Astron. Astrophys. 358, 923–928 (2000)

ASTRONOMY AND ASTROPHYSICS

Internal velocity dispersion in the Hyades as a test for Tycho-2 proper motions*

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Received 20 March 2000 / Accepted 22 April 2000

Abstract. The Hyades stars have highly coherent motions in space which reflect in the convergence of their astrometric proper motions in or about a common convergent point. The internal dispersion of the Hyades velocities is as low as about 0.3 km s^{-1}. This is comparable with the expected uncertainty of the Tycho-2 proper motion at the distance of the Hyades. The classical approach of using the proper motion components normal to the convergent point direction is employed for some 200 bona fide cluster members located in an area of some $2\,000$ deg^2 and ranging in V magnitude 3.4 to 12.1. It is demonstrated that with the most precise Tycho-2 proper motions for some 50 stars, the intrinsic dispersion is measurable at the level of 0.32 km s^{-1}, in agreement with previous estimations obtained from the Hipparcos data and radial velocities. When only 30 stars out of the 50 are considered, which are not known to be spectroscopic binaries, the observed scatter suggests a dispersion of only 0.22 km s^{-1}. The approach in use is model independent, and sets an upper limit on the intrinsic dispersion of velocities. It is shown for some 180 stars in common, that the Tycho-2 proper motions have a very similar precision to that of Hipparcos, but reveal fewer extreme deviants from the common convergent point direction. Tycho-2 proper motions are based on long series of observations, up to a 100 years, and are therefore less subject to the orbital motion effects in binaries. The ratio of the external error to the formal error of the Tycho-2 proper motions may be up to 1.3 for stars fainter than $V_T = 8.5$ mag. An alternative explanation for the extra scatter in low-precision subsets is discussed, that less massive stars may indeed have larger observed velocity dispersion due to the binarity effect.

Key words: Galaxy: open clusters and associations: individual: Hyades – stars: kinematics – astrometry

1. Introduction

Direct, model independent determination of velocity dispersion inside the Hyades open cluster is important for our understanding of the kinematics of this cluster and similar intermediate age Galactic clusters. In particular, the basic issue can be addressed, whether the Hyades cluster is in a state of dynamical equilibrium, expansion or, speculatively, gravitational contraction. The explicit assumptions on the basic parameters of the dynamical model should also be checked, e.g. the total mass of the cluster and its luminosity function. The Hyades, due to their proximity (46.3 pc) are the best studied, and a wealth of observational information on some 300 members can be found in the literature. Astrometric proper motions and radial velocities, which are required for a kinematic assessment, have been observed and collected during a few decades of comprehensive study.

Kinematics, however, proved a testing subject for ground-based observation techniques. The motions of the Hyades stars are coherent to a high degree, so that the precision of both astrometric measurements and spectroscopic radial velocities has been insufficient to resolve the intrinsic dispersion. A spectacular breakthrough in astrometric precision was achieved with the advance of the Hipparcos satellite data (ESA, 1997). Proper motions precise to 1–2 mas/a were routinely obtained for brighter stars, complemented by trigonometric parallaxes of similar accuracy and precision. This already comes close to the point where the intrinsic dispersion can be directly measured from the proper motions. For a cluster like the Hyades, the intrinsic dispersion, in dynamical equilibrium, is estimated at 0.23 km s^{-1} (Gunn et al. 1988). This value translates into a 1.04 mas/a scatter in proper motions, assuming the average distance of 46.3 pc to the cluster. The best precision obtained with Hipparcos falls short of this value. An attempt to estimate the dispersion from Hipparcos proper motions alone was however not successful (Brown et al. 1997), since the observed scatter was found smaller than the median error.

Perryman et al. (1998) investigated a high-precision subset of the Hipparcos sample with 40 stars without any indications of multiplicity, having precise radial velocities and standard errors of proper motion and parallaxes of less than 2 mas/a and 2 mas, respectively. Evidence of an extra dispersion, with regard to the expected scatter of velocity components, was detected, which could be accounted as an intrinsic velocity dispersion of about 0.3 km s^{-1}. It is pointed out, that the actual dispersion can be smaller than this value, because undetected binarity

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* Based on observations made with the ESA Hipparcos satellite.

may increase the observed scatter in proper motions and radial velocities. The Hipparcos proper motions are based on the 3.5 year-long observational period of the satellite. This is not long enough to average out the orbital motions of most of the so-called astrometric binaries. The contribution of the orbital motion scatter in the Hipparcos proper motions is impossible to estimate, and the value of 0.3 $\mathrm{km\,s^{-1}}$ should be taken as an upper bound for the given set of stars.

A fitting maximum-likelihood method was developed and applied by Dravins et al. (1997) to the Hyades proper motion and parallax data in Hipparcos. No radial velocity observations are used, but 'astrometric' radial velocities are derived, thanks to the considerable angular extent of the cluster. The centroid space velocity vector $\boldsymbol{v}$ and the internal velocity dispersion σ_v (i.e., standard deviation in each coordinate) are the basic model parameters subject to an iterative adjustment, while the astrometric proper motions, positions and parallaxes are the input data. Besides the astrometric radial velocities, improved parallaxes are derived, consistent with the observed proper motions and the assumption of a common motion of the member stars. The improvement of parallaxes arises from the much better relative precision of the proper motions ($\approx$ 2% for the average $\mu = 110$ mas/a) compared to the relative precision of the trigonometric parallaxes, about 5 to 10%. When applied to the whole sample of firm Hyades members in the Hipparcos Catalogue, the method produced a $\sigma_v = 0.98$ $\mathrm{km\,s^{-1}}$. After removal of one third of the original sample in an iterative cleaning of kinematic outliers, the method gave a drastically smaller 0.15 $\mathrm{km\,s^{-1}}$. The authors found out by Monte Carlo simulations, that the latter value might be strongly statistically biased, and corrected it to 0.25 $\mathrm{km\,s^{-1}}$.

Using a very similar approach on a sample of some 50 stars with accurate Hipparcos proper motions, Narayanan & Gould (1999) arrived at an estimate of 320 ± 39 $\mathrm{m\,s^{-1}}$ for the internal dispersion. Interestingly, their estimated bulk velocity vector deviates from that in (Perryman et al., 1998) by 0.4 $\mathrm{km\,s^{-1}}$ in magnitude and 0.9° in direction. This shows that a significant uncertainty can be introduced by slightly different methods and sample selection, when applied to the same data.

We conclude that the Hipparcos astrometry provides only an upper limit for the internal velocity dispersion of ≈ 0.3 $\mathrm{km\,s^{-1}}$. The real dispersion may be smaller, but a better estimate is difficult to achieve because of the additional scatter of physical origin in the motions, most notably from the orbital motions of unresolved astrometric binaries. Strong evidence of a deterioration in the Hipparcos proper motions, based only on a 3.5 years series of in-orbit observation, due to undetected orbital motions, was produced by a comparison with FK5 (Wielen et al. 1999) and ACT (Odenkirchen & Brosche 1999) proper motions. In this paper we are using the main asset of Tycho-2 proper motions, namely that they are based on much longer observation series and, therefore, are less affected by binarity, to obtain a tighter estimate of the internal velocity dispersion.

The recently published Tycho-2 Catalogue includes 2.5 million stars and covers the entire sky (Høg et al. 2000a). Proper motions are derived for 96 percent of the stars from the observed positions in Tycho-2, the Astrographic Catalogue and 143 other ground-based catalogues (Høg et al. 2000b). As described in the paper on the construction of the Tycho-2 Catalogue (Høg et al. 2000c), the Hipparcos positions were not explicitly used in the Tycho-2 proper motions derivation. They were used only for a re-calibration of the Astrographic Catalogue and other ground-based source catalogues and for bringing them into the ICRS reference system, as defined by Hipparcos. Therefore, the system of Tycho-2 proper motions is tied to that of Hipparcos systematically, on the large and intermediate scales. As far as accidental errors for individual stars are concerned, the Tycho-2 and Hipparcos proper motions are statistically independent, i.e. uncorrelated.

Despite the much poorer positional precision of Tycho-2 observations and other source catalogues, the sheer duration of the observation record (over 100 years sometimes) makes the Tycho-2 proper motions even more precise than those of Hipparcos, for some stars. The median formal standard errors of Tycho-2 proper motions are equal to 1.0 mas/a for stars with Tycho V_T magnitude brighter than 7, and 1.5 mas/a for stars with V_T between 9 and 10 mag. For some stars, the formal errors can be as small as 0.7 mas/a. We show in this paper that the Tycho-2 proper motions for a selected subset of the Hyades members provide a purely observational, model-independent estimation of the intrinsic velocity dispersion in this cluster. This work provides also an external check for the Tycho-2 proper motions and confirms their high quality.

2. Velocity dispersion estimation

We selected a sample of 217 probable members of the Hyades, having proper motions in Tycho-2 (several more known members are present in the catalogue, but without proper motions). Most of the stars were taken from the list in Stern et al. (1995), cross-matched with the Tycho-2 catalogue. A score of members missing in the Stern et al.'s list were added from the sample in Perryman et al. (1998). Sequentially, several objects were deleted from the list, marked as nonmembers by Perryman et al. Finally, we added several probable members from the Tycho-2 catalogue itself, fulfilling the 3.5σ criterion on proper motion convergence, as explained in the following.

The sample thus constructed is rather homogeneous, in the sense that it includes almost all confident members of the cluster down to a limiting magnitude of about 11.5, with a few omissions caused mainly by the lack of proper motions in Tycho-2. The sample occupies an area of 50° by 40° centred at $(\alpha, \delta) = (67^\circ, 16^\circ)$. The centre of the cluster is at 46.3 pc from the Sun, with the most distant from the cluster centre member at 43.8 pc. There might be more distant members in the cluster's halo, but they were not included, being useless for an internal dispersion estimation. The range of V magnitudes in the sample is 3.4 to 12.1. Two stars in the sample may be new members of the Hyades, viz. the K0 dwarf HD 287240, which seems to have erroneous photometry in the Simbad data base, and TYC 1815-0680-1.

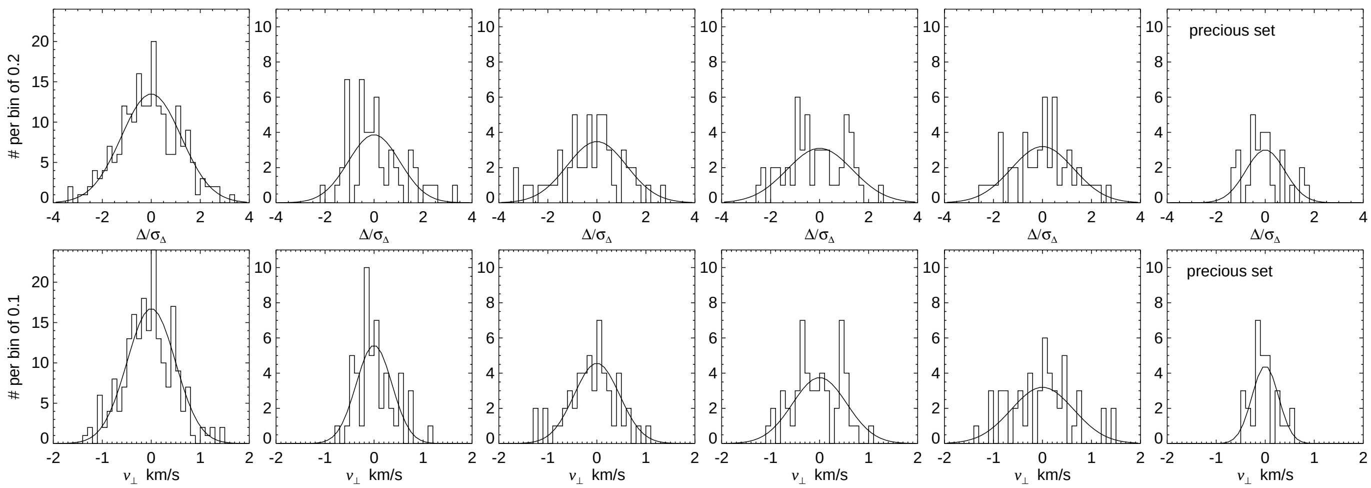

Fig. 1. Observed histograms of Δ/σ_Δ (upper row) and $v_\perp$ (lower row) for the first 5 samples in Table 1 and the precious set (see text). A Gaussian least squares fit is shown for each histogram.

For a given star in the sample, its coordinates (α, δ) and proper motion components $(\mu_{\alpha*}, \mu_\delta)$ are known, in the equatorial coordinate system, where $\mu_{\alpha*}$ denotes $\mu_\alpha \cos\delta$. The proper motion components define a proper motion vector $\boldsymbol{\mu}$ tangential to the celestial sphere at the given point. When projected onto the sphere and extended around it, the vector draws very close to the common convergent point of the cluster. We adopt in this paper the well-established coordinates $(\alpha_{\rm CP}, \delta_{\rm CP}) = (97\overset{\circ}{.}91, 6\overset{\circ}{.}66)$, derived for 134 Hipparcos stars in the inner 10 pc of the cluster (Brown et al. 1997). For each star, we compute the position angle p of the proper motion vector reckoned from north through east, i.e. $\sin p = \mu_{\alpha*}/\mu$ and $\cos p = \mu_\delta/\mu$. We compute furthermore the differences Δ between p and the position angle of the direction from the star position to the convergent point. The observables Δ include two independent kinds of statistics, the error of the computed proper motion and intrinsic velocity dispersion, both in the direction normal to the convergent point direction. Since Δ is very small for a member star, the expected error of transverse proper motion is, in the first order approximation,

$$\sigma^2_{\mu\perp} = \frac{1}{\mu^2}(\mu^2_{\alpha*}\sigma^2_{\mu\delta} + \mu^2_\delta \sigma^2_{\mu\alpha*}), \quad (1)$$

where $\mu = |\boldsymbol{\mu}|$ and $\sigma_{\mu\alpha*}$ and $\sigma_{\mu\delta}$ are the standard formal errors of the proper motion components $\mu_{\alpha*}$ and μ_δ, as given in the catalogue. The expected error of the transverse tangential velocity, in $\mathrm{km\,s^{-1}}$, is

$$\epsilon_{v\perp} = 4.74 D \sigma_{\mu\perp}, \quad (2)$$

where D is the distance to the star in parsec, and $\sigma_{\mu\perp}$ is in arcsec yr^{-1}. The expected variance of the angular deviation from the convergent point is

$$\sigma^2_\Delta = \frac{\epsilon^2_{v\perp} + \sigma^2_v}{(4.74 D\mu)^2}. \quad (3)$$

The internal velocity dispersion σ^2_v is assumed to be isotropic in this formula.

By the classical moving cluster method (e.g., Smart 1938), the distance to each star is obtained from the relation

$$v \sin\lambda = 4.74\,\mu D, \quad (4)$$

where λ is the angular distance between the star and the convergent point, and v is the bulk space velocity of the cluster. We accept in this paper the velocity vector $\boldsymbol{v} = (-6.28, +45.19, +5.31)\,\mathrm{km\,s^{-1}}$ (ICRS), determined in Perryman et al. (1998) for the inner 10 pc of the cluster. Finally, introducing D into Eq. (3),

$$\sigma^2_\Delta = \frac{\sigma^2_{\mu\perp}}{\mu^2} + \frac{\sigma^2_v}{v^2 \sin^2\lambda}. \quad (5)$$

The following analysis is based on 207 Tycho-2 stars out of the original 217 with Δ/σ_Δ less than 3.5, computed under the basic assumption of a $\sigma_v = 0.3\,\mathrm{km\,s^{-1}}$. Among the 10 rejected stars, 7 are in the Hipparcos catalogue, viz. HIP 14838, 16548, 16908, 19386, 20601, 21788 and 22271. Some of these stars may be statistical interlopers, e.g. HIP 21788, while others may well be real kinematic escapers or binaries with a considerable orbital motion. The distribution of all the observed transverse velocities $v_\perp$, i.e. the tangential velocity components normal to the convergent point directions,

$$v_\perp = v \sin\lambda \sin\Delta \quad (6)$$

is fitted by the least squares method by a Gaussian with a $\sigma = 0.49\,\mathrm{km\,s^{-1}}$, Fig. 1, leftmost in the second row. This value sets the absolute upper bound on the internal dispersion. The real dispersion is, however, significantly smaller.

In order to obtain a better estimate of the internal velocity dispersion, the general sample is split into roughly 4 quarters according to the formal astrometric error in the transverse velocity, $\epsilon_{v\perp}$. The estimated standard deviation for the most precise quarter is only 0.36 $\mathrm{km\,s^{-1}}$, cf. second plot in the second row of Fig. 1 and Table 1. This is closer to the true value of the dispersion, because the contribution of the astrometric errors is

Table 1. Subsamples of the Hyades stars with Tycho-2 proper motions, and observed standard deviations of the tangential velocity component $v_\perp$, normal to the convergent point direction, and of the ratio of the deviation from the convergent point direction to the expected one, under the assumption of an intrinsic velocity dispersion of 0.3 km s^{-1}.

Subsample	Median $\epsilon_{v\perp}$ or V_T	N	s.d. $v_\perp$	s.d. Δ/σ_Δ
With Tycho-2 proper motions:				
All	0.262 km s^{-1}	207	0.49 km s^{-1}	1.22
$\epsilon_{v\perp} \in [0.066, 0.201]$ km s^{-1}	0.167 km s^{-1}	51	0.36 km s^{-1}	1.05
$\epsilon_{v\perp} \in [0.201, 0.262]$ km s^{-1}	0.235 km s^{-1}	53	0.46 km s^{-1}	1.21
$\epsilon_{v\perp} \in [0.262, 0.322]$ km s^{-1}	0.295 km s^{-1}	52	0.55 km s^{-1}	1.34
$\epsilon_{v\perp} \in [0.322, 0.714]$ km s^{-1}	0.403 km s^{-1}	51	0.64 km s^{-1}	1.27
$V_T \in [3.41, 6.64]$ mag	5.61 mag	53	0.42 km s^{-1}	1.16
$V_T \in [6.64, 8.52]$ mag	7.53 mag	53	0.44 km s^{-1}	1.13
$V_T \in [8.52, 9.99]$ mag	9.16 mag	50	0.53 km s^{-1}	1.32
$V_T \in [9.99, 12.27]$ mag	10.90 mag	49	0.64 km s^{-1}	1.30
Precious set	0.163 km s^{-1}	30	0.27 km s^{-1}	0.80
With Hipparcos proper motions:				
All	0.260 km s^{-1}	162	0.50 km s^{-1}	1.18
$\epsilon_{v\perp} \in [0.116, 0.205]$ km s^{-1}	0.173 km s^{-1}	42	0.35 km s^{-1}	1.05
$\epsilon_{v\perp} \in [0.205, 0.260]$ km s^{-1}	0.222 km s^{-1}	39	0.47 km s^{-1}	1.25
$\epsilon_{v\perp} \in [0.260, 0.348]$ km s^{-1}	0.288 km s^{-1}	39	0.63 km s^{-1}	1.49
$\epsilon_{v\perp} \in [0.348, 1.554]$ km s^{-1}	0.454 km s^{-1}	42	0.64 km s^{-1}	1.00
$V_T \in [3.41, 6.13]$ mag	5.41 mag	40	0.41 km s^{-1}	1.16
$V_T \in [6.13, 7.80]$ mag	7.08 mag	38	0.54 km s^{-1}	1.35
$V_T \in [7.80, 9.34]$ mag	8.68 mag	41	0.49 km s^{-1}	1.12
$V_T \in [9.34, 11.84]$ mag	10.15 mag	43	0.57 km s^{-1}	1.05
Precious set	0.205 km s^{-1}	29	0.32 km s^{-1}	0.88

small, according to Eq. (5). The effect of increasing astrometric errors is seen in the widening of the observed distributions for the remaining, less precise subsets.

Assuming a certain σ_v, the distribution of the Δ/σ_Δ values can be computed from Eq. (5). If the assumption is correct, and the formal errors are realistic, the expected standard deviation of this distribution is close to unity. The upper row in Fig. 1 shows such distributions and their least squares fits for the general sample and precision subsamples with a $\sigma = 0.30$ km s^{-1}. The standard deviation for the general sample is 1.22 (Table 1). This extra scatter can be accounted for in two different ways. The true astrometric errors may be systematically larger than the formal errors given in the catalogue. More interesting from the astrophysical point of view is the possibility that the intrinsic velocity dispersion is significantly larger than 0.3 km s^{-1}, at least for some groups of stars. The most precise quarter, where the contribution of astrometric errors (and of their possible bias) is relatively small, matches a dispersion at 0.32 km s^{-1}. This subset includes mostly the brightest stars, while the other quarters, with fainter stars, clearly indicate an extra scatter. When the sample is quartered according to V_T magnitudes (Table 1), it appears that stars fainter than 8.5 mag have markedly larger excess scatter in proper motions. The observed histograms can be approximately reconciled with the expectation by multiplying all the proper motion errors by a factor 1.3. On the other hand, it is conceivable that fainter stars can have higher velocity dispersion within the cluster.

We repeated the convergence analysis with Hipparcos proper motions instead of Tycho-2 (in that case, Eq. (1) includes the correlation coefficient between the proper motion components). In the sample of 217 stars, 178 Hipparcos stars are found. Interestingly, 16 stars exceed the 3.5σ limit with the Hipparcos proper motions, i.e. 9 percent, compared to the 4 percent for the Tycho-2/Hipparcos sample. The increased outlier rate is clearly a manifestation of the additional error due to the orbital motion in binaries.

The 16 Hipparcos outliers and the 10 Tycho-2 outliers have only four stars in common, namely HIP 14838, 19386, 20601 and 21788. Very close estimates of the transverse velocity component $v_\perp$ were found in Hipparcos and Tycho-2 for two of these stars, HIP 14838 ($v_\perp = -2.99$ km s^{-1} with HIP, -2.64 km s^{-1} with Tyc) and HIP 21788 ($v_\perp = +3.82$ km s^{-1} with HIP, $+4.13$ km s^{-1} with Tyc). The HIP 14838 is suspected to be double in the Hipparcos Catalogue. Since the proper motion measurements in Hipparcos and Tycho-2 both deviate from the expected convergent point direction, but agree between each other quite well, we suspect that the star has an undetected companion, which is a few magnitudes fainter, at a considerable separation (1 to 2 arcsec), so that the orbital period is a few hundred years for this system. Other stars with significant and highly correlated transverse velocities $v_\perp$ are HIP 16548, 19386 and 22271. A possibility that these stars are real escapers can not be precluded, however, since some of them are farther than 15 pc from the cluster's centre. The star 19386, at 43.8 pc from the cluster's centre, is by far the most distant in the sample.

We want to establish now that the increased outlier rate in Δ/σ_Δ with the Hipparcos proper motions is not due to underestimated formal errors in this catalogue. The deviation of the observed proper motion vector from the convergent point direction for each star can be expressed in terms of the transverse velocity component $v_\perp$, cf. Eq. (6). Stars with perfectly parallel space motions would have zero transverse velocities. We calculate now the number of absolute deviants in $|v_\perp|$, which is virtually independent of the formal errors. The presence of highly disturbed Hipparcos proper motions is evident: among the 178 Hipparcos stars, 25 have $|v_\perp|$ above 1.2 km s^{-1} when proper motions from Hipparcos are used for computation, and only 11 with Tycho-2. We found 17 stars above the limit of 1.5 km s^{-1} with Hipparcos data, and only 6 with Tycho-2. Some examples of stars which improved their convergence by more than 0.5 km s^{-1}, in terms of the transverse velocity, from Hipparcos to Tycho-2, are HIP 20086, 20215, 20255, 20553, 20719, 20885, 21280, 21588, 22221, 22265, 22607. The star HIP 20255, for example, has an estimated $v_\perp = 2.5$ km s^{-1} in Hipparcos, and only 1.2 km s^{-1} in Tycho-2, and it is a spectroscopic binary.

We return now to the 162 members with Hipparcos proper motions within the 3.5σ interval. The histograms, based on the Hipparcos proper motions, yield very similar standard deviations of 0.47 km s^{-1} in $v_\perp$ and 1.18 in Δ/σ_Δ as with Tycho-2. A subset of 42 star with most precise astrometry is again consistent with a velocity dispersion of 0.32 km s^{-1}. Importantly, an extra scatter is detected again for the less precise subsets, at the level of about 30 percent. Thus, both with Hipparcos and Tycho-2 data, the most precise quarters strongly indicate a velocity dispersion of about 0.3 km s^{-1}, but the other subsets seem to exhibit significantly larger dispersions.

Our final analysis concerns the possibility to put a tighter bound on the internal velocity by removing known binaries in the sample and thus diminishing the hampering effect of orbital motion. A smaller subset is constructed, which is called a ‘precious set’ in the following, on the two principles:

– the star has $\epsilon_{v\perp}$ below 0.20 km s^{-1}, i.e. the star is in the first Tycho-2 precision quarter;
– the star is not a known spectroscopic binary, and not flagged with ‘X’ in the Hipparcos field H59 or ‘S’ in H61, according to the Table 2 in Perryman et al. (1998).

An ‘X’ in the field H59 indicates a highly disturbed solution, most likely due to the presence of an unresolved companion, or a significant orbital motion. An ‘S’ in the field H61 stands for a star suspected to be binary from the Hipparcos observations. Other Hipparcos flags indicative of possible duplicity, appear rarely in the sample. The resulting set of, to the best of our knowledge, single stars includes 30 objects, all in Hipparcos. In a similar way as before, the histograms of $v_\perp$ and Δ/σ_Δ are computed for the precious set.

The result is an impressive testimony to the quality of Tycho-2 proper motions. The observed standard deviation of $v_\perp$ is only 0.27 km s^{-1} over the precious set. This is consistent with a σ_v of 0.22 ± 0.02 km s^{-1}, where the error is roughly estimated by linear interpolation between the near percentiles. With Hipparcos data, the standard deviation of the transverse velocity is 0.32 km s^{-1}. Some of the stars in the precious set may still be astrometric binaries with perturbed motions.

3. Discussion and conclusions

We have shown that a direct, model-independent estimation of the internal velocity dispersion in the Hyades open cluster is possible with the most precise of Tycho-2 proper motions. Through the analysis of tangential velocity components normal to the convergent point direction for each star, the internal dispersion is estimated at about 0.3 km s^{-1} for the most precise 50 stars, and as small as 0.22 ± 0.02 km s^{-1} when only 34 stars not known to be spectroscopic or orbiting doubles are retained. Thus, the influence of orbital motions in binaries increases the observed velocity dispersion by 25 percent, in the most precise subsample.

A conundrum is, however, that the less precise subsets exhibit a larger scatter in the transverse velocities, than should be expected. This implies either too small formal errors in the catalogue, underestimating the true errors by up to 30 percent, or a yet stronger influence of astrometric binarity in these subsets. Although it is conceivable that some of the ground-based catalogues, used in the proper motion derivation, have underestimated astrometric errors at faint magnitudes, their relative weight was small in the calculations, compared with the Astrographic Catalogue positions, the new reduction of which (AC-2, Urban et al., in preparation) is believed to have very reliable formal errors. A factor of 1.3 seems therefore too much on the high side. We would be tempted to put the blame on the binarity effect, in view of the very similar results obtained with virtually independent Tycho-2 and Hipparcos proper motions. Moreover, Gunn et al. (1988) found a similar excess scatter in low-precision radial velocity subsets and concluded that “... the excess dispersion at the low-accuracy end is caused by something the stars are doing.” They consider binary motion with long orbital periods and low-mass companions as the most likely reason.

The most precise quarter of the Hyades sample contains mostly the brightest, and hence the most massive stars in the cluster. If the mass function of the unresolved companions in binaries is rather independent of the mass of the primary, we should expect, statistically, a relatively much lighter companion to a very massive star. The orbital motion of the massive component will then have a low amplitude, and its proper motion is virtually undisturbed. A small mass star, on the contrary, will often have a companion of comparable mass, and its orbital motion is much more significant. Direct observational evidence that massive stars have relatively lighter companions in physical binaries can be found in the recent Tycho photometric solution for 9473 components of close Hipparcos double and multiple stars (Fabricius & Makarov 2000). We selected 812 definite main sequence – main sequence pairs with angular separations 0.3 to 2.5 arcsec and precise parallaxes in the Hipparcos Catalogue. Absolute M_V magnitudes were computed from the observed B_T and V_T magnitudes and parallaxes and converted to masses by approximate relations given in Reid (1992). The diamonds in

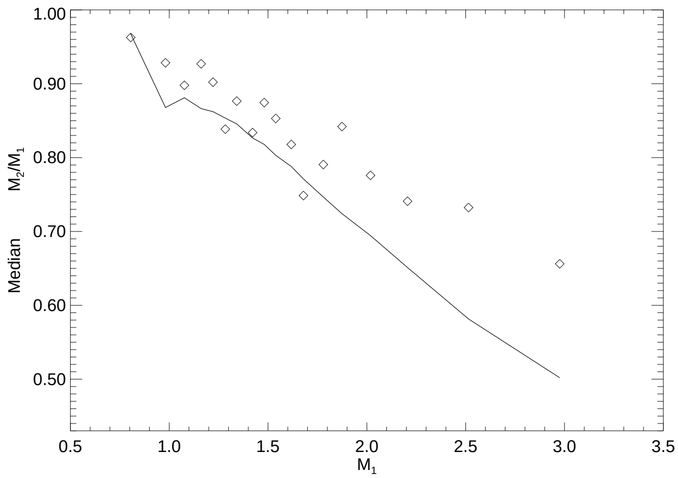

Fig. 2. Median component mass ratio against the primary component mass. The diamonds indicate the observed relation for a set of 812 close Hipparcos doubles with precise Tycho photometry, each symbol for a bin of 45 pairs. The full line is the expected relation, if the component masses are completely uncorrelated and the general mass function is given by the observed mass distribution for the primary components in the sample.

Fig. 2 show the relation found between the mass of the primary component, M_1, and the median ratio of the secondary component mass to the primary, M_2/M_1. The typical relative mass of the secondary component drops from almost 1 for subsolar mass stars to below 0.7 at $M_1 \approx 3$. The full line in Fig. 2 represents the expected relation for the given mass distribution function, computed under assumption of *completely uncorrelated* masses of the components. The discrepancy between the observed and predicted relations is likely due to the observational detection bias, that is the inability of the Hipparcos instrument to resolve a binary of a large magnitude difference. Hence, the observed relation is the upper bound for the effect in question.

The real influence of the binary component mass function on proper motions is a complex matter, which should be treated by rigorous simulations. What is actually observed for a binary in astrometric measurements, is the photocentre of the system, i.e. the weighted light of the components. Obviously, the photocentre effect has the counter tendency of diminishing the observed orbital motion for binary components of similar masses.

Finally, our data do not make us doubt the high quality of the Hipparcos proper motions. Rather, the much increased rate of kinematic outliers in Hipparcos with respect to Tycho-2 is clear evidence that the long-term Tycho-2 proper motions are less prone to the effects of stellar binarity.

Acknowledgements. The work of one of the authors (VVM) was supported by the Danish Space Board. Claus Fabricius and Erik Høg gave useful comments on the paper.

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