VARIATIONS IN EXTERNAL PARALLAX ERRORS

A. R. Upgren
Van Vleck Observatory
Wesleyan University
Middletown, Connecticut

The present astrometric program of the Van Vleck Observatory began in 1967. Since then it has emphasized parallaxes and proper motions of stars of the lower main sequence which are not identified on the basis of proper motion and are therefore not biased towards high space velocity. Later an analysis was made from parallax and proper motion data from 70 stars in the spectral range dK3-M2 (Upgren 1973) which found the average external mean error in parallax to be 8.0 ± 1.7 mas (milliarcseconds). This external error was found to vary little from one parallax to another and to have no correlation with the formal internal errors for the individual parallax determinations. Hanson and Lutz (1983) confirm this result using the parallaxes of 14 members of the Hyades cluster also determined at Van Vleck. They find a mean external parallax error of 9.4 ± 1.8 mas and suggest that the proximity of the two determinations may be evidence that Van Vleck parallaxes may be characterized by a single external error. Their slightly larger figure may or may not reflect the relatively fewer plates and epochs of observation from which the Hyades parallaxes were determined.

At the present time, parallaxes and photometry of 210 stars in the same spectral range have been published in the course of this program (Weis et al. 1983 and references) and are available for a more extended analysis. This paper reports an attempt to determine the degree to which the external parallax errors are dependent upon the properties of the observations and measures. Specifically, the variation of the external error with the number of photographic plates, the number of comparison stars in the reference frame, and the size of the unit-weight error will be considered in the present report.

The program stars are almost all brighter than V = 11 and represent about one fifth of all similar dwarfs in the entire sky brighter than this magnitude. The distribution in magnitude of the stars is shown in Table 1 along with the distribution in the average magnitudes of the comparison stars. The group is not significantly limited in magnitude at the bright end, since the brightest main

H. K. Eichhorn and R. J. Leacock (eds.), Astrometric Techniques, 247–251.

sequence star in the entire sky within this spectral region is of the fifth magnitude and only about 15 are brighter than the seventh magnitude. At the faint end this sample is clearly magnitude limited, as Table 1 illustrates. It can also be seen that magnitude reduction is common for stars brighter than the tenth magnitude but is much less frequent for the fainter stars.

TABLE 1 - MAGNITUDE DISTRIBUTION

V Magnitude	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5
Central star	3	12	16	51	44	37	29	10	8
Ave. of ref. stars	0	0	1	8	21	37	65	51	27

The method used in deriving the external errors is described in the earlier study mentioned above. It is based upon the positions of the stars in the M(v),R-I color-magnitude diagram. This diagram is shown in Figure 1 for the program stars. The main sequence which they define can be represented by the linear relation given by $M(v) = 4.52 + 5.67(R - I)$ for the Hyades. This is almost identical to the relation for the field stars (Upgren 1978) after the volume correction derived by Lutz and Kelker (1973) is applied to them. The linearity of the main sequence in this region is well known and is at least partly a result of the fact that the R-I color index is almost solely a measure of surface temperature. This is also the portion of the main sequence least affected or contaminated by pre- or post-main sequence evolutionary effects.

The external errors in parallax account for most of the scatter of the points in Figure 1. The dispersion due to intrinsic differences among the stars is very close to ± 0.4 mag. (Upgren 1973, Veeder 1974) and the balance is assumed to be due to the observational process. The increase in dispersion in absolute magnitude with decreasing M or R-I is due to the high degree of correlation between either variable and mean distance for this apparent magnitude limited sample. The mean parallax varies from about 35 mas at R-I = 0.35 or M = 6.5 to about 125 mas at R-I = 1.05 or M = 10.5, the approximate upper and lower limits in color and mean absolute magnitude of the stars shown in Figure 1.

With few exceptions, the numbers of plates included in the parallax measures and reductions varies from 20 to 45 with the median at 31. The dispersion of the stars with fewer plates than this figure is only about 5% greater than that of stars with longer series, well within the uncertainty of the determination. A negligible variation is also found as a function of numbers of reference stars measured. These numbers vary from 5 to 20 with the median at 9. The variation in m.e.1(x), the unit-weight mean error in the x or right ascension

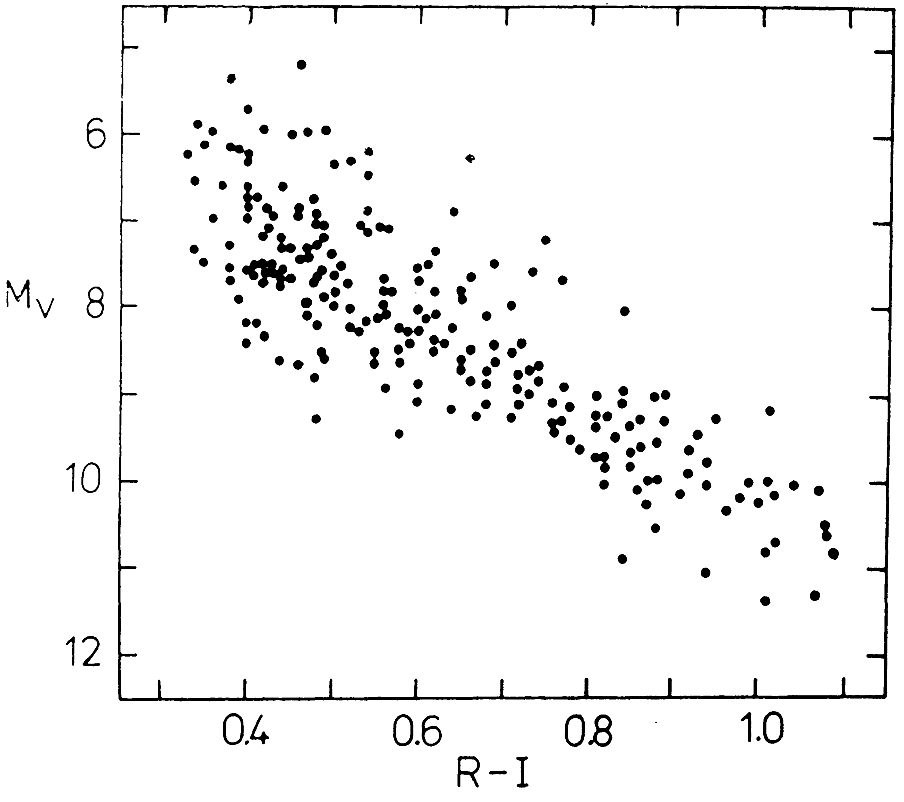

Fig. 1. Color-magnitude diagram for 210 dK3-M2 stars with Van Vleck parallaxes.

coordinate, range with few exceptions from 28 mas to 58 mas with the median at 46 mas. The variation in external parallax error with this variable is marginally significant; the errors for solutions with unit-weight mean error of 40 mas and smaller, is 10% less than those for solutions with unit-weight error larger than 50 mas.

These results are provisional and several points must be mentioned in their interpretation. The number of plates in a parallax solution is slightly inversely correlated with their average quality. This is not surprising since observations found to be of relatively low quality are frequently repeated immediately. A more significant variable may be the number of evening and morning epochs at which observations are made. However, in this sample, the number and spacing of epochs has not been permitted to vary significantly but is nearly equal for all stars (almost all of the series include five or six evening epochs and the same number of morning epochs). The absence of variation of error with number of reference stars is perhaps more

https://doi.org/10.1017/S0074180900076658 Published online by Cambridge University Press

surprising. However, a positive correlation is present between this richness of the reference frame and its (linear or angular) size. The effects of coma and vignetting are relatively small for the Van Vleck refractor but are not negligible, and either may act to diminish the precision gained from more extensive reference frames which are more likely to be spread over larger areas on the plates. The parallaxes from which these results were made, employed linear plate constants in the solutions. It is possible that higher-order plate constants may need to be used in order to maximize the potentially superior precision of the richer reference frames.

A more complete analysis and the details of the individual parallax solutions are too extensive to be included here and will appear in another place. However, two conclusions can be made at this time. First, the variations between the errors in Van Vleck parallaxes are very small over the ranges of all of the independent variables studied except, marginally, the size of the mean error of unit weight. This supports the suggestion mentioned above that Van Vleck parallaxes can be realistically assigned a single external error with some confidence. Second, the correlation of the external error with unit-weight error suggests that even a slight reduction of the latter is worth every effort to achieve. The size of the average unit-weight mean error of 46 mas (or 1.9 microns at a plate scale of 24.5 arcsec/mm) is partly due to the lack of repeatability in the hand measures made on the Mann measuring machine of Van Vleck. Measures made on automatic machines with negligibly small measuring error are expected to reduce the total variance by about one-third (Upgren 1977). Thus, we can expect automatic measures to reduce the mean error of unit weight, and consequently the external parallax error as well by a small but significant amount. Efforts in this direction are presently under way.

This research was supported by grant no. AST-8121463 from the National Science Foundation.

REFERENCES

Hanson, R.B. and Lutz, T.E. 1983, Mon. Not. Royal Ast. Soc. 202, 201.
Lutz, T.E. and Kelker, D.H. 1973, Publ. Ast. Soc. Pacific 85, 573.
Upgren, A.R. 1973, Astron. J. 78, 79.
Upgren, A.R. 1977, Vistas in Astronomy 21, 241.
Upgren, A.R. 1978, I.A.U. Symp. No. 80, "The HR Diagram", A.G. Davis Philip and D.S. Hayes, eds., D. Reidel, Dordrecht, p. 39.
Veeder, G. 1974, Astron. J. 79, 1056.
Weis, E.W., Nations, H.L. and Upgren, A.R. 1983, Astron. J. 88, 1515.

Discussion:

HEMENWAY: Where do you suspect the other two-thirds of the errors are coming from, instrumentation and atmospheric effects?
UPGREN: Instrumental, atmospheric, motion problems, the usual combination.
van ALTENA: You find that a larger number of reference stars yields somewhat poorer accuracy. If you have reference frames with larger numbers of reference stars cover a larger area, then perhaps that indicates that the plate models are not adequate.
UPGREN: I have been looking for this for some time, but I haven't enough stars to make a judgment. I am pursuing the matter, though.
EICHHORN: With regard to van Altena's remark I suspect that the increase of the formal standard error is purely mathematical. The fewer stars have to be fit to a particular model, the more will the real measuring residuals be represented by the residuals and not be absorbed by certain changes in the adjustment parameters.
UPGREN: This is also possible.