Testing Hipparcos K giants as grid stars for SIM

Sabine Frink

Center for Astrophysics and Space Sciences, University of California, San Diego, 9500 Gilman Drive, Mail Code 0424, La Jolla, CA 92093-0424, USA

Andreas Quirrenbach

Center for Astrophysics and Space Sciences, University of California, San Diego, 9500 Gilman Drive, Mail Code 0424, La Jolla, CA 92093-0424, USA

Siegfried Röser

Astronomisches Rechen-Institut Heidelberg, Mönchhofstraße 12-14, D-69120 Heidelberg, Germany

Elena Schilbach

Astrophysikalisches Institut Potsdam, An der Sternwarte 16, D-14482 Potsdam, Germany

Abstract. We investigate some astrometric properties of Hipparcos K giants with the aim to explore their suitability as SIM (Space Interferometry Mission) grid stars. After discriminating the K giants from K dwarfs using photometry and parallaxes provided by the Hipparcos Catalogue, we eliminate unwanted variable and double stars from the sample by applying a number of different criteria. These include the various flags given in the Hipparcos Catalogue indicating either photometric variability or problems with the astrometric solution as well as a consistency check between the proper motion given in the Hipparcos Catalogue on one hand and the ACT and TRC proper motion catalogs on the other hand. We end up with a sample of about 12 000 K giants as candidate grid stars, which could serve as a starting point for further investigations aimed at finding the best subsample to represent the SIM astrometric grid.

1. Introduction

The basic measurements of the SIM interferometer are time delays which can be converted to 1-dimensional projected separations of stars when the baseline is known. In order to tie these individual measurements together into a 2-dimensional global catalog, a grid of stars with very well determined astrometric parameters is needed.

The absolute minimum number of grid stars is about 1000, but presently numbers of 3000–4000 grid stars are envisaged (NASA 1999, Boden 1999) to guarantee the required sky density even if some of the stars will turn out to be unsuited as grid stars during the mission. The astrometric jitter, i.e. the residual non-modeled uncertainty for the positions of the grid stars, should not exceed 1–4 μas. Ideally, there should be no binary stars among this sample, because a companion considerably complicates the precise determination of astrometric parameters.

These requirements make the selection of suitable SIM grid stars a highly challenging task. In this paper we follow an approach which makes use of the astrometric measurements of the Hipparcos satellite and examine various properties of K giants included in the Hipparcos Catalogue (ESA 1997) with the aim to test their suitability as SIM grid stars.

2. The case for the K giants

Various types of stars have been proposed as SIM grid stars, among others early-type main sequence stars at distances of ≈ 1 kpc, G dwarfs or bright giants and supergiants (Boden 1999). The most important criterion, except for the fact that there must be enough objects of a particular type brighter than ≈ 12 mag, is the absence of possible companions which hinders the precise determination of astrometric parameters.

Clearly, the absence of planets cannot be assured for such a large number of stars. According to Marcy & Butler (1998) the mass distribution of companions seems to be bimodal, peaking at masses of main-sequence stars as well as in the planetary mass range with a so-called brown-dwarf desert in between. Therefore we first aim at making sure that the candidates have no stellar companion and then we select objects with the largest distances, i. e. the highest absolute magnitudes, thus minimizing the disturbing effects of possible planetary companions.

The intrinsically brightest stars, the supergiants, are too rare to provide the majority of the SIM grid stars. Going down in the HR diagram, the next brightest objects are O and B stars as well as K giants. O and B stars are very young and thus found preferentially in associations located in spiral arms, which means that they are not distributed uniformly over the sky. Also, radial velocities of early-type stars cannot be measured very precisely, so that the detection of e.g. spectroscopic binaries might be difficult. The very bright M giants are not considered here, because many of them are variable.

All these problems do not apply to K giants. They are quite numerous (about 25% of the stars in the Hipparcos Catalogue are K giants), found in all directions of the sky, and their radial velocities can be measured with sufficient precision. Moreover, we already have an initial record of their astrometric parameters from the Hipparcos Catalogue. Some of the K giants may be chromospherically active, and due to starspots the photocenter may not be constant. But since K giants are so numerous, one could hopefully concentrate on the more stable ones.

G dwarfs, which have also been suggested as grid stars, might be well suited in terms of their astrometric properties. However, their absolute magnitudes are on average about 5 mag fainter than those of K giants. Therefore they would

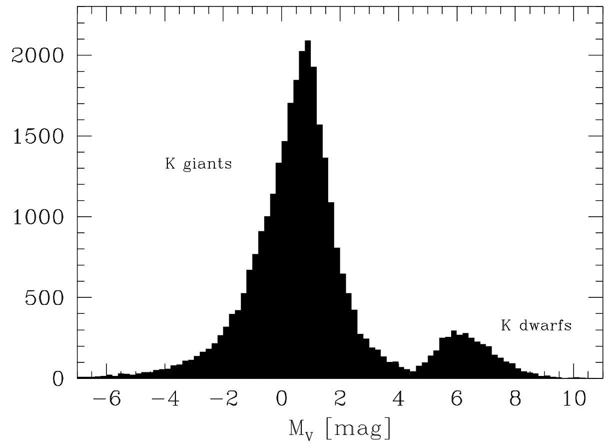

Figure 1. Histogram of absolute magnitudes M_V based on Hipparcos parallaxes for all stars of spectral type K with non-negative parallaxes in the Hipparcos Catalogue (altogether 31 817 stars). The combination of the Hipparcos limiting magnitude of $m_V \approx 12$ mag and the mean error of the parallax measurements (≈ 1 mas) yields a bimodal distribution of K stars and thus allows for the separation of K dwarfs and K giants.

have to be located at 1/10 of the mean distance of the K giants, which means that they would be more prone to the disturbing effects of possible planetary companions.

In the following we will investigate the properties of Hipparcos K giants with respect to their suitability as SIM grid stars in more detail.

3. Identification of K giants in the Hipparcos Catalogue

For most of the stars spectral types taken from the literature are provided in the Hipparcos Catalogue. As luminosity classes are rarely available for the northern hemisphere, we used the absolute magnitudes, calculated from the measured apparent V magnitudes and the trigonometric parallaxes, to discriminate between K giants and K dwarfs. The accuracy of the Hipparcos parallax measurements is sufficient to separate giants from dwarfs: the resulting distribution in absolute magnitudes of all Hipparcos K stars is bimodal (Fig. 1). Setting the limit between K giants and K dwarfs at $M_V = 4.5$ mag, which is justified from the distribution in Fig. 1 as well as from astrophysical considerations, we end up with a total of 29 466 K giants (including 1156 K stars with negative parallaxes which are very unlikely to be dwarfs because of their large distances). It is still possible that there are a few K dwarfs among our sample of K giants, but certainly they are not large enough in number to change the mean properties of the sample significantly.

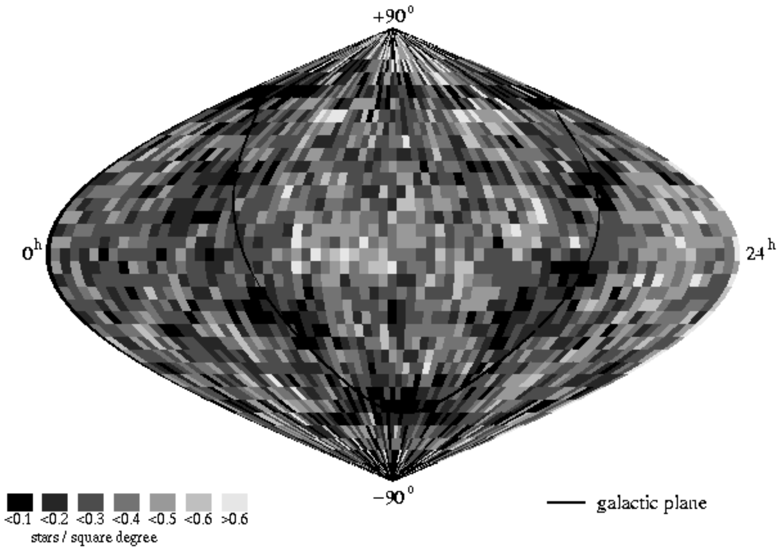

Figure 2. Sky density distribution of our final sample of 11 813 grid star candidates (Hipparcos K giants). The solid black line indicates the galactic plane where fewer K giants are found than at higher latitude.

4. Selection of grid candidate stars

In order to select the best suited SIM grid candidates from our sample, we used the various astrometric and photometric parameters given in the Hipparcos and Tycho Catalogues (ESA 1997) as well as in the ACT Reference Catalog (Urban et al. 1997) and the Tycho Reference Catalogue TRC (Høg et al. 1998). We applied a total of 17 different criteria to reject all stars showing indications of variability or multiplicity. Some of the criteria are quite similar to each other, so that often a star is rejected by more than one criterion.

Our criteria can roughly be divided into 3 categories concerning a) astrometric quality, b) variability and c) duplicity. They are listed in detail in Table 1.

Criteria 1–13 refer to flags or parameters in the Hipparcos, Tycho or TRC catalogs. In order to sort out possible astrometric binaries among our sample we performed a comparison of the proper motions in the Hipparcos and ACT/TRC catalogs, testing whether the 'instantaneous' Hipparcos proper motion (derived from measurements collected over a timespan of 3 years) is consistent with the proper motion determinations based on a larger epoch difference ($\approx$ 80 years for ACT/TRC). Significant differences might reflect orbital motions due to companions. We followed the approach by Wielen et al. (1999) who defined a test parameter F which is basically the ratio of the proper motion difference and its expected error in both directions of the error ellipsoid. A star is classified as 'single-star candidate' when $F < 2.49$, corresponding to a 2σ criterion. Criteria 14–17 are resulting from this approach. From the comparison of the

Hipparcos proper motions with those from ACT and TRC, respectively, about 4 000 stars of our initial sample were rejected.

After application of all our selection criteria a total of 11 813 grid candidate stars is left for further investigation.

Table 1. The criteria which were applied to the 29 466 K giants in the Hipparcos Catalogue, ending up with a final sample of 11 813 preliminary grid candidate stars. Following a running number in the first column the second column specifies the field name of the parameter in the original catalog (H for Hipparcos, T for Tycho, and q_pm and ACTflg refer to fields in TRC). The third column provides a short explanation of the parameter or flag, and the last column finally shows our requirements (⊔ means that this flag is not set for the star). For a more detailed explanation of criteria 1–13 see ESA (1997) and Høg et al. (1998), respectively. Criteria 14–17 are explained in the text.

astrometric quality			
1	H29	[percentage of rejected data]	0%
2	H30	[goodness-of-fit statistic]	< 3
3	q_pm	[TRC quality flag for proper motion]	≤ 2
variability			
4	H6	[coarse variability flag]	⊔
5	H46	[scatter of Hp observations]	< 0.1 mag
6	H52	[type of variability]	⊔
7	T47	[previously known or suspected as variable]	⊔
8	T48	[variability of the Tycho measurements]	⊔
duplicity			
9	H2	[proximity flag]	⊔
10	H55	[CCDM identifier]	⊔
11	H59	[double and multiple systems annex flag]	⊔
12	H61	[suspected non-single]	⊔
13	ACTflg	[proper motion difference TRC-ACT]	⊔
14	$\Delta\mu_{\mathrm{TRC,HIP}}$	[total proper motion difference TRC-HIP]	< 10 mas/a
15	$F_{\mathrm{TRC,HIP}}$	[significance of $\Delta\mu_{\mathrm{TRC,HIP}}$]	< 2.49
16	$\Delta\mu_{\mathrm{ACT,HIP}}$	[total proper motion difference ACT-HIP]	< 10 mas/a
17	$F_{\mathrm{ACT,HIP}}$	[significance of $\Delta\mu_{\mathrm{ACT,HIP}}$]	< 2.49

5. Properties of candidate grid stars

The vast majority of stars in our sample of candidate grid stars defined in the last section has apparent V magnitudes in the range 8–9 mag, easily accessible with SIM. For a typical K giant (absolute magnitude of 0.5 mag) this corresponds to distances of 350–550 pc.

The sky density distribution of these stars is shown in Fig. 2. The density is lower in the galactic plane which probably is a selection effect in the Hipparcos Input Catalogue (the number of stars per square degree was limited with Hipparcos, and in the galactic plane probably more interesting objects than K giants were proposed). But even in the galactic plane the sky density is still larger than needed for the grid (3000 evenly distributed stars correspond to a sky density of 0.07 stars/square degree).

6. Conclusions

This study is the first step to examine the properties of various types of objects in order to test whether they might be suitable to serve as SIM grid stars. From the first results we conclude that Hipparcos K giants seem to be promising candidates. Even if future radial velocity surveys will find that a portion of them has presently unknown companions, the number of K giants will still be large enough for the SIM grid. From the Hipparcos catalog we already got an initial record of their astrometric parameters which could be valuable on their own or in combination with possible measurements from the planned DIVA or FAME missions.

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