Astrometric Grid and Reference Stars for the Space Interferometry Mission

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1 Introduction

The Space Interferometry Mission (SIM) is designed to perform astrometry at the 4 μas level in its wide-angle mode and at the 1 μas level in its narrow-angle mode. This unprecedented accuracy strongly depends on the astrometric stability of grid and reference stars. The grid consists of several thousand stars distributed uniformly over the sky and allows to tie the individual measurements into a global reference frame (wide-angle mode). In addition, reference stars located close to the targets are needed to obtain the highest astrometric precision (narrow-angle mode). It has been shown (Patterson et al. 1999, Frink et al. 2001) that K giants are the best type of stars for use as grid and reference objects. However, double and multiple stars with periods smaller than about 300 years have to be eliminated, since their photocenter motion would exceed the tolerable amount for astrometric stability. Furthermore, both components in such a long period system would have to be photometrically stable, since otherwise detectable photocenter motion could occur.

While there seems to exist a strategy on how to effectively select and ensure the astrometric quality of grid stars, reference stars are harder to find. They have to fulfill tighter constraints regarding astrometric stability as well as position on the sky (close to the target), so that they are much harder to find and probably will have to be fainter than the grid stars. Furthermore, a systematic observational search for grid stars is being undertaken already (see Poster 62.03 by Rhee et al.), whereas no systematic search for reference stars has been started yet.

2 Photometric Stability Constraints

Analytic calculations (Gould 2001) as well as Monte Carlo Simulations (Frink et al. 2001) have shown that the final grid, after radial velocity screening for companions, will still contain a number of long period binaries that cannot be identified with current observational techniques from the ground. They are not detrimental to the grid, since no significant orbital motion will be detectable over the relatively short mission duration of SIM (5 years) compared to the period of those systems ($>$ 300 years). However, if one of the components in these binary systems is photometrically variable, this will give rise to a motion of the photocenter with the period of the variability, which can be a large fraction of the separation of the two components. This was first noticed during the reduction of the Hipparcos Catalogue, which contains a few hundred so-called VIM's (variability induced movers, see Wielen 1996).

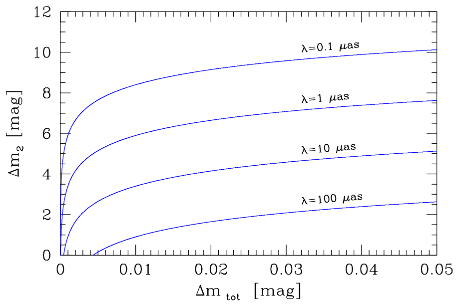

Fig. 1: The expected photocenter shift λ as a function of the variation in the combined magnitude (Δm_{tot}) and the magnitude difference between the constant star and the combined magnitude (Δm_2) for a system with a separation of 50 AU at a distance of 2 kpc.

The total amount of photocenter shift λ in units of the separation of the two components is given by

$$\lambda = 10^{-0.4\Delta m_2}(1 - 10^{-0.4\Delta m_{tot}})$$

(Wielen 1996), where Δm_2 is the magnitude difference between the constant star and the combined magnitude of the system, and Δm_{tot} is the total variability of the combined magnitude. As can be seen, λ will be much larger when the fainter component is the variable one ($\Delta m_2 \mapsto 0$, see Fig. 1). In general, fortunately, the brighter K giant is more likely to be variable than a much fainter main-sequence companion. However, even then the required astrometric stability places tight constraints on the allowed photometric variability of the combined system. Assuming a typical separation of 50 AU for the unidentified long-period systems in the grid, a typical distance of 2 kpc and a magnitude difference Δm_2 of 5 mag, the grid stars would have to be photometrically constant at a level of 4 millimag to ensure that possible photocenter shifts are smaller than 1 μas.

3 Availability of Grid and Reference Stars

A systematic search for grid stars is being undertaken in Virginia, consisting of a photometric identification of subsolar metallicity K giants with a specialized set of filters and a subsequent spectroscopic verification (the so-called GGSS - Grid Giant Star Survey, see Poster 62.03 by Rhee et al.). The GGSS is ultimately expected to yield enough grid stars for the whole SIM grid. However, the search is confined to 1306 'bricks' of $\approx$ 0.5 square degrees with a mean separation of 6 degrees, so that in general it cannot supply the reference stars that are needed within a radius of 1 degree around a given science target.
In need for an alternative source of reference stars, we tried to identify K giants in the Tycho-2 Catalogue, which is the faintest astrometric catalog with color information (B_T and V_T). For every potential K giant we computed two different Johnson B and V colors (assuming either a K giant or a K dwarf) and retained only those stars with 1.0 mag $< B - V <$ 1.6 mag.

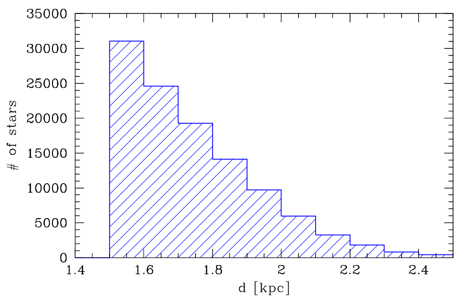

Fig. 2: Photometric distance distribution of all bona-fide Tycho-2 K giants with derived distances larger than 1.5 kpc. There are about 100 000 such stars.

The next step involved the calculation of two different photometric distances (and ultimately space velocities using the Tycho-2 proper motions), assuming again either a K giant or a K dwarf nature. In most cases this allowed a doubtless identification of a given star as giant or dwarf, just by rejecting very extreme values for the distances and/or space velocities.
We verified our method by applying it to a Hipparcos sample and found that less than 10% of all K stars would be misclassified. Since there are about 10 times as many K giants as K dwarfs in the magnitude limited samples considered here, a bona-fide K giant sample will contain less than 1% K dwarfs. Altogether we were able to identify about 100 000 K giants in Tycho-2 with photometric distances larger than 1.5 kpc; their distance distribution is shown in Fig. 2.
The mean density of Tycho-2 K giants is thus 2.5–3 stars per square degree, which corresponds to a mean number of 8 Tycho-2 K giants that are available as possible reference stars within a search radius of 1 degree around every science target.

References

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