Distance to the Pleiades

• ‘Long’ distance is $132 \pm 3$ pc
  – main sequence fitting (Johnson 1957, Meynet et al 1993)
  – HD 23642 (Munari et al 2004) and Atlas (Pan et al 2004)

• ‘Short’ distance is $118 \pm 3$ pc

• Possible solution: Pleiades is metal-poor
  – (van Leeuwen 1999, Castellani et al 2002)
  – but Boesgaard & Friel (1990) spectroscopy gives solar Z
  – Stello & Nissen (2001) analysis also disagrees with this

• Possible solution: Hipparcos parallaxes correlated
Eclipsing binary HD 23642

- Spectroscopic binary discovered in 1957 by Pearce (1957) and (Abt 1958)
- Eclipses found in Hipparcos light curves (Torres 2003)
- Period: 2.46 days    Spectral type: A0 Vp (Si) + Am
- Munari et al found distance: $131.9 \pm 2.1$ pc
  - Light curve fitted using Wilson-Devinney code
  - Distance comes from $M_{bol}$ and bolometric corrections
Light curve analysis

- *B* and *V* light curves observed by Munari et al
  - Light curves analysed using EBOP
  - Spectroscopic light ratio (Torres 2003) used
  - Possible 5% third light included
Monte Carlo analysis

- Used Monte Carlo simulations to find light curve uncertainties
  - Limb darkening coefficients perturbed
  - Diagram shows the parameter correlations for which the spectroscopic light ratio was needed to avoid
  - Munari uncertainties underestimated

- Effective temperatures found from spectral synthesis
  - $9750 \pm 250$ K and $7600 \pm 400$ K including peculiarity
Pleiades has solar metal abundance

- Masses and radii:
  - $M_1 = 2.19 \pm 0.02$
  - $M_2 = 1.55 \pm 0.02$
  - $R_1 = 1.83 \pm 0.03$
  - $R_2 = 1.55 \pm 0.05$

- Comparison with Granada models gives $Z \approx 0.02$
  - Pleiades distance scales cannot be reconciled by adopting a low metal abundance

Granada theoretical models
(age 125 Myr, $Z = 0.01, 0.02, 0.03$)
Distance to the Pleiades

• Distance from luminosity + bolometric correction:
  \[ L = 4 \pi R^2 \sigma T_{\text{eff}}^4 \Rightarrow M_{\text{bol}} \]
  \[ M_{\text{bol}} + \text{B.C.} + V \Rightarrow M_V + V \Rightarrow \text{distance} \]

• Problems:
  – B.C.s are model-dependent
  – Needs fundamental effective temperatures
  – Solar \( M_{\text{bol}} \) and luminosity are slightly uncertain
  – Consistent solar \( M_{\text{bol}} \) and luminosity values needed

• Munari’s distance to the Pleiades: \( 131.9 \pm 2.1 \) pc
  – What we get using Bessell (1998) B.C.s: \( 134.5 \pm 2.5 \) pc
  – What we get using Flower (1996) B.C.s: \( 135.4 \pm 2.6 \) pc
  – What we get using our analysis: \( 138.1 \pm 4.7 \) pc
Distance from surface brightness calibrations

- Use zeroth-magnitude angular diameter $\Phi^{(m=0)}$
  - $S_V = V_0 - 5 \log \Phi$ so $\Phi^{(m=0)} = \Phi 10^{(0.2 \text{ m})} = 0.2 S_V$
  - Kervella et al (2004) give $\Phi^{(m=0)}$ -- log Teff calibrations

$$d = 10^{0.2m_\lambda} \sqrt{\left[ \frac{2R_A}{\phi_A^{(m_{\lambda}=0)}} \right]^2 + \left[ \frac{2R_B}{\phi_B^{(m_{\lambda}=0)}} \right]^2}$$

- Use 2MASS JHK photometry: IR relations better
  - Distance found: $139.1 \pm 3.6 \text{ pc}$
  - Individual uncertainties:
    - Effective temperatures: 0.7 pc 1.4 pc
    - Stellar radii: 1.4 pc 1.5 pc
    - Apparent K magnitude: 2.1 pc
    - `Cosmic’ scatter in calibration: 1.4 pc
The Pleiades distance is ....?

- Long distance scale: $132 \pm 3$ pc
  - main sequence fitting
  - study of astrometric binary Atlas
- Short distance scale: $118 \pm 3$ pc
  - Hipparcos parallaxes
- Distance to HD 23642: $139 \pm 4$ pc
  - only weakly dependent on temperatures and radii
- The Pleiades is not metal-poor
  - from comparison between the masses and radii and theoretical evolutionary models
- HD 23642 needs better light curves + spectroscopy