PROPER MOTIONS OF 47 TUC AND NGC 362 RELATIVE TO THE SMALL MAGELLANIC CLOUD

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ABSTRACT. The proper motions of the galactic globular clusters 47 Tuc and NGC 362 are currently being measured relative to the background of the Small Magellanic Cloud. This paper reports on the reduction routines developed so far for the simultaneous computation of several thousands of stellar proper motions. A preliminary result for NGC 362 is given.

Introduction

Absolute proper motions of galactic globular clusters, together with the more readily available radial velocities, provide important clues to the dynamics of Population II. Galaxies, expected to show zero proper motions within the present accuracy of measurement, have previously been used for the determination of absolute proper motions of globular clusters (Brosche et al. 1985, Tucholke et al. 1987). In this paper the chance superposition of the galactic globular clusters 47 Tuc (NGC 104) and NGC 362 on the halo of the Small Magellanic Cloud (SMC) is used to measure their quasi-absolute proper motions. The proper motion of the SMC is predicted to be 0.2"/100 yr (Lin and Lynden-Bell 1982) and will be measured by HIPPARCOS, whose proper motions will be tied to a non-moving reference frame. By this calibration the proper motions of the two clusters will be made absolute.

At the present time, nine plates have been measured, and routines for the bulk reduction of several thousands of proper motions are being developed and tested. Examples are given for the field of NGC 362, which has a richer background of SMC stars compared to 47 Tuc.

Observational Material and Measurements

First-epoch plates, taken at the Harvard Southern Station in the years 1895 to 1899 with the 24" Bruce Refractor (scale 60.0"/mm) and the 13" Boyden Refractor (scale 42.4"/mm), were available from the Harvard Plate Collection. Blue (IIa-O) and red (098-04 + RG 630) second-epoch plates were taken in 1985 with the 40cm GPO-astrograph (scale 51.1"/mm) at ESO,

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La Silla. The limiting magnitudes of the first-epoch plates range from m_{pg} = 16 to 17; the GPO plates reach B ≈ 18.5.

All plates are measured with the PDS 2020GM microdensitometer at the Astronomisches Institut Münster, which shows a repeatability of star position measurements of 0.7 μm and a positional stability of ≤ 1.0 μm over an interval of 12 hours (Tucholke 1983). Since there is almost no information on SMC membership in the fields of the two clusters, the complete useful field of the plates is measured, and each object above a preselected density threshold is stored. Each plate is scanned in two orientations rotated by 180 degrees.

Reductions

Object positions and internal magnitudes are computed from Gauss-fits to marginal distributions. After a linear transformation the measurements in the two plate orientations are combined into a best set of image parameters. All plates are referred to the coordinate system of a deep master plate for each of the two fields (47 Tuc and NGC 362), which is selected from the second-epoch plates.

The transformation from each first-epoch plate to the master plate is computed by an iterative procedure: For the large time base of 90 years the preferred transformation stars are SMC members because of their negligible proper motion. However, in a first approximation one has to use a random selection of stars evenly distributed over the 2°x2° field of the master plate. Since most of them are galactic foreground stars with considerable proper motions, the transformation shows a large scatter. Stars with small proper motions are considered as SMC candidates. In the next approximation the transformation stars are selected from this list, still maintaining an even distribution over the field of the master plate. This procedure is iterated, until the SMC candidates show a reasonably small scatter around zero proper motion.

In Fig. 1 more than 3000 proper motions measured from one plate pair (epoch difference 87.7 yr) are shown. The proper motions crowd around two maxima - the SMC at zero proper motion and NGC 362 - superposed on an ellipsoidal "background" of galactic foreground stars.

The difference in proper motion between the SMC and NGC 362 is more evident in Fig. 2, where $\mu_\alpha \cos\delta$ is plotted *versus* declination (a) and right ascension (b). The main purpose of these types of diagrams is to check the transformation between two plates: The proper motion of the SMC stars should be 0, independent of coordinate or magnitude (not shown here). As indicated by the slight dependence of $\mu_\alpha \cos\delta$ on α, the transformation used (including linear and quadratic terms in the coordinates as well as magnitude and magnitude-coordinate terms) still shows small systematic errors. This deficiency might be remedied by allowing for color-dependent terms.

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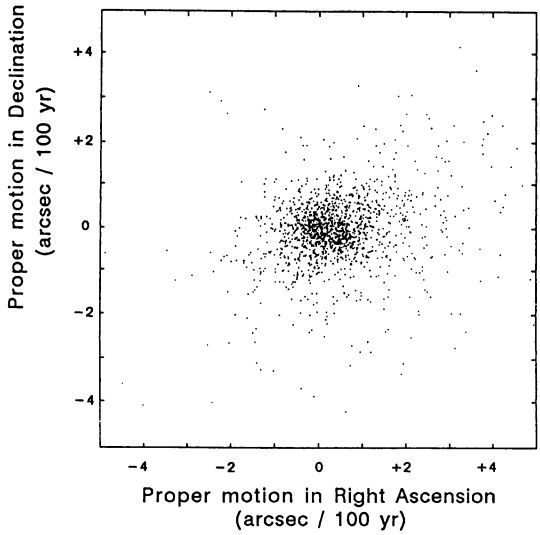

Fig. 1: Proper motions from one plate pair with an epoch difference of 87.7 years in a 1.6*1.6° field centered on NGC 362.

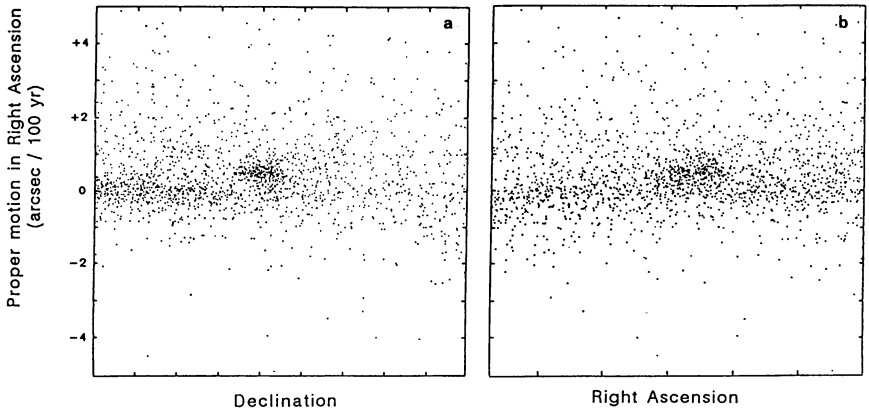

Fig. 2: The proper motions in right ascension from Fig. 1 are plotted *versus* declination (a) and right ascension (b). Both α and δ increase to the right, with scale steps of 10 arc minutes; the position of NGC 362 is 1ʰ01ᵐ33ˢ, -71°07.0" (1950.0). The NGC 362 stars clump around $\mu_\alpha \cos\delta$ = +0.5"/100 yr. In (a) the number of zero proper motion stars, probably SMC members, decreases markedly with increasing declination, as expected from the cluster position north of the SMC main body.

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One is tempted to make a first guess on the proper motion of NGC 362 relative to the SMC (from only one plate pair):

$$\mu_\alpha \cos\delta = +0.48 \pm 0.19 \text{ "/100 yr},$$
$$\mu_\delta = -0.15 \pm 0.27 \text{ "/100 yr}.$$

Assuming a distance of 9.1 kpc to NGC 362 (Bolte 1987), this translates to velocities of +209 ± 82 and -65 ± 116 km/s in the direction of right ascension and declination, respectively.

Future Steps and Prospects:

The properties of the telescopes used for the first-epoch plates will be tested with plates of the astrometric standard region Praesepe (Russell 1986). The more rigorous plate model will include color-dependent terms.

Another 11 first-epoch and 4 second-epoch plates (so far) await measurement and reduction, once the reduction procedures are fully established.

Among the expected results are:
- quasi-absolute proper motions for 47 Tuc and NGC 362,
- quasi-absolute proper motions for two samples of galactic field stars, possibly restricting galactic kinematic models,
- lists of candidates for SMC membership in two SMC halo fields,
- lists of probable members of 47 Tuc and NGC 362.

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