Ground-based parallaxes for nearby stars

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Abstract

Trigonometric parallax measurements constitute the basic data for nearby stars. The distance limits of the various catalogs of nearby stars published in the past were chosen in such a way that the trigonometric parallaxes could provide significant values. Whilst in the first half of our century mostly bright stars were selected for observing programmes, during recent decades trigonometric parallax work concentrated more and more on presumably nearby candidates as originating, for example, from proper motion surveys or spectroscopic surveys. Simultaneously, the accuracy of the measurements could be considerably improved. So, that at present a large amount of high precision parallax data for nearby white and red dwarf stars is available.

Nevertheless, the output of ground-based trigonometric parallaxes cannot compete with the output of other data. Photometric parallaxes become of growing importance. Their determination is by far less time consuming, and in the present edition of the *Catalogue of Nearby Stars* (CNS3) almost 50 per cent of the distances were based on photometric measurements.

HIPPARCOS parallaxes will become available very soon. Nevertheless, there will be still a need for ground-based trigonometric parallaxes - at least for fainter stars and for the next decades.

1 Introduction

Having a look in the astronomical literature for publications on nearby stars, one can recognize that the term *nearby* may be applied by different authors with quite different meanings. In our days *nearby* may even be applied for stars out to several hundred parsec. Already in the early 1920 three papers on nearby stars were published with quite different distance limits: E. Hertzsprung (1922) with $r_{lim} = 5$ pc, W. Luyten (1923) with $r_{lim} = 10$ pc, and J. Haas (1923) with $r_{lim} = 15$ pc. Later on it was after all Peter van de Kamp (1953) who updated very regularly the list of stars within 5 parsec.

Then, in early 1950 Wilhelm Gliese, stimulated by van de Kamp, started his work on nearby stars. In view of the fact that the average parallax error of the just published *General Catalog of Trigonometric Stellar Parallaxes* (Jenkins, 1952) was estimated by E. Hertzsprung (1952) to $\pm 0\farcs016$, he came to the conclusion that a distance of 20 pc would still be appropriate to get fairly significant parallaxes.

The first catalogue CNS1 (Gliese, 1957) contained 915 systems with altogether 1094 components within 20 pc. Table 1 lists also the content of several following compilations of nearby stars until the most recent CNS3 (preliminary version). The increasing number of objects reflects the large progress achieved since 1957. Within 20 pc the number of known stars was practically doubled during the past 35 years. Table 1 also shows that this increase of newly detected nearby stars is even steeper for the

Table 1: Number of objects in different catalogues of nearby stars

reference	$\pi \geq 0\farcs050$	$\pi \geq 0\farcs045$	$\pi \geq 0\farcs040$
Gliese (1957)	1094		
Gliese (1969)	1277	1585	
Woolley et al. (1970)			2150
Gliese & Jahreiß (1979)	1476	1848	
Gliese & Jahreiß (1991)	2031	2570	3120

Table 2: Average error of trigonometric parallaxes in mas

source	N	$\pi_{91} - \pi_{old}$	$\Delta\pi_{old}$	$\Delta\pi_{91}$
CNS1 (1957)	816	+3.0	11.5	6.3
CNS2 (1969)	1325	–0.3	8.7	7.3
GJ-stars (1979)	180	–0.4	4.3	3.9
new (r $<$ 25 pc)	264			5.2

last decade. Nevertheless, we still know only 50 per cent of the stars predicted by a commonly accepted stellar luminosity function for the solar neighbourhood.

The second edition CNS2 (Gliese, 1969) was extended to 22 pc, and the recently released preliminary version of the CNS3 (Gliese and Jahreiß, 1991) intends to list all known stars within 25 pc. It contains 3264 systems with altogether 3803 components. Yet, we estimate that only 3120 of these stars may really be nearer than the catalogue limit. Some properties of the CNS3 were already described in Jahreiß and Gliese (1993).

2 Trigonometric Parallaxes

The basic distance parameter is the trigonometric parallax. Most of the 806 CNS1 parallaxes came from the GCTSP (Jenkins, 1952) containing 8 853 trigonometric parallax measurements for 5 822 stars. But due to Schlesinger's programme, that covered all stars brighter than 5.5 mag, except stars of spectral class earlier than A and late-type giants, the GCTSP contains too many stars with too small parallaxes: $\pi_{med} = +0.''018$ by an average error of $\pm0.''016$. All parallaxes were transformed to the system of the Allegheny Observatory. A procedure which was later on critized by several authors (see Strand, 1963) since it seemed to be not justified and required negative systematic corrections for practically all other parallaxes series.

With respect to these findings the observatory corrections were removed in the second edition CNS2 (Gliese, 1969), and the new parallaxes were calculated according to the precepts proposed by Strand (1963). The differences in the parallax system between CNS1 and CNS2 can be seen in Fig. 1a. The original 806 parallaxes used by Gliese in 1957 are no longer available in digitized form. Therefore, GCTSP parallaxes from the 1961 version were taken. This increased the number of parallax stars to 816, but, certainly doesn't affect the results presented here.

One can recognized that there are several distinct offsets from zero up to $+0.''006$, almost independent from M_V. This reflects very nicely the systematic corrections applied to the GCTSP parallaxes. The first line in Table 2 summarizes these corrections to a systematic difference of $+0.''003$ between the GCTSP (1952, 1961) and the YPC (1991). Apart from these systematic effects Figure 1a shows almost no scatter. In other words, only very few new trigonometric parallaxes were determined for CNS1 stars during the sixties.

In the early seventies the first results of the USNO astrometric reflector - installed at Flagstaff - became available and also other observatories concentrated their programmes on nearby candidates. So, that within only ten years 180 new trigonometric parallaxes larger than $0.''045$ were published (Gliese and Jahreiß, 1979). These new parallaxes were determined with considerably increased accuracy. Was the average mean error for the CNS1 stars 11.5 mas, and for the CNS2 stars 8.7 mas - indicating already an improvement of the more recent measurements, it dropped to only 4.3 mas now (see column 4 in Table 2). Biweighted means were calculated throughout Table 2) to reduce the influence of outliers on the results.

The new *General Catalog of Trigonometric Stellar Parallaxes* YPC (van Altena et al. 1992) - containing 13 936 measurements for 7 874 stars - constituts the principal source of the CNS3 parallaxes. Figure 1b shows the difference between CNS2 and CNS3 for 1325 stars. There are no systematic differences (Table 2 lists an average difference of –0.3 mas). In other words, the YPC introduces no new system. Convincing arguments for an omission of systematic corrections are presented by Prof. van Altena in the following paper.

On the other hand, a significant scatter is present in Figure 1b with a slight tendency to negative values. This is very probably due to the fact that in a volume-limited sample stars with positive parallax

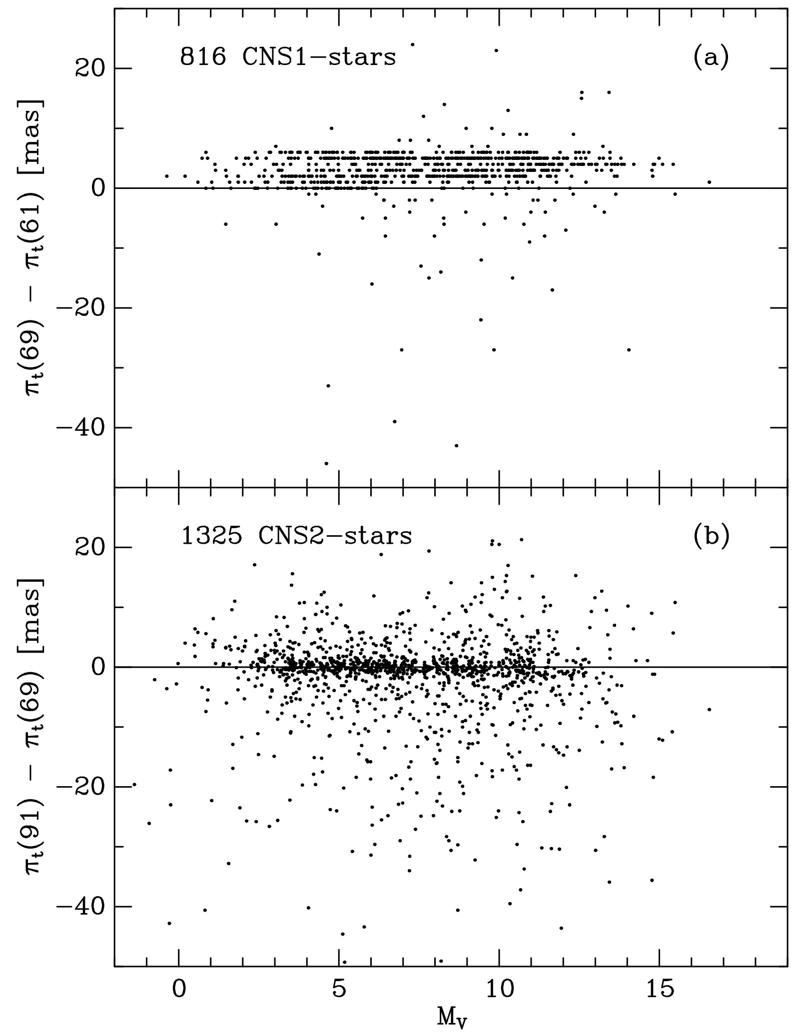

Figure 1: Differences of new and old trigonometric parallaxes as a function of absolute visual magnitude M_V (CNS3). (*a*) CNS2 - CNS1 parallaxes for 816 CNS1 stars; $\pi_t(61)$ from GCTSP and its supplement (1961). (*b*) CNS3 - CNS2 for 1325 CNS2 stars; $\pi_t(69)$ as listed in CNS2 and $\pi_t(91)$ from YPC(1991).

errors are overrepresented, i.e. on the average the parallaxes are too large. This effect is more pronounced for less accurate measurements, so, that new parallaxes which are of higher accuracy should correct for it. The last column of Table 2 shows an average error of 5.2 mas for the 264 newly added stars within 25 pc. But, it is even more important that 50 per cent of these stars are fainter than $m_V = 12\overset{m}{.}45$, which is about the magnitude limit of the Hipparcos satellite.

3 Photometric and spectroscopic parallaxes

Spectroscopic parallaxes were taken into account already in 1957 for the CNS1 in order *to complete the material.* Thus 109 stars without trigonometric parallaxes were added, and for another 161 stars trigonometric and spectroscopic parallaxes were combined to a resulting parallax with the intention to improve their distances.

In the course of the compilation of the CNS2 in 1969 also broad-band photometry UBVRI was added as far as available. Colour-luminosity calibrations carried out by Gliese (1971) allowed then the determination of additional photometric parallaxes. Thus again 121 stars with unknown π_t could be

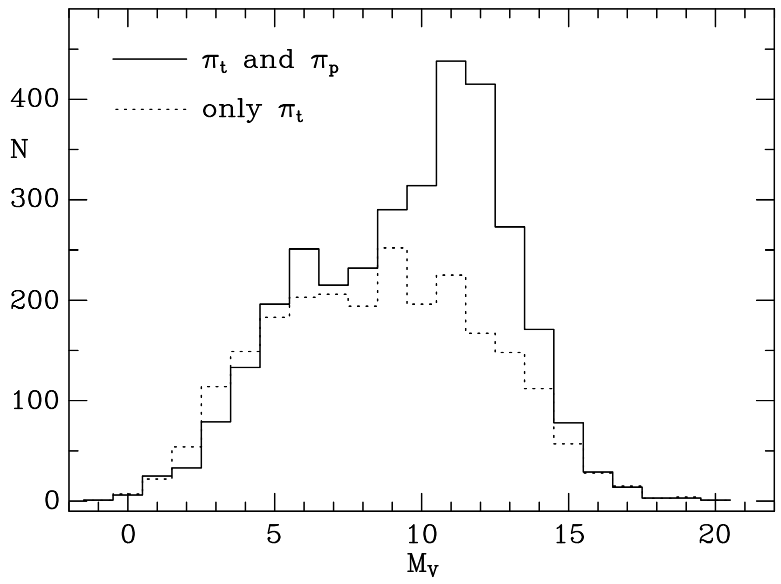

Figure 2: Number of stars within 25 pc as a function of absolute visual magnitude M_V. Full line: trigonometric and photometric or spectroscopic parallaxes were taken into account. Dotted line: only trigonometric parallaxes were considered.

included and another 328 trigonometric parallaxes were *improved* with the help of spectroscopic and/or photometric parallaxes.

During recent years a lot of photometric observations were carried out on high-proper motion surveys or spectroscopic surveys of red dwarf stars. This results in an immense increase of *non-trigonometric* nearby stars. In the present version of CNS3 1165 stars were included due to photometric or spectroscopic distance estimates, and for additional 734 stars the photometric parallax was found superiour to the trigonometric one.

The contribution of spectroscopic or photometric parallaxes to the compilations of nearby stars raised from 30 per cent in 1957 to 40 per cent in 1969, and to 50 per cent in 1991. The importance for the completeness of the CNS3 is demonstrated in Figure 2. If only trigonometric parallaxes would have been considered (dotted histogram) the number of bright stars $M_V < 5^m$ is overestimated by 25 per cent. This is due to the selection effect at the catalogue limit where the positive parallax errors dominate. This effect is strenghtened by the poor parallaxes of the bright nearby stars. Figure 2 shows that the contribution of the photometric parallaxes reaches its maximum at $M_V = 12^m$ with almost 60 per cent. Whereas, the distances of the very faint stars $M_V > 15^m$ rely almost exclusively on trigonometric parallaxes.

There may be two arguments against an application of photometric or spectroscopic parallaxes. First, the distance modul may be falsified by the presence of undetected companions. This can be circumvented only in carrying out systematic searches for unseen companions by radial velocity work or other means. Second, the broad-band colours allow only a calibration of the *mean* main sequence for red dwarf stars. In doing so, the cosmic dispersion which is of the order of $0\overset{m}{.}5$ is suppressed. Yet, in any way, additional spectroscopic or photometric means are required to study the fine-structure of the lower main-sequence in more detail. Therefore, certain subsamples of the CNS3 can be regarded as preselection of promising candidates for further observation - at least.

4 Conclusions

The average error of the parallax of a nearby star decreased from 14 mas in 1957 to 11 mas in 1969, and to 8 mas in 1991. Very soon HIPPARCOS will supply us with trigonometric parallaxes having errors in the order of 2 mas. Not in the HIPPARCOS *Input Catalogue* are only 15 per cent of the stars in our working file accessible to HIPPARCOS, i.e. with visual magnitudes brighter than about $12\overset{m}{.}5$.

Table 3: Sources of trigonometric parallaxes

observatory	1950	1962	1968	1978	1993
Allegheny	1642	242	130	53	20:
Cape	1404	428		4	83
Greenwich	759	1		51	28
Lick				109	16
McCormick	1669	230	60	79	91
McC. South.					28
Mt. Wilson	470	1	7		
Sproul	343	50	155	151	737
US Naval Obs.			1	497	411
US Naval CCD					72
Van Vleck	187	54	13	269	122
Yale	1734	295	56	46	13
Yerkes	364	24		76	34
other	295	37	4	30	30:
sum	8853	1362	426	1365	1685

Table 3 summarizes the amount of trigonometric parallaxes published by the principal observatories since the very beginning of photographic parallax work early this century. In view of HIPPARCOS it presents the almost final result of long chapter of astronomical observations. Indeed, it can be seen, that many important parallax series were terminated in the past and some further will very probably terminate in the near future.

There is a necessary trend to CCD parallaxes which allows to observe more fainter stars. But, there also is a trend to very small parallax series making it very difficult, if not impossible to study systematic effects. And, there still exists a north-south discrepancy, already in 1923 Schnauder (1923) stated that *87 per cent of all parallaxes relate to stars in the northern hemisphere.* Hopefully, things will improve soon, and we must not wait until ROEMER (Hoeg, these proceedings) will provide us next century with the predicted high accuracy astrometric and photometric measurements of all stars down to $m_V = 17\overset{m}{.}5$.

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