A Revised Pre-Main-Sequence Age Scale

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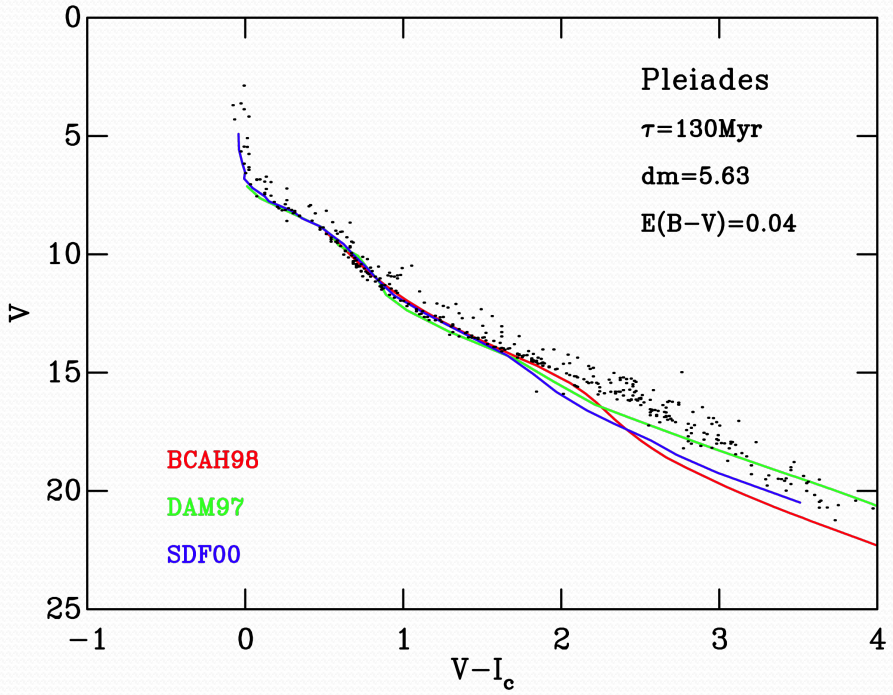
Setting the scene

- Why the poor fit in the pre-MS regime?
  - photometric calibration
  - transformation from H-R to CMD
  - extinction as a function of colour
  - problems with models themselves



Photometric data from Stauffer et al. 2007

Setting the scene

- Why the poor fit in the pre-MS regime?
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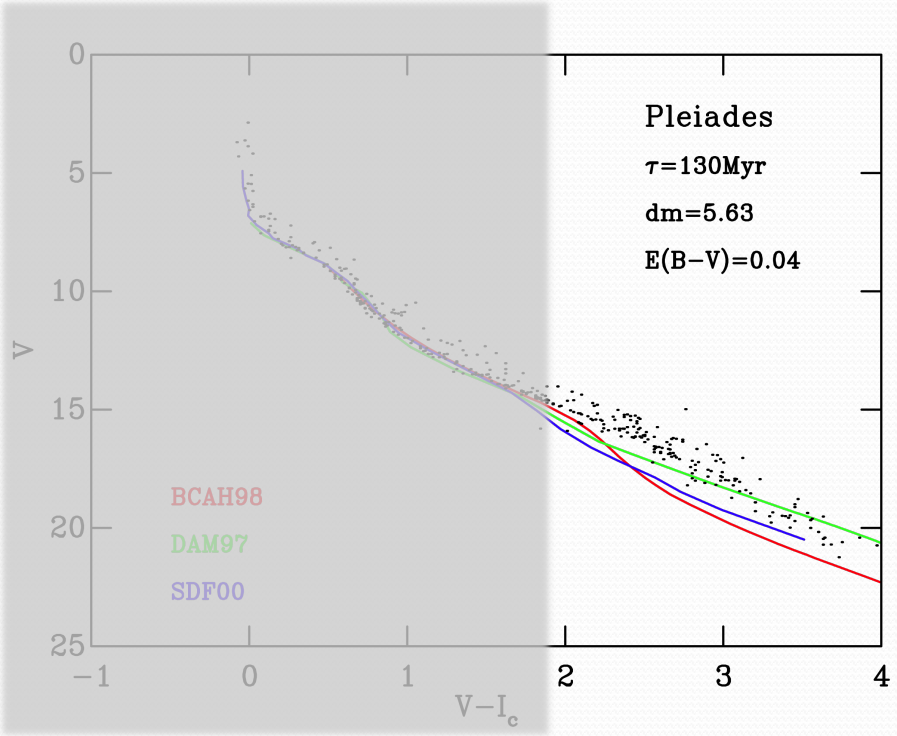
  - extinction as a function of colour
  - problems with models themselves

⇒ spread in pre-MS ages for a given region!



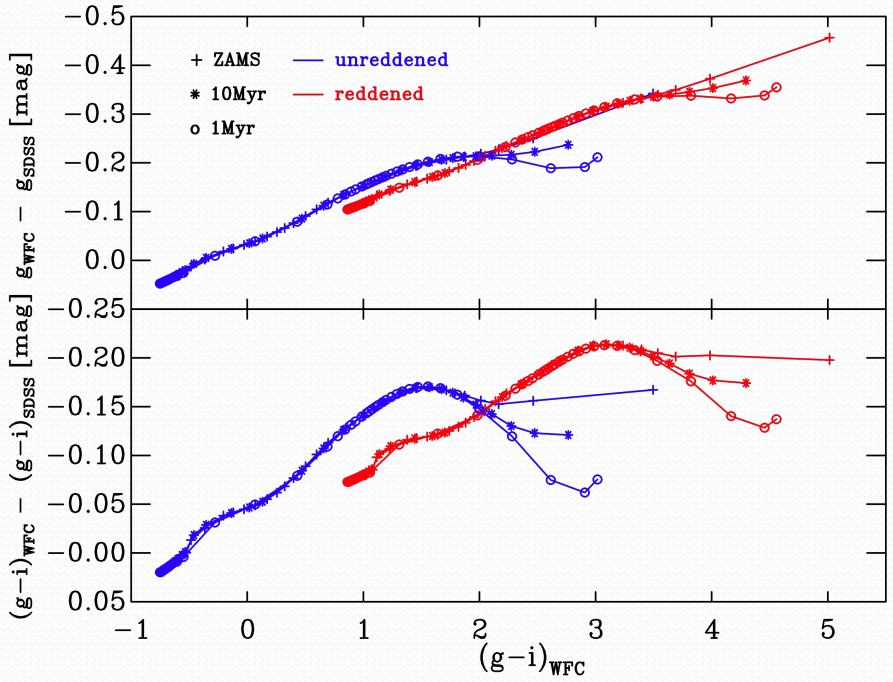
Photometric data from Stauffer et al. 2007

Photometric calibration

- Like to convert INT-WFC survey to SDSS
  - main-sequence star observations.
- Model INT-WFC system responses
  - transformations.
- Traditional calibration would place pre-MS stars in wrong position in CMD space

⇒ continue study in natural INT-WFC photometric system.

Cep OB3b, χ Per, IC 348, IC 5146, λ Ori, NGC 1960, NGC 2169, NGC 2244, NGC 2362, NGC 6530, NGC 6611, NGC 7160, ONC, Pleiades, σ Ori



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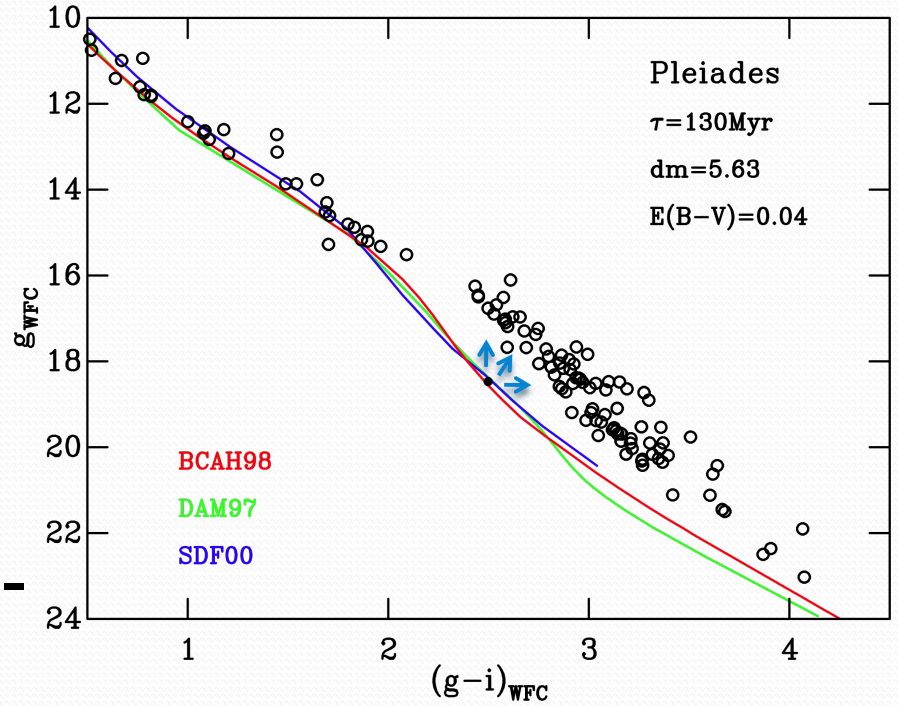
A simple test

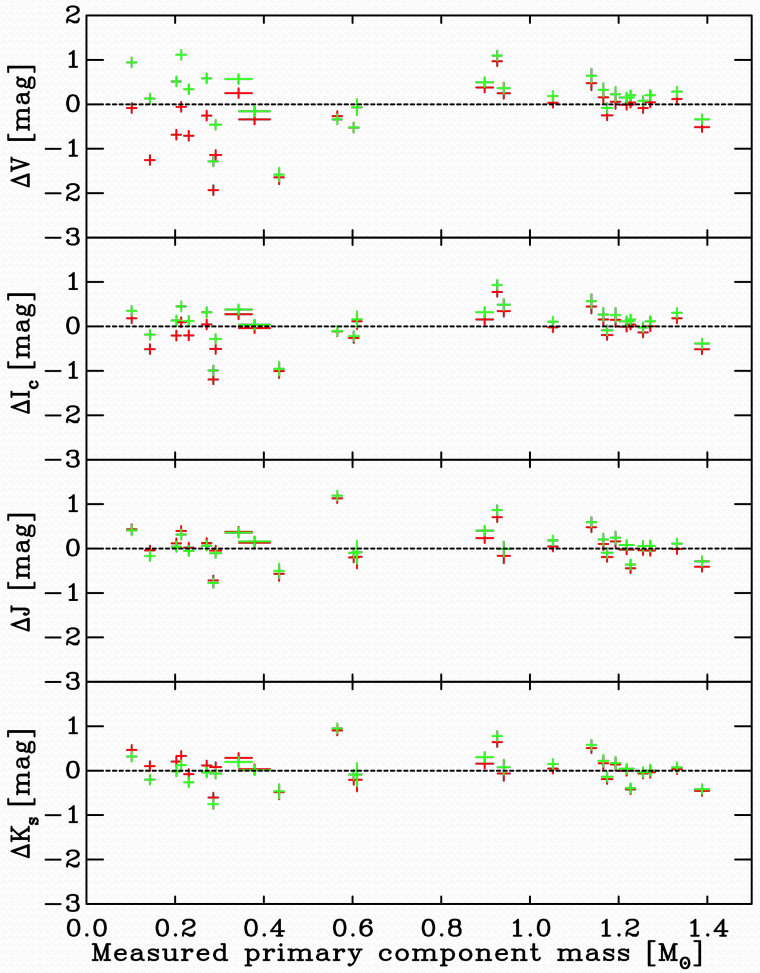
- Still notice that the models do not fit pre-MS population
  - missing sources of opacity?
  - treatment of convection?
  - missing physics?



- Create semi-empirical pre-MS isochrones using an empirical sequence.

Defining the mass scale

- Eclipsing and spectroscopic binaries give system magnitude
  - q $\longrightarrow$ 1 (same mass)
  - q $\longrightarrow$ 0 (mass = primary)



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Defining the mass scale

- Eclipsing and spectroscopic binaries give system magnitude
  - q $\longrightarrow$ 1 (same mass)
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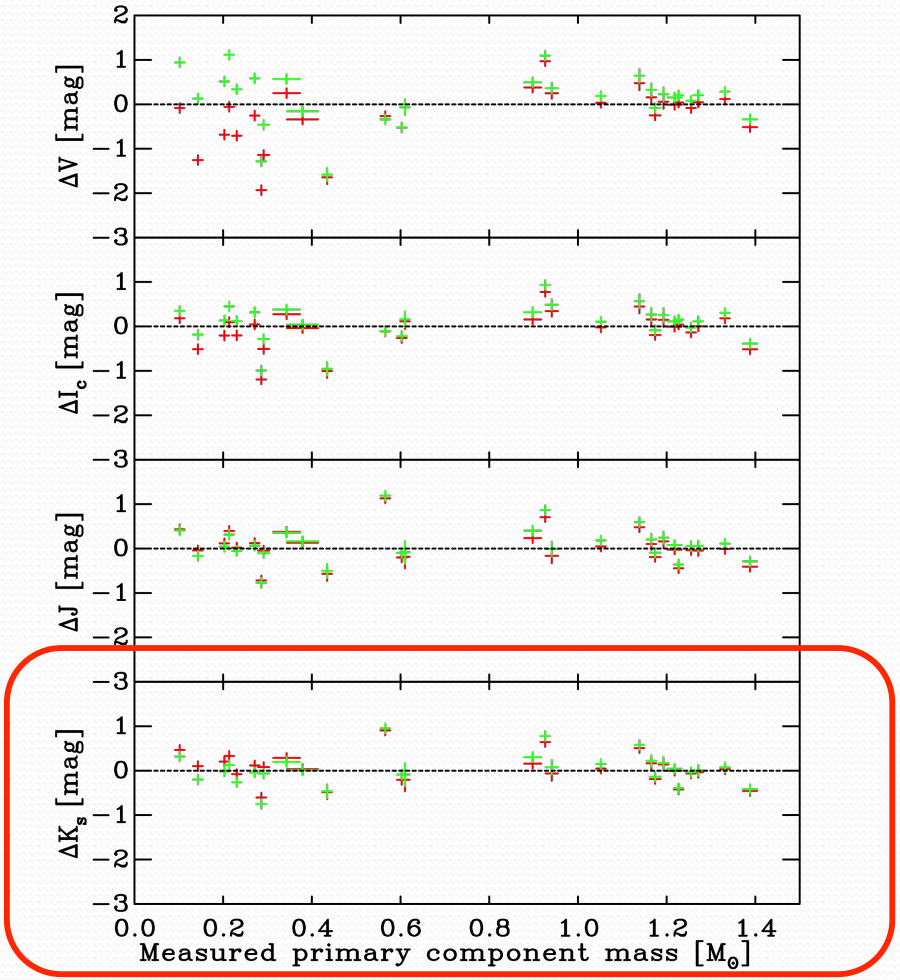
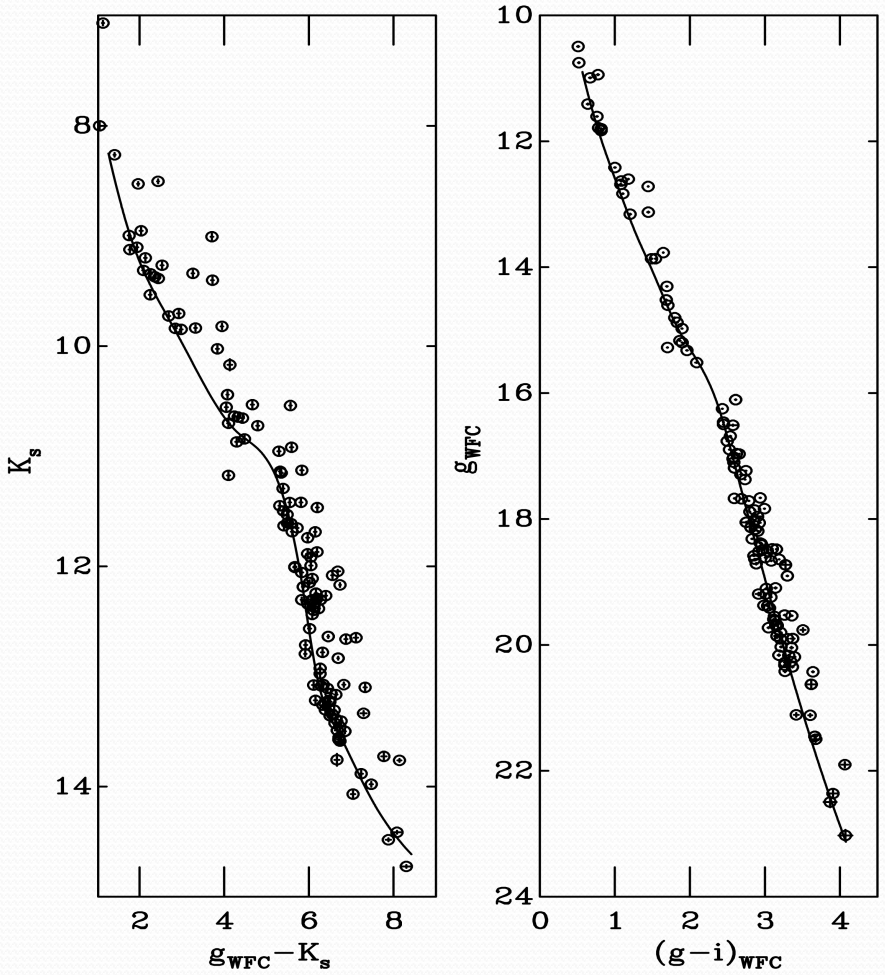
- Use K_s-band as a reliable mass indicator

$\Rightarrow$ “tune” other bandpasses.



Semi-empirical pre-MS models

- Empirical fit to observed sequence.



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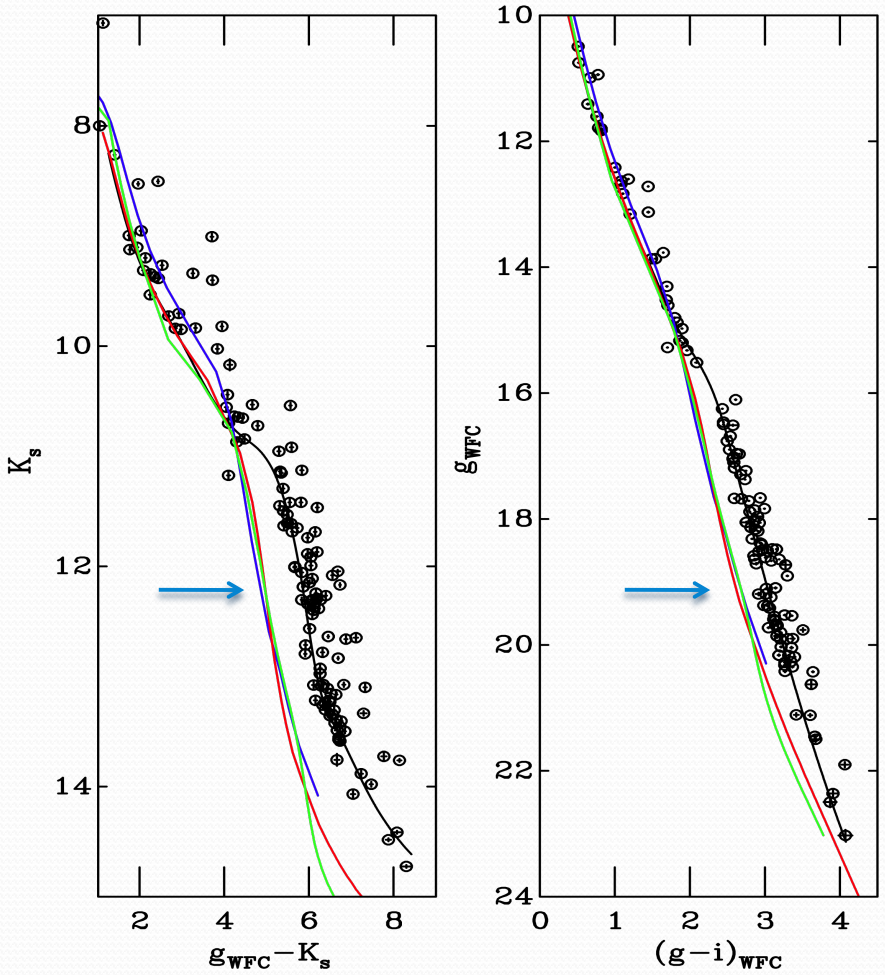
Semi-empirical pre-MS models

- Empirical fit to observed sequence.

- "Tune" other photometric bandpasses assuming $K_{obs} = K_{calc}$ at a given T_{eff}.



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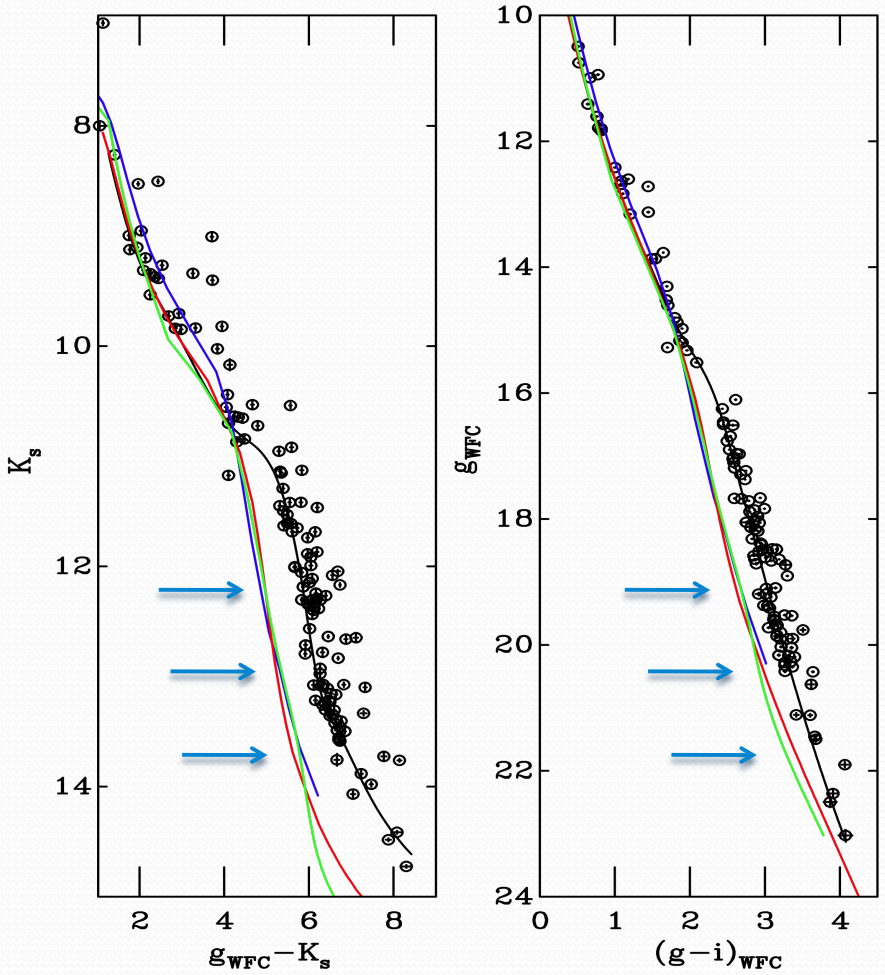
Semi-empirical pre-MS models

- Empirical fit to observed sequence.
- "Tune" other photometric bandpasses assuming $K_{obs} = K_{calc}$ at a given T_{eff}.
- Repeat for all T_{eff} along isochrone and for each bandpass

$\Rightarrow$ recalibrated bolometric correction relation.



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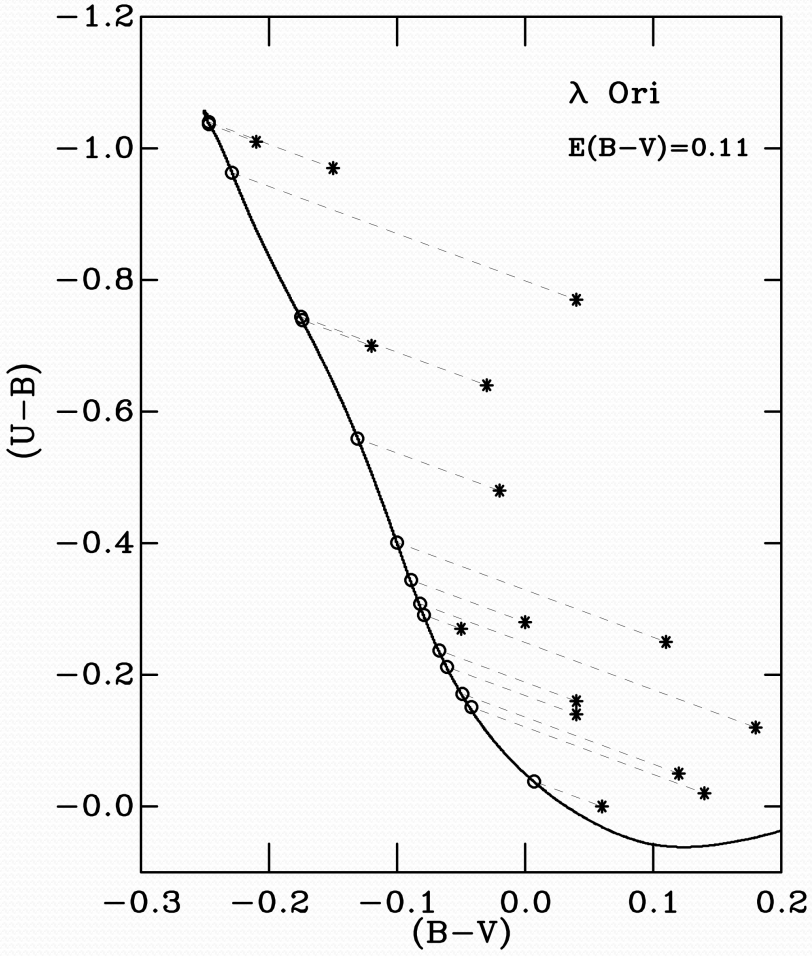
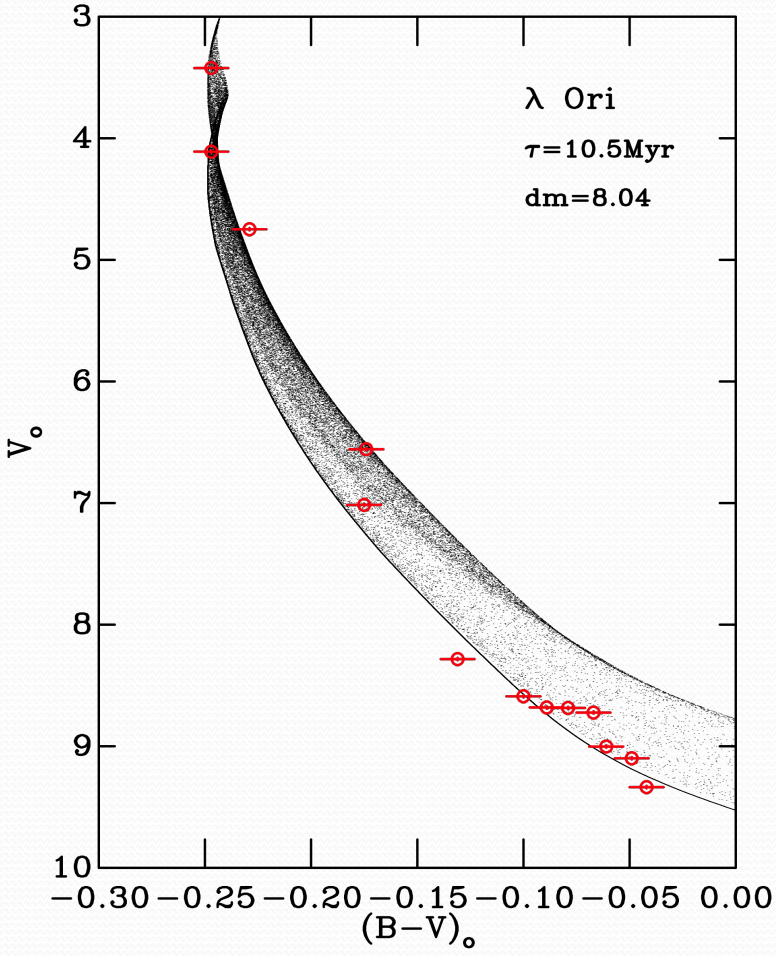
Fitting the main-sequence

Reddening



Distance and age



Photometric data from Murdin & Penston 1977

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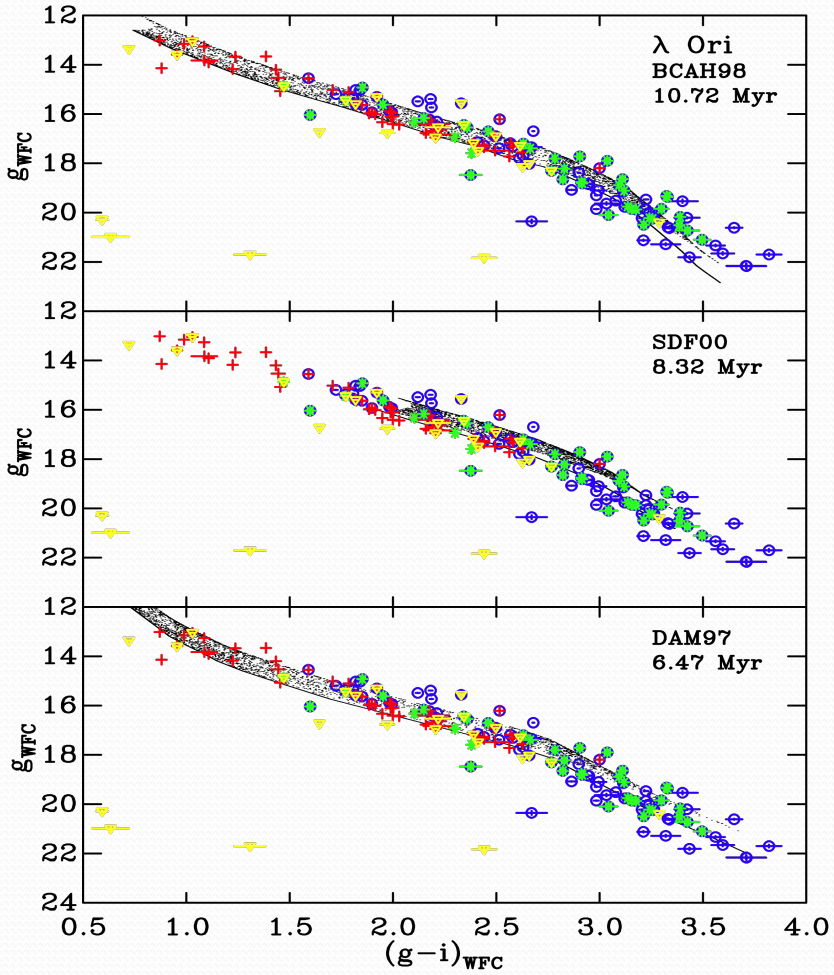
Fitting the pre-MS

- Model CMD comprises 10^6 stars based on stellar interior models.
- Fit using τ^2 fitting statistic (see Naylor & Jeffries 2006).
- Use main-sequence distance and allow age to float.



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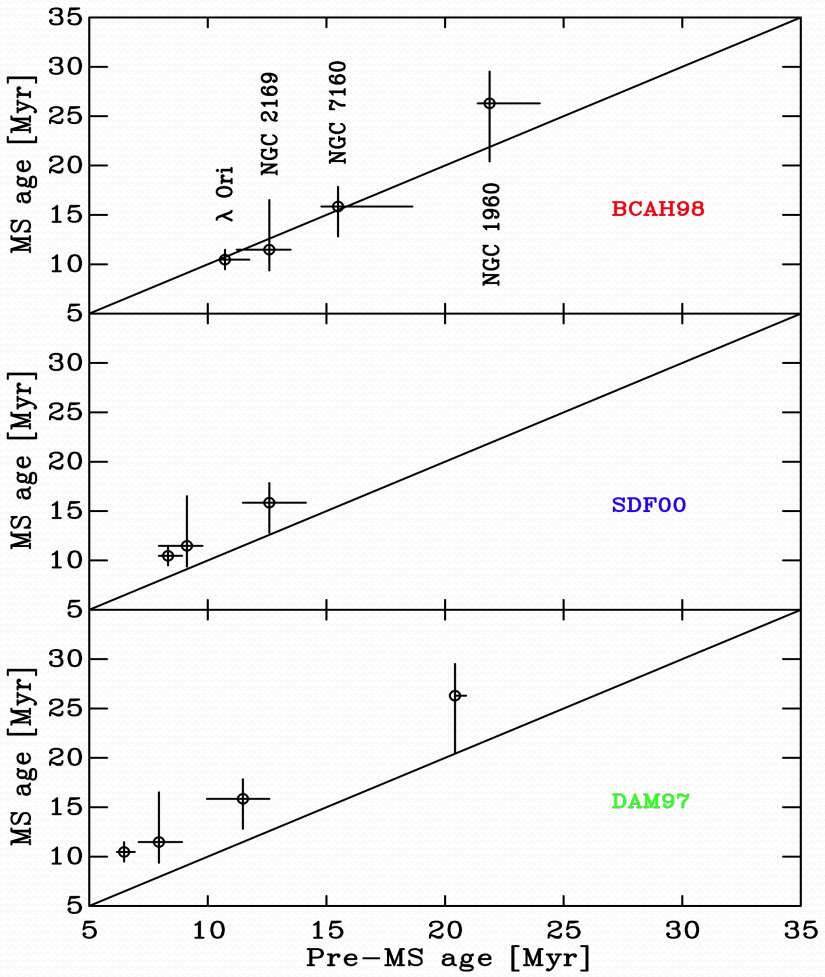
Revised pre-MS age scale?

- Consistent main-sequence and pre-MS ages.



Revised pre-MS age scale?

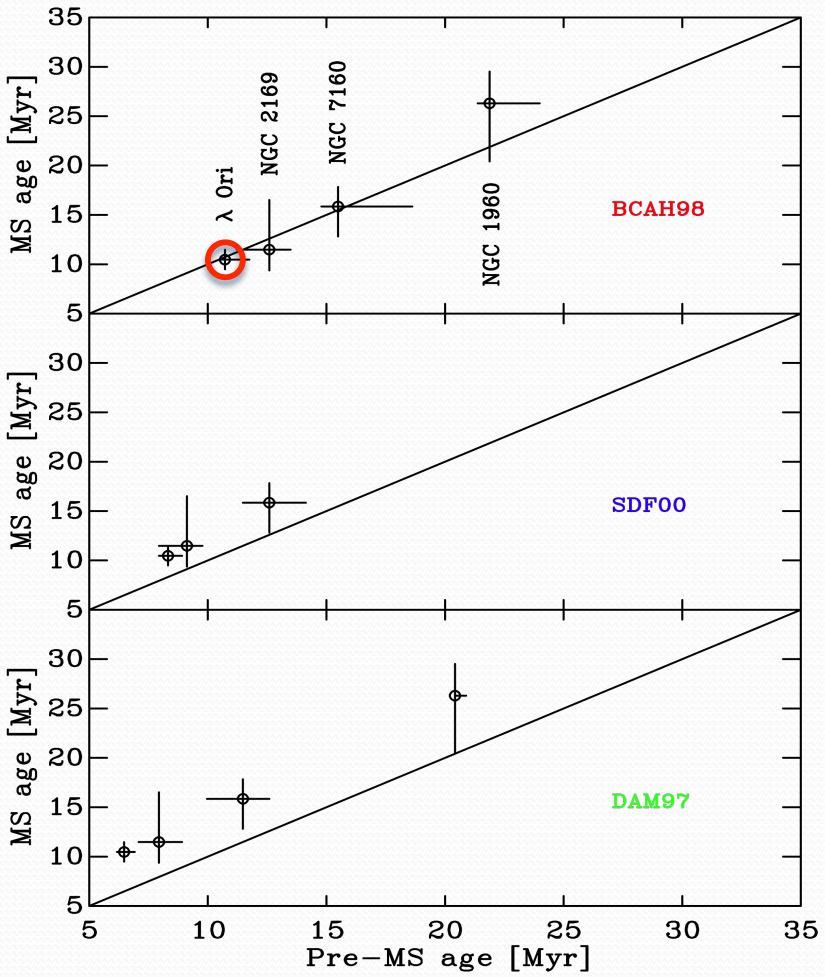
- Consistent main-sequence and pre-MS ages.

- Compare λ Ori with recent results of Upper Sco (Pecaut et al. 2012)

⇒ pre-MS ages for clusters are a factor 2 too young.

- Circumstellar disc fraction of ~ 20% at ages of 11Myr

⇒ simple solution to disparity between planet formation timescales and disc lifetimes.



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Thank you and questions?

- Created set of semi-empirical pre-MS isochrones.
- Consistency between main-sequence and pre-MS age derivations.
- Pre-MS ages are a factor of 2 older.
- Circumstellar discs survive long enough to create gas giant planets without invoking additional physics.

Main-sequence ages

- Age derived from star between the ZAMS and TAMS.
- Example – NGC 6530
- Left panel
  - Age=2Myr
  - $P_r(\tau^2)=0.03$
- Right panel
  - Age=5.5Myr
  - $P_r(\tau^2)=0.67$

Figure taken from Naylor 2009