Influence of Hipparcos on Hyades age estimates from three binary systems

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Abstract.
Three independent sets of stellar theoretical models are tested with well-detached systems of the Hyades open cluster: 51 Tau, V818 Tau, and \( \theta^2 \) Tau. The choice of these objects is discussed and a statistical method is described and applied to the colour-magnitude diagram (CMD) of the selected stars, giving rise to contour levels in the metallicity-age plane. The effects of the Hipparcos parallaxes on these confidence regions, with influence on both age and metallicity, are studied for the V818 Tau system through a comparison with very accurate but older orbital parallaxes. Finally, theoretical simultaneous age-metallicity estimates are given for the three binaries and compared with observational constraints.

1. Introduction
The main advantage to choose binaries which are members of the Hyades open cluster is that the heavy element abundance of the Hyades has been extensively studied and estimated by different authors. The more recent determinations of the Hyades metallicity have been reviewed by Perryman et al. (1998): [Fe/H] = 0.14 ± 0.05, i.e. \( Z = 0.024^{+0.0025}_{-0.003} \) assuming a subsolar helium abundance (\( Y = 0.26 \)), which is the value found by Lebreton et al. (1997) in order to reproduce the Hyades main sequence. A second advantage is that very accurate parallaxes are now available from Hipparcos for the systems 51 Tau, V818 Tau, and \( \theta^2 \) Tau. Moreover, Torres et al., 1997 ([TSL97a], [TSL97b] and [TSL97c]) obtained the first complete visual-spectroscopic solutions for the 3 above-mentionned sys-
tems, from which they carefully derived very accurate parallaxes and individual masses. They also gathered some individual photometric data in the Johnson system. Furthermore, we found useful trigonometric parallaxes information in the Hipparcos catalogue (ESA, 1997). By combining the two sources of data, we investigate the influence of the Hipparcos parallaxes on our method which was developed to test stellar evolutionary models in HR diagrams.

Tests in the CMD: The tests we want to perform are the following:

1. to check whether the two components of the systems are on the same isochrone, i.e. on a line defined by the same age and the same chemical composition for the two single stars.

2. since all the selected stars are members of the Hyades whose metallicity has been well measured, we can also check that the predicted metallicities from theoretical models are correct.

3. for 51 Tau and $\theta^2$ Tau, the individual stellar masses are known with an accuracy of about 10%, and for V818 Tau, masses and radii are known with an accuracy close to 1-2%, allowing further tests with the theoretical models (see Lastennet et al. 1999b for details on this point).

Therefore, if one of these criteria is not clearly fulfilled by a given set of tracks, then these models have obvious problems because they do not account for several observational constraints (the metallicity, mass, radius, and/or the photometric data).

2. An example: the V818 Tau binary system

The V818 Tau system is a double-lined eclipsing binary (Mc Clure, 1982) with very well estimated masses (actually the most accurate masses known for Hyades members). Indeed, the relative errors on the masses are less than 1%, and the secondary component is particularly interesting because it is one of the rare stars which is less massive than the Sun and whose mass is known with such an accuracy (cf. Andersen 1991).

2.1. Brief description of the method

In order to derive simultaneously the metallicity ($Z$) and the age ($t$) of the system, and to produce confidence level contours (see Figure 1), we minimize the $\chi^2$-functional defined as:

$$\chi^2(t,Z) = \sum_{i=A}^{B} \left[ \left( \frac{M_V(i)_{\text{mod}} - M_V(i)}{\sigma(M_V(i))} \right)^2 + \left( \frac{(B-V)(i)_{\text{mod}} - (B-V)(i)}{\sigma((B-V)(i))} \right)^2 \right]$$

(1)

where $A$ is the primary and $B$ the secondary component. $M_V$ and $(B-V)$ are the observed values, and $M_V_{\text{mod}}$ and $(B-V)_{\text{mod}}$ are obtained from the synthetic computations of the BaSeL (Basel Stellar Library) models (see Lejeune et al. 1997, 1998 and Lastennet et al. 1999a) using a given set of stellar tracks from
the Geneva group (see Charbonnel et al. 1993 and references therein), the Padova group (see Fagotto et al. 1994 and references therein), and from Claret & Giménez (1992) (CG92 thereafter). For reasons developed in Lastennet et al. (1999b), we assume that the calibrations from the BaSeL models are reliable enough for this work.

2.2. Results

Fig. 1 shows that the Hipparcos parallaxes have a strong influence on the solutions of V818 Tau in the metallicity-age plane: the solutions obtained with the parallaxes of Torres et al. are too old and metal rich. In contrast, the Hipparcos parallaxes give contours in agreement with the metallicity of the Hyades. Hence, the Padova tracks provide 1σ-contours in agreement with the Hyades metallicity only if one takes into account the Hipparcos parallax. It is also worth noticing that the isochrone corresponding to the Perryman et al. (1998) solution does not fit the system in the CMD.
The table below briefly summarizes, for the three systems, the results of the theoretical simultaneous age–metallicity estimates obtained from isochrone age fitting (1σ level) taking into account the Hipparcos parallax.

| System        | Geneva   | Padova  | CG92   |
|---------------|----------|---------|--------|
|               | Z        | log t   | Z      | log t   | Z      | log t   |
| 51 Tau        | 0.020^{+0.010}_{-0.008} & 8.88^{+0.22}_{-0.23} & 0.017^{+0.021}_{-0.005} & 8.96^{+0.15}_{-0.55} & 0.018^{+0.012}_{-0.006} & 8.92^{+0.23}_{-0.17} |
| V818 Tau      | 0.033^{+0.017}_{-0.015} & 7.30^{+3.50}_{-2.30} & 0.027^{+0.023}_{-0.011} & 8.80^{+0.03}_{-0.11} & 0.027^{+0.003}_{-0.005} & 8.88^{+0.02}_{-0.02} |
| θ² Tau        | 0.027^{+0.013}_{-0.010} & 8.80^{+0.05}_{-0.09} & 0.027^{+0.023}_{-0.011} & 8.80^{+0.03}_{-0.11} & 0.027^{+0.003}_{-0.005} & 8.88^{+0.02}_{-0.02} |

For 51 Tau and θ² Tau, the 3 sets of isochrones give good fits in the CMD, in agreement with previous estimates (Perryman et al.) of age (log t = 8.80^{±0.02}; from isochrone fitting technique with the CESAM stellar evolutionary code (Morel 1997)) and metallicity ([Fe/H] = 0.14 ± 0.05). The Geneva and CG92 models can not be tested with the less massive component of V818 Tau. It is also interesting to mention that the masses predicted by the 3 sets of tracks are in good agreement with the measured individual masses of each system but the Padova isochrones can not fit the system V818 Tau in a mass-radius diagram (see Lastennet et al. 1999b for more details).

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