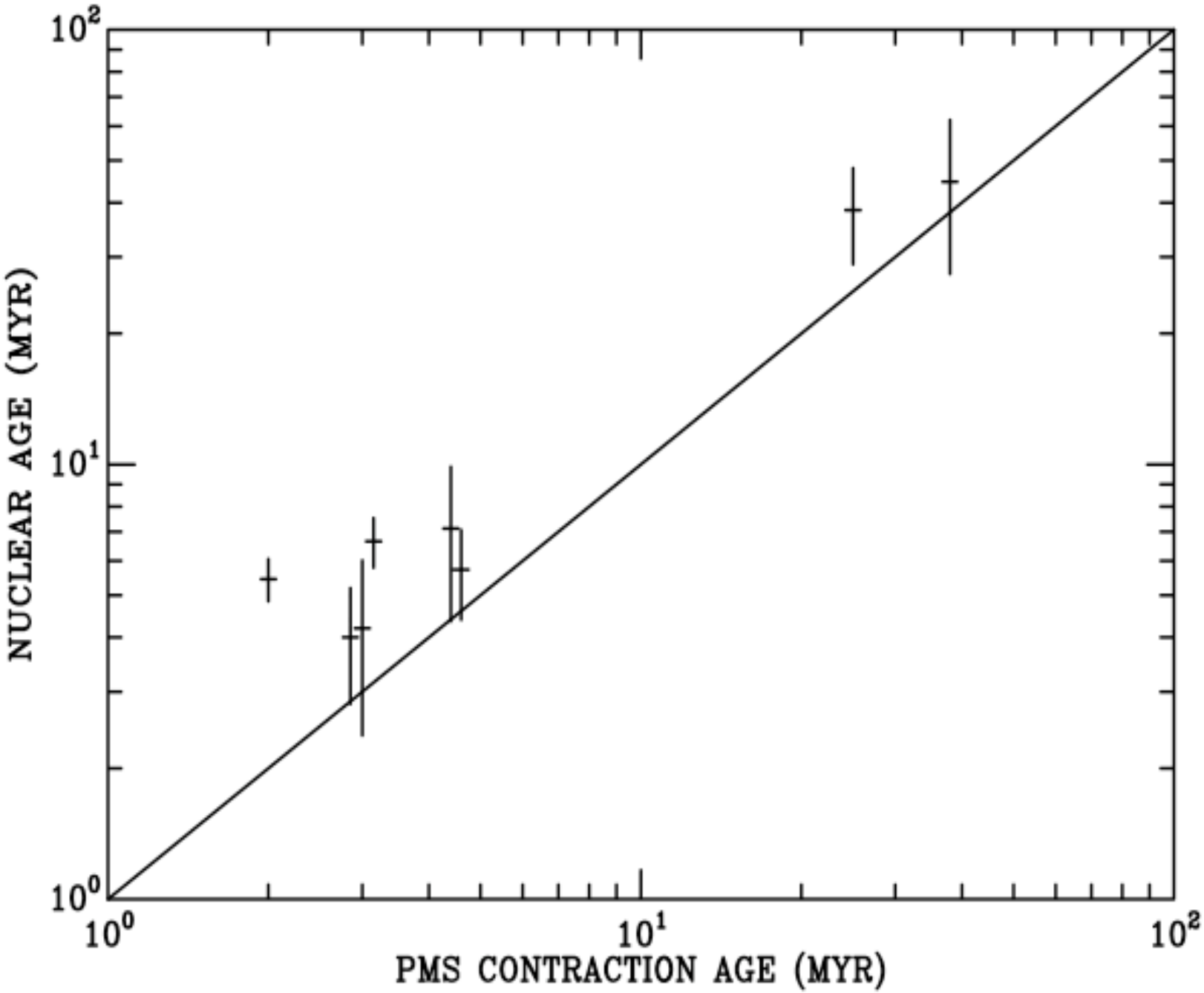
Nuclear Ages

- NGC 6530
- 0.25 Myr (Geneva-Bessell)
- $Pr(\tau^2)=0.03$



Nuclear Ages

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


NUCLEAR AGE (MYR)
PMS CONTRACTION AGE (MYR)
10^0
10^1
10^2

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.