A Proper Motion Survey of the Hyades

The Hyades cluster has long served as one of the more important steps in defining the distance scale. It is also the nearest open cluster and, as such, can be used to probe both the dynamical evolution and the initial conditions during the formation of these systems. However, with the Hyades covering more than 100 square degrees of the sky, proper motions and good photometry are essential prerequisites to segregate the candidate Hyads from numerous background (and foreground) stars in the field — particularly at faint magnitudes. While there have been many previous surveys of the cluster — notably by van Altena (1969), Hanson (1975) and Luyten et al. (1981) — only the last covers the full area of the cluster, and none provide photometry of even moderate accuracy fainter than B ~ 15. We have just completed a proper motion survey covering ~ 115 square degrees and extending to $V \sim 19.5$, allowing us both to determine the luminosity function to $M_v \sim +16$ and the extent of mass segregation within the cluster.

Our survey is based on COSMOS scans of POSS I O/E plate pairs matched against UKST B and V plates (2 in each passband) in four fields ($\alpha = 4^h\,5^m, 4^h\,30^m$, $\delta = +12^\circ, +18^\circ$). Our photometry is calibrated using CCD data obtained with a TI CCD on the Palomar 60-inch telescope, and is good to ~ ±0.1 mag. for $V < 17.5$, with the uncertainties rising to ~ ±0.2 magnitudes at V = 19.5. The plate material give baselines of 33 – 35 years, and proper motions have been computed following the same methods outlined in the NGP study described in Reid (1990). Again, we have tied the system to an absolute frame using our measurements of galaxies (identified using standard star/galaxy separation techniques). As to the accuracy of our data, both internal (i.e. V vs. E against B vs. O pairs) and external (vs. Hanson, Luyten et al.) comparisons indicate accuracies of better than 7 $masyr^{-1}$ to V = 17, rising to ~ 15$masyr^{-1}$ for the fainter stars.

Figure 1 shows the proper motion diagram we derived for stars in the magnitude range $13 < V < 17$ (i.e. $8.5 < M_v < 12.5$), where we have both transformed to a co-ordinate system aligned with

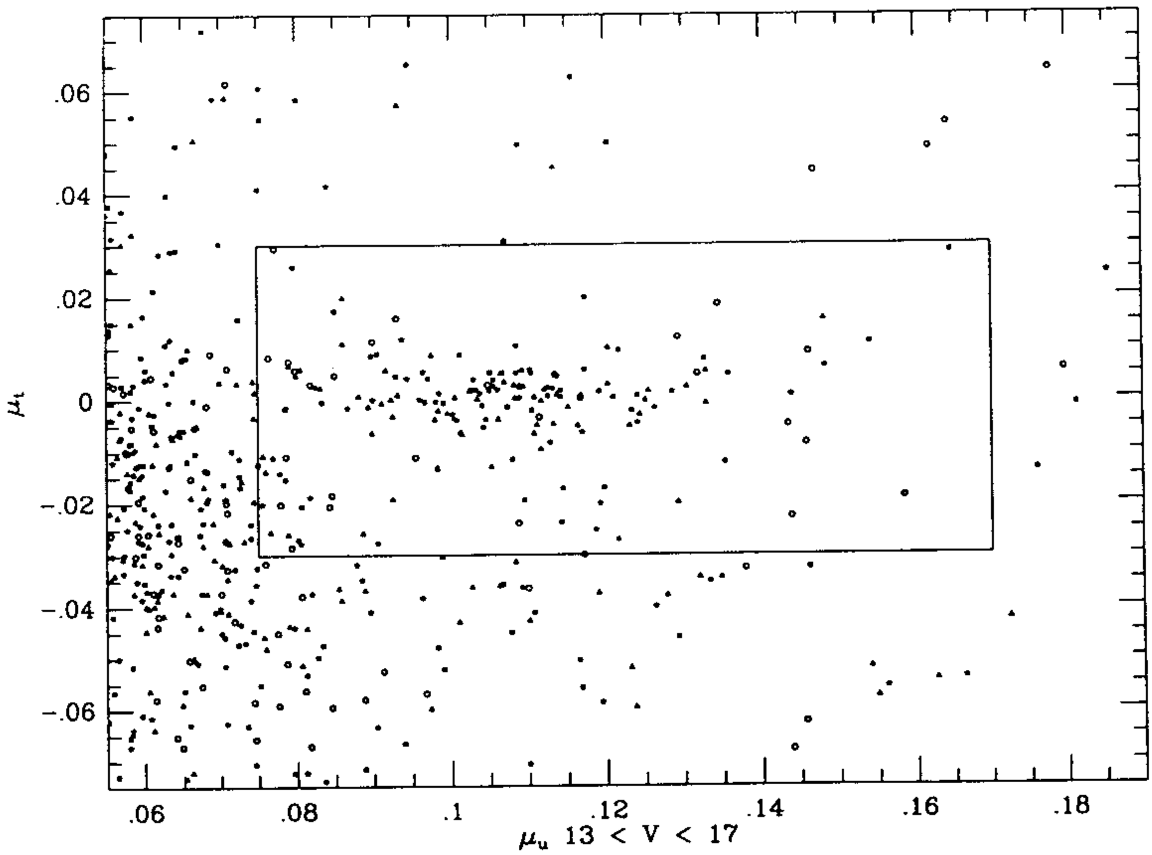

Figure 1.

the direction toward the convergent point and corrected the motions to the cluster centre. (The four symbols refer to the four fields surveyed.) The Hyades cluster stars form an obvious sequence in this diagram. (Note that the reflex solar motion vector intersects the bottom left section of this diagram., and this is reflected in the increased number of stars in this area.) Since we know the radial velocity at the cluster centre, and the recent studies by Gunn et al. (1987 — GGGZ) and Schwan (1991) provide an accurate estimate of the position of the convergent point, we can use the relation

$$r=\frac{V_s \sin\lambda_c}{k\mu_s^c} \tag{1}$$

where V_s is the space motion, λ_c the distance from the convergent point and μ^c_s the mean motion, to derive an estimate of the distance. Our mean motion of 0".111 ± 0".005yr^{-1} leads to a distance of 48.5 ± 0.4 parsecs (we quote the formal uncertainty in the mean). This is in excellent agreement with the recent estimate of 47.9 ± 0.8 parsecs derived by Schwan from the FK5 proper motion measurements of the brightest Hyades stars. This agreement implies that our absolute proper motions are at least in good agreement with the FK5 system.

As to the cluster luminosity function, Fig. 2 shows our results based on two criteria — first, including all stars within the box outlined in Fig. 1 (the upper histogram in Fig. 2); and second, a 'pruned' sample, limited to

$$0''.075 \le \mu_s \le 0''.17$$

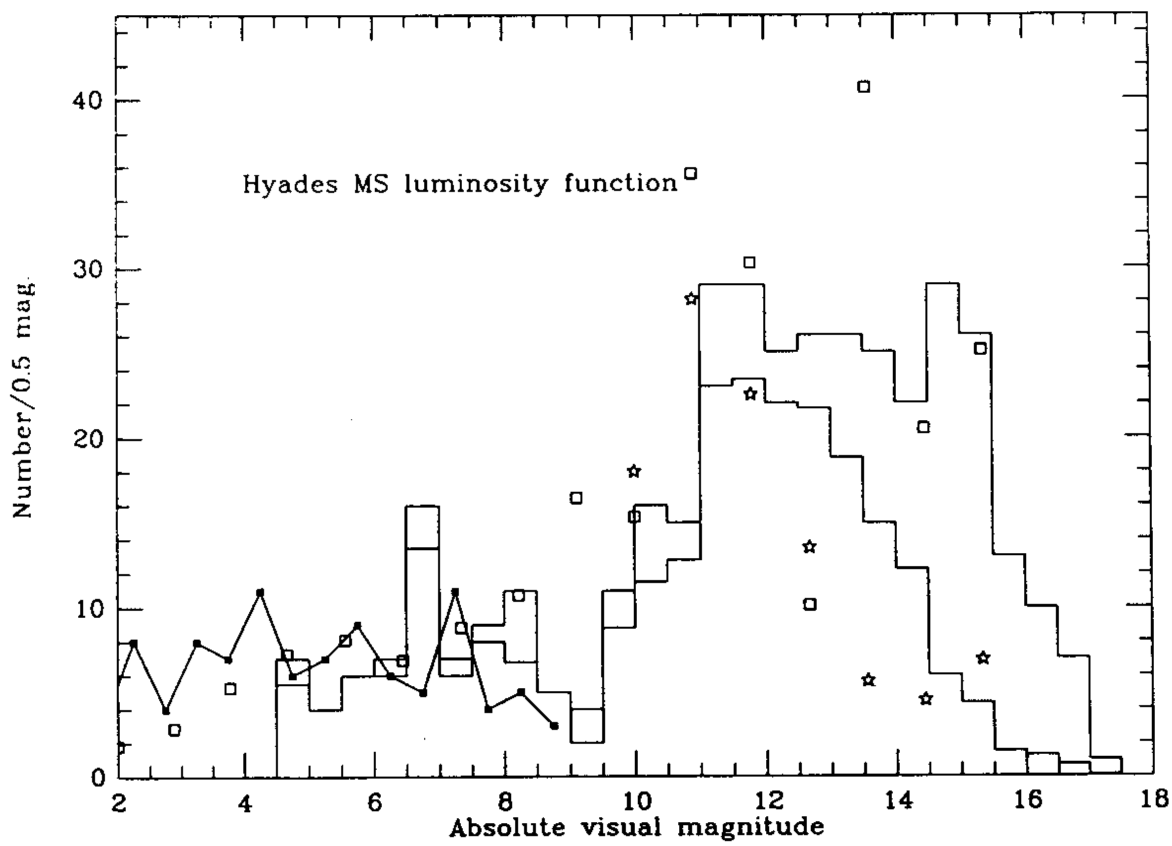

Figure 2.

and

$$|\mu_t| \le 0''020, \;\; V < 11.5$$
$$|\mu_t| \le 0''015, \;\; 11.5 \le V < 15$$
$$|\mu_t| \le 0''020, \;\; 15 \le V < 18$$
$$|\mu_t| \le 0''025, \;\; 18 \le V$$

Moreover, we have applied weights of

50% for $0''.075 \le \mu_u < 0''.080$, $V < 18$

90% for $0''.080 \le \mu_u < 0''.085$, $V < 18$

25% for all stars $18 < V < 19$

and 10% for all stars $19 < V$.

The results are plotted as the lower histogram in Fig. 2.

All other stars in the sample have unit weight. The lower weights at lower μ_u take into account the increased inclusion of nearby disk stars (distributed along the reflex solar motion vector), while at fainter magnitudes there are numerous stars at all (μ_u, μ_t). We (Reid and Mateo [OCIW]) are currently obtaining VRI CCD photometry of all stars with $V > 14$ in the pruned sample, and our preliminary results (for 95 of 221 stars) tend to confirm the low probabilities associated with the fainter stars. Hence our results suggest that the Hyades have a luminosity function broadly consistent with that of the field (the stars plotted in Fig. 2), peaking at $M_v \sim +12$ and with few low luminosity stars. Leggett and Hawkins (1988) derived similar results from their RIJHK photometry of Luyten proper motion stars in a single Schmidt field.

Clearly Hyades members are spread over a substantial range of μ_u in Fig. 1 and, since the velocity dispersion is only 0.25 kms^{-1}, equation (1) shows that a considerable spread in distance is the only factor that can produce this result. Indeed, there are stars known to be Hyads at distances of

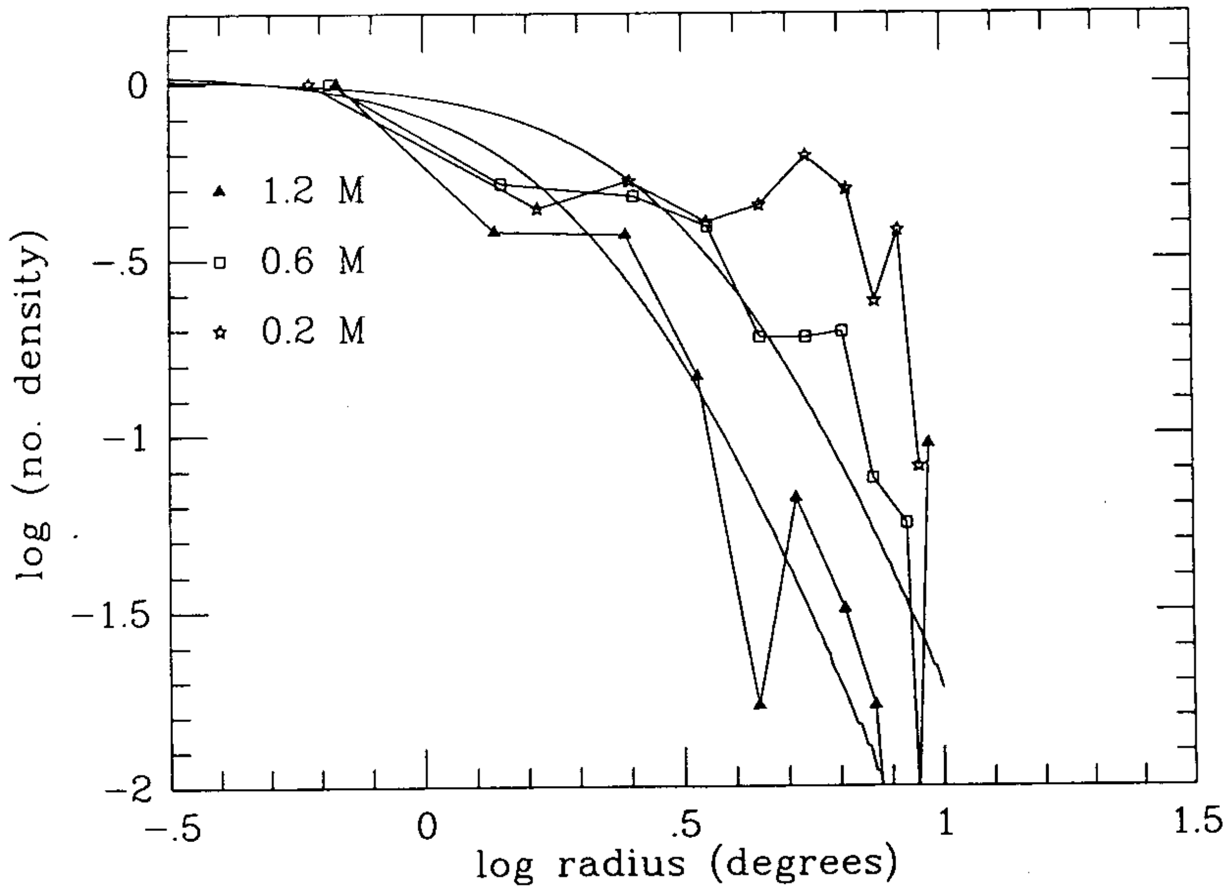

Figure 3.

from 33 to 65 parsecs — as compared with a binding radius of ~10.5 parsecs for a mass of ~$450M_\odot$. Moreover, our results show strong evidence for mass segregation — in contrast to the findings of GGGZ. Figure 3 plots the radial distributions for three mass intervals. Clearly the lower mass stars have a significantly more extended distribution than the brightest stars, and while this may reflect field star contamination for the $0.2M_\odot$ grouping, it emphatically does not for the intermediate-mass range. Following GGGZ, we have plotted the best-fit Plummer laws

$$\Sigma(r)=N\times(1+\frac{r^2}{A^2})^{-2}$$

where A, the core-radius, is 3°.98 (from GGGZ) for the intermediate-mass stars, but 2°.5 for the $1.2M_\odot$ group — that is, the more massive stars have a more compact distribution, as one expects from mass segregation. Clearly this has a bearing on whether more distant clusters — which are often only surveyed in the immediate vicinity of the brightest members — really have a deficit of low-mass stars.

Apart from obtaining VRI photometry — both of this sample and of fainter Luyten stars in the same fields — we (Reid, Mateo and Hawley [Lawrence Livermore]) are currently using the 200-inch Hale telescope to study the range in chromospheric activity amongst the lower luminosity Hyads. We are also working on a similar analysis of the more distant Pleiades cluster using POSS I and POSS II plates.

References

van Altena, W.F., 1969, *Astr.J.*, 74, 2.

Gunn, J.E., Griffin, R.F., Griffin, R.E.M., and Zimmerman, B.A., 1988, *Astr.J.*, **96**, 198 (GGGZ).

Hanson, R.B., 1975, *Astr.J.*, **80**, 379.

Leggett, S.K. and Hawkins, M.R.S., 1988, *Mon. Not. R. astr. Soc.*, **234**, 1065.

Luyten, W.J., Hill, G. and Morris, S., 1981, *Proper Motion Survey with the 48-inch Schmidt Telescope, LIX*, Minnesota Univ., Minneapolis, Minnesota.

Reid, I.N., 1990, *Mon. Not. R. astr. Soc.*, **247**, 70.

Schwan, H., 1991, *Astr. Astrophys.*, in press.

Neill Reid
Palomar Observatory
Pasadena
CA 91125
U.S.A.