CAN A SYSTEM BE DEFINED FOR THE NEW EDITION OF THE YALE PARALLAX CATALOGUE?

William van Altena
Yale University Observatory
P.O. Box 6666
New Haven, CT 06511

Abstract

A preliminary analysis has been made of data in the forthcoming edition of the Yale Parallax Catalogue to study the possibility of defining a system of observatory zero-points and external accuracies. Based on this analysis and those of several other authors, I conclude that it is not likely that a unique system of zero-points can be established. It may, however, be possible to establish some values for the average external accuracy of the parallaxes, but more work remains to be done on both of these issues. These conclusions are in agreement with those reached by several other authors.

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1. INTRODUCTION

More than twenty years have passed since the previous edition of the Parallax Catalogue was published by Jenkins (1963). During that time the accuracy of trigonometric parallaxes has changed dramatically due to improvements in the methods of observation, measurement and reduction. Because of the resulting heterogeneous nature of a composite catalogue, it is necessary to provide not only "best" values for the average parallaxes, but also auxiliary data and references for the critical user. In this review I will describe some of the problems encountered in trying to establish a system for the catalogue and discuss the extent to which such a system can be defined.

2. ON THE LACK OF STANDARD STARS

The principal source of the problem encountered in constructing a system for the catalogue is that standard stars do not exist. It is a well accepted fact that the observation of standard stars is a necessary part of determining the magnitudes, colors, spectral types and radial velocities of stars. On the other hand, in spite of similar recommendations for parallax observers by Schlesinger (1925), Strand (1963), Atkinson (1971) and Lutz (1978) there still exist no systematic observations of parallax standards. Following Lutz's (1978) plea for such observations, a working group on parallax standard stars was set up by IAU commission 24 under the chairmanship of A. R. Upgren. That working group has circulated a list of standard stars suitable for all telescopes and it is now up to the observers to rectify this problem for the future.

Given that we have no standard stars to work with, we must use a variety of methods to compare the individual parallaxes, keeping in mind the limitations of each approach. For example, when analyzing the difference in parallax for stars observed at two observatories, a knowledge of why those stars were observed is instructive. Lutz et al (1981) illustrate the frequency distribution of parallaxes versus magnitude and declination for several observatories in their Fig. 1. One of the major systematic differences in the Jenkins (1952) catalogue is between Allegheny and Yale. Yet, as is apparent from the figure, those stars common to both programs lie in a small equatorial zone and bear no similarity to the declination distribution of the majority of stars observed at either observatory. Why then, should systematic corrections derived from the declination biased sample be applicable to the body of parallaxes derived at either observatory?

Another example given by Lutz et al (1981) is the case of Yale and Cape, where most Yale stars are bright while the Cape stars are primarily faint. The faint Cape stars picked out by Yale to observe may have been a biased sample, for example, those stars with the largest parallaxes and therefore of some intrinsic interest. The sample would then consist of stars whose measured Cape parallaxes were on average too large, thus vitiating any comparisons between the parallaxes. Other examples or hypotheses can be constructed to illustrate the pitfalls of using parallax differences, but the above cases should make us seriously question the results of such analyses. More detailed discussions of the drawbacks of using the observatory corrections have been given by Schilt (1954), Strand (1963), Vasilevskis (1966) and Hanson and Lutz (1983).

3. METHODS OF ANALYSIS

3.1. Parallax Differences

In spite of these problems, the parallax differences have been analyzed and both weighted and unweighted systematic differences and errors derived as follows. Let the parallax difference for a given star observed at observatories A and B be represented by

$$\Delta_{ab} = \pi_a - \pi_b, \tag{1}$$

and the weight of that difference by

$$W_{ab} = \varepsilon_a^{-2} + \varepsilon_b^{-2}, \tag{2}$$

where the εs are the published standard errors of the parallaxes. Using the method of probability plots described by Lutz (1978), and the Hamaker (1978) algorithm to invert the cumulative probability distribution, the weighted mean differences and dispersions were obtained for the major parallax observatory pairs. The zero-point, Z, or the negative of the "systematic error" in an observatory's parallaxes, is then found from the set of equations:

$$\langle\Delta_{ab}\rangle = Z_a - Z_b \tag{3}$$

and the dispersion, σ, from

$$\sigma_{ab}^2 = \sigma_a^2 + \sigma_b^2, \tag{4}$$

where the average difference, $\langle\Delta_{ab}\rangle$, and its dispersion, σ_{ab}, are found from the probability plots. Since the normal equation matrix derived from the set of Eqn (3) is singular, it is necessary to enforce a constraint, which in this case is arbitrarily taken as $Z_a = 0.0$. Both weighted and unweighted solutions have been made, but the differences between the solutions are not significant.

An inspection of Fig. 1 in Lutz et al (1981) shows that the distribution of parallax differences consists of subsets with different dispersions. Since the same is true of many of the probability plots used in this analysis, the results represent only average values. A more detailed analysis will be attempted in the future.

3.2. Comparison with "Known" Parallaxes

A variation of the analysis of parallax differences is to consider the case in which one of the parallaxes is known with arbitrarily high accuracy. Examples of this case are encountered when we compare measured parallaxes of stars in clusters with kinematically determined distances, or stars with accurate spectroscopic or photometric parallaxes. Unfortunately, there are relatively few stars in the nearby clusters with measured parallaxes. Hanson and Lutz (1983) have analyzed the Allegheny parallaxes for stars belonging to the Hyades, Ursa Major and Coma Berenices clusters.

Since the error in a spectroscopic or photometric parallax is generally a constant in terms of the distance modulus, the derived parallax error is very small when small parallaxes are considered. This method has the advantage that there are many stars with otherwise useless small parallaxes that can be used to study the distribution of errors in parallaxes. However, in the end, it is still only safe to use those results for stars of the same spectral type distribution. Numerous investigators have used these methods including Turon Lacarrieu and Crézé (1977), West (1969), Norgaard-Nielsen (1977) and Breakiron and Upgren (1978).

3.3. The Distribution of Parallaxes

Hertzsprung (1952) first pointed out that the distribution of negative parallaxes in the Jenkins (1952) catalogue was nearly normal, with a characteristic dispersion of ±0".016 (s.e.). This feature is easily understood as being primarily due to the sharp increase in the number of stars with decreasing true parallax for a uniform distribution of stars. These stars are then scattered into the negative parallax area by observational errors. Upgren and Carpenter (1977) repeated this test and several of the observatories have also been analyzed here using the Hertzsprung method. The principal drawback to the method, is that it relies on the measured stars being a random selection of stars in space, and this is usually not the case. For example, a selection based on proper motion will significantly alter the results. Another drawback is that there is little guarantee that the accuracy of small parallaxes bears any relation to that for large parallaxes.

A significant improvement on the Hertzsprung method was developed by Hanson (1980), where the full distribution of parallaxes is modelled instead of only the negative tail. In this case, one assumes that the observed stars are a random sample of stars drawn from a true parallax distribution that is proportional to π^{-n} and within some minimum true parallax. The minimum parallax is related to the relative number of stars with large and small parallaxes by Hanson's (1980) Eqn. 5, so one is left with two parameters to determine, the average dispersion and the power law index, n. The disadvantages to Hanson's approach are that once again the parameters refer to the average population and many stars are required to accurately define the distribution.

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4. PRELIMINARY RESULTS FROM THE METHOD OF PARALLAX DIFFERENCES

The results of this preliminary analysis are summarized in Figures 1 and 2, where the zero-points and the dispersions are plotted against the magnitude for a selection of stars from the new Yale Parallax Catalogue. In Fig. 1 the zero-points are all relative to the Allegheny Observatory, which has been arbitrarily set to zero. Since this preliminary analysis was done before magnitudes were available for those stars added to the YPC following the Jenkins (1963) Supplement, the new parallax observatories are not included in this discussion. In addition, several observatories with smaller numbers of parallaxes were also not included. All will be included in the analysis to be published with the new YPC. In each figure the run of the zero-point and dispersion is identified by the observatory code used by Jenkins (1952). The most noteworthy characteristics of Fig. 1 are the rather large scatter, and as Hanson (1978) has already pointed out, there appears to be an Allegheny magnitude equation for the brighter stars. Based on this preliminary analysis, it appears that the Allegheny magnitude equation may be somewhat smaller than that proposed by Lutz et al (1981).

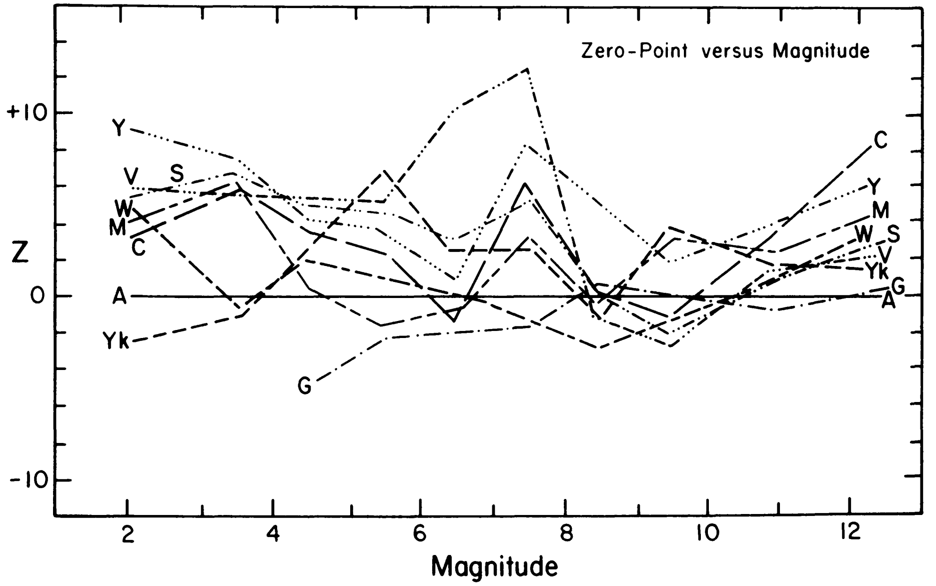

Fig. 1: The zero-point in milli-arc-seconds for each observatory's parallaxes as a function of the magnitude, with Allegheny taken as the arbitrary zero-point for all parallaxes. Each observatory is identified by the code used in Jenkins (1952). The deviation of most observatories from Allegheny for the bright stars indicates that there may be a magnitude dependent error in the Allegheny parallaxes as was first pointed out by Hanson (1978).

The plot of the external parallax error versus magnitude is shown in Fig. 2. In general, most observatories seem to be consistent in their average accuracy, except for Mt. Wilson. In the latter case the 60-inch and 100-inch telescope parallaxes have been analyzed together, so no far reaching conclusions ought to be drawn from this preliminary analysis.

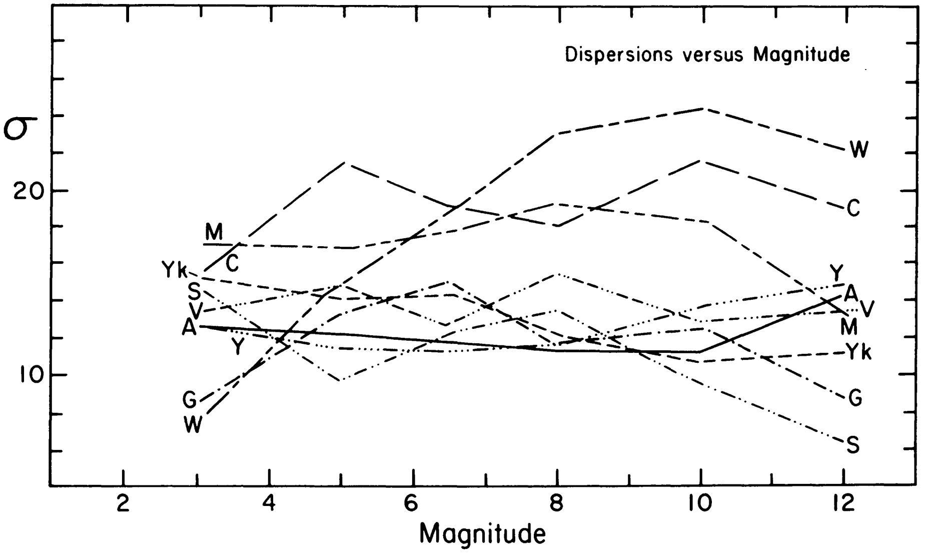

Fig. 2: The parallax dispersions in milli-arc-seconds for each observatory as a function of magnitude. The identifications for each observatory are those used by Jenkins (1952). Most observatories are seen to be fairly consistent in the accuracy of their parallax determinations as a function of magnitude. Mt. Wilson (W) may be an exception to this, however the data plotted are derived from a combination of the 60-inch and 100-inch parallaxes which may vitiate the trend shown.

5. CONCLUSIONS

The one inescapable conclusion of this analysis and the results of the other referenced work is that the new Yale Parallax Catalogue will be a heterogeneous collection of parallaxes. The YPC will provide weighted average parallaxes, but the critical user will probably still wish to use the references given to the source of publication for each parallax to evaluate the merits of the average weighting scheme as applied to the star in question.

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Discussion:

GLIESE: I am happy to hear that we may expect your catalogue this year. Could one give precepts as to how to incorporate future observations into your system?

van ALTENA: I'll try. I believe on the average we will define a fairly good system. The main problem is the determination of the correct weights.

UPGREN: Could the large deviations between observatories for apparent magnitudes between 5^m and 8^m be explained by a relative scarcity of stars? The program of Schlesinger emphasized stars brighter than 5^m whereas recent programs emphasize stars below 8^m. Since these all have measurable parallaxes - could the gap between be due to a shortage of good data?

van ALTENA: There is an adequate number of stars; there are well-defined substantial differences between the observatories, even though there is a lot of scatter.

STRAND: I believe the reason for the agreement between Allegheny and cluster parallaxes is that the Allegheny parallaxes were instrumental either directly or indirectly in determining the cluster parallaxes.

van ALTENA: No. These are kinematic distances determined from proper motions alone. The convergent point method is used for the Hyades and for the UMa cluster, and I believe also for the Coma Cluster. These are therefore not dependent on trigonometric parallaxes.