How Complete is our Knowledge of the Nearby Stars?

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Abstract: A fairly complete picture of the solar neighbourhood can be received if one accounts for the various selection effects caused by the different ways to detect nearby stars.

1 Introduction

The aim of the Third Catalogue of Nearby Stars (CNS3) is to list all presently known stars within a distance of 25 pc from the Sun. It should provide as far as possible information on proper motions, radial velocities, absolute magnitudes, colours, spectral types as well as information on duplicity and variability. This information should allow the analysis of the different groups of nearby stars under various aspects.

Since there exists no dedicated project to detect nearby stars the CNS3 lists objects from a large variety of observing programmes and must therefore be rather inhomogeneous with respect to its content and completeness. It can be recognized that there exists some sort of feed-back in such a way that only the publication of stars in a former version stimulated observing programmes for the missing supplementary data. Starting an investigation of a nearby star sample one must be cautious to avoid selection effects.

A preliminary version of the CNS3 was released in 1991 (Gliese and Jahreiß, 1991). This version listed altogether 3803 objects out of 5078 contained in our working file. Since then another 110 objects could be added and a lot of additional information was incorporated. Results about the progress achieved since the publication of the second edition (CNS2) in 1969 were presented for example in Jahreiß and Gliese (1993). At the same time it could be confirmed that the largely improved data caused no major changes in the basic properties of the nearby stars known since several years.

2 Distances

The basic distance parameter is the trigonometric parallax. The distances of the 1991-version of the CNS3 depended on trigonometric parallaxes graciously made available to us in 1989 by Dr. van Altena and collaborators in a predecessor of the Yale Parallax Catalog (YPC) (van Altena et al., 1991). For the nearby stars the most recent version of the YPC contains only marginal systematic changes.

As secondary distance parameters absolute magnitudes derived from anew calibrated broad-band colours and spectral types were taken into account. Within the recent years they got growing importance not only to complement the catalogue in the case no trigonometric parallaxes were available, but also to replace poor trigonometric parallaxes.

A closer look on the sources of the CNS3 distances shows very nicely the interaction of trigonometric and photometric parallaxes. For many absolutely bright stars the presently available trigonometric parallaxes are rather poor. Consequently, the CNS3 constitutes a volume limited sample, many more stars are entering the catalogue falsely than were left outside. This bias can be corrected by using more precise photometric parallaxes (usually derived from broad-band and Strømgren photometry).

Almost half of the fainter dwarf stars, i.e. $M_V \geq 9^m$ enter the catalogue on the basis of photometric parallaxes. These are much easier to obtain than trigonometric parallaxes, but may be falsified by unresolved binaries or undetected giants. The principal sources were VRI photometry (presently limited to $m_V \sim 15^m$) for red dwarf stars found in spectroscopic or high-proper motion surveys. For objects fainter than $M_V \geq 17^m$ photoelectric VRI colours saturate and fail therefore to provide unique absolute magnitudes. With infrared colours it is possible to proceed to fainter absolute magnitudes. But, the required observing programmes are not yet so numerous to contribute a significant number of new nearby objects.

3 Completeness

The CNS3 can be considered as (statistically) complete for stars brighter than $M_V \sim 8^m$ though its distance limit was extended to 25 pc. For fainter stars an increasing incompleteness with decreasing absolute magnitude exists in such a way that for $M_V \geq 12^m$ only the innermost 5 pc from the sun can be regarded as complete. Of course, even this cannot be ascertained definitively. The absolutely faintest stars presently known are at larger distances. LHS 2924 – the faintest one – is even at 10.5 pc distance.

A lack of observational programmes in the southern hemisphere causes another bias. Considerably more faint nearby stars are known north of $\delta = -30°$ than further south. Only very recently a revival of trigonometric parallax work especially for faint southern objects can be recognized.

4 Luminosity Function

A proper account of these deficiencies in dependence on the absolute magnitude led to the stellar luminosity function in Wielen et al. (1983). Applying the same restrictions to the CNS3 data to obtain complete subsamples yields almost identical values. Now, infrared colours became available for all red dwarfs entering the determination of the luminosity function. This, in combination with an intensive search for faint companions among the sample stars allowed more direct luminosity functions in M_K or M_{bol} (Jahreiß, 1994).

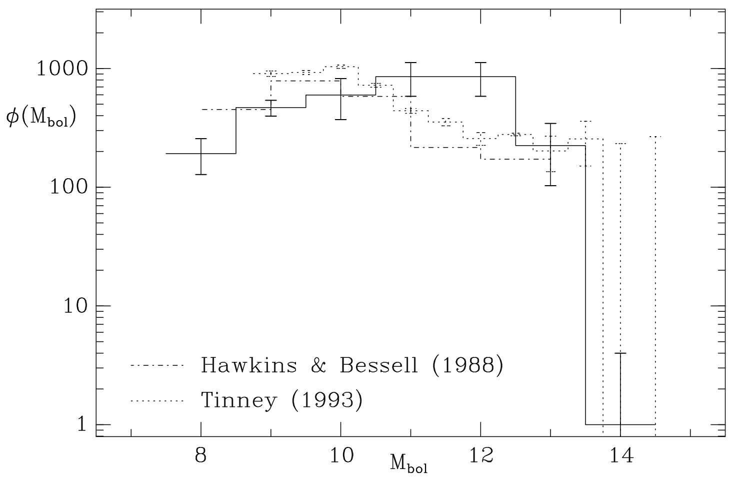

Fig. 1. The luminosity function (number of stars within 20 pc) in M_{bol}. The CNS3 function (full line) is compared with functions from recent photometric surveys: Hawkins and Bessell (1988) (dashed-dotted line) and Tinney(1993) (dotted line). The error bars are Poisson errors.

A completely different approach was chosen by W. Luyten, the method of mean absolute magnitudes. This method starts from a proper motion survey. Deducing absolute magnitudes only in a statistical sense via the reduced proper motions $H = m + 5 + 5\log\mu$ a complete knowledge of the distribution of the tangential velocities is required. Furthermore, it must be assumed that the kinematics of the stars is independent from the absolute magnitude. In spite of the completely different method Luyten's (1968) determination fitted reasonably well the function of Wielen et al. (1983). Yet, more recent attempts to repeat this method or similar ones on complete LHS subsamples failed in such a way that the resulting luminosity functions were systematically too small.

Deep photometric surveys, presently limited to small areas of the sky are the basis of another method. It is characterized by the determination of photometric distances (limit about 150 pc) and the subsequent application of M. Schmidt's

$1/V_{max}$ method. The latter may yield an underestimate in the case of small numbered bins.

The most recent application of this method covering an area of altogether 270 square degrees was published by Tinney (1993). It is plotted (dotted line) in Figure 1 together with an older determination (dashed-dotted line) by Hawkins and Bessell (1988) covering 85 square degrees. The CNS3 luminosity function (full line) made use of Tinney's (1993) bolometric correction. The two faintest magnitude bins depend on stars outside the 5 pc volume chosen as completeness limit.

It can be seen that the photometric luminosity functions show an earlier maximum. These differences may be a real feature. The CNS3 function presents mainly the 5 pc-volume around the sun, and may not represent a larger volume. On the other hand, the photometric surveys may be falsified by unresolved doubles, and the very small number counts may bias the resulting $1/V_{max}$ values. Nevertheless, if one allows for larger errors the accordance of the LF determinations can be regarded as rather satisfactory.

It would be interesting to know if the luminosity function is influenced by the kinematics of the stars as assumed in Bessell and Stringfellow (1993). But, the missing data do presently not allow a final decision. In any case, if our claim is correct that the CNS3 subsample used for the derivation of the LF is complete, then there should be also no kinematical bias.

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