

Proper motion measurements in the Quintuplet cluster

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Introduction

The three young, massive star clusters found in the galactic centre region (Young Nuclear Cluster, Arches and Quintuplet cluster) are among the six most massive, open clusters in our galaxy with masses similar to low-mass, extragalactic starburst clusters. The conditions for star formation in this region are extreme and likely comparable to the ones found in the HII regions in starburst galaxies and tidal interaction zones of mergers. As the inner galactic star clusters can be resolved they can serve as templates for extragalactic starburst clusters. With the knowledge of the spectral types, masses and ages of the individual stars their stellar population can be studied in detail allowing the derivation of their present day mass function (PDMF).

The Quintuplet cluster with an age of about 4 Myr [1] displays the lowest spatial density of the three Galactic centre clusters. In order to derive an unbiased sample of cluster stars and determine the mass function correctly cluster and field stars have to be discerned out to radii where the member density drops below the field star density. We present the first determination of a membership sample for the Quintuplet cluster based on proper motion measurements. By comparing two high precision astrometric VLT/NACO datasets with a time baseline of 5 years the proper motion of the individual stars was measured and a selection of proper motion cluster members could be established.

Method

- The stellar positions and fluxes in the three images (Ks 2003, H 2003 and Ks 2008) were determined using the *starfinder* code [3].
- The zeropoints for the photometric calibrations were obtained from the fluxes of stars which could be unambiguously assigned to calibrated sources in the UKIDSS catalogue [4].
- Stellar positions on the first epoch Ks 2003 image were transformed to the second epoch Ks 2008 image, as described in the next section. The deeper Ks 2008 image provides the more accurate astrometry and was therefore used as the reference image.
- After the coordinate transformation, proper motions were extracted from the matched source catalogues.
- We define color-magnitude diagrams for various proper motion selected samples.

Proper motion members

The proper motion diagram (Fig. 3) shows the presumed cluster stars as a dense clump at the origin and the field stars mainly distributed in the south-west quadrant within an ellipsoidal shape, the axis of which is parallel to the galactic plane. The Quintuplet cluster, like the Arches cluster [5], therefore moves in the north-east direction relative to the field. The distributions of cluster and field stars are not clearly distinct but possess an overlap in the lower part of the cluster clump. This strong overlap is mainly due to faint stars belonging to the field (see Fig. 4) or to stars with large astrometric uncertainties.

In order to derive a criterion for the selection of proper motion members, the distribution of stars in the proper motion diagram was split in two halves by the dotted line, which runs through the origin and is perpendicular to the assumed direction of the cluster's motion (see Fig. 3). As the upper part (north-east segment) is less contaminated with field stars (see Fig. 5) the distribution of the proper motions ($\mu = \sqrt{\mu_{Ks}^2 + \mu_{EW}^2}$) from this segment was fitted by a Gauss function. The retrieved standard deviation ($\sigma = 2.50$ mas/yr) of this fit is used for the selection of proper motion members. The detected field and cluster stars in the north-east and the south-west segment are given in Tab. 2. The color magnitude diagrams for both segments with the proper motion members plotted in red are shown in Fig. 6.

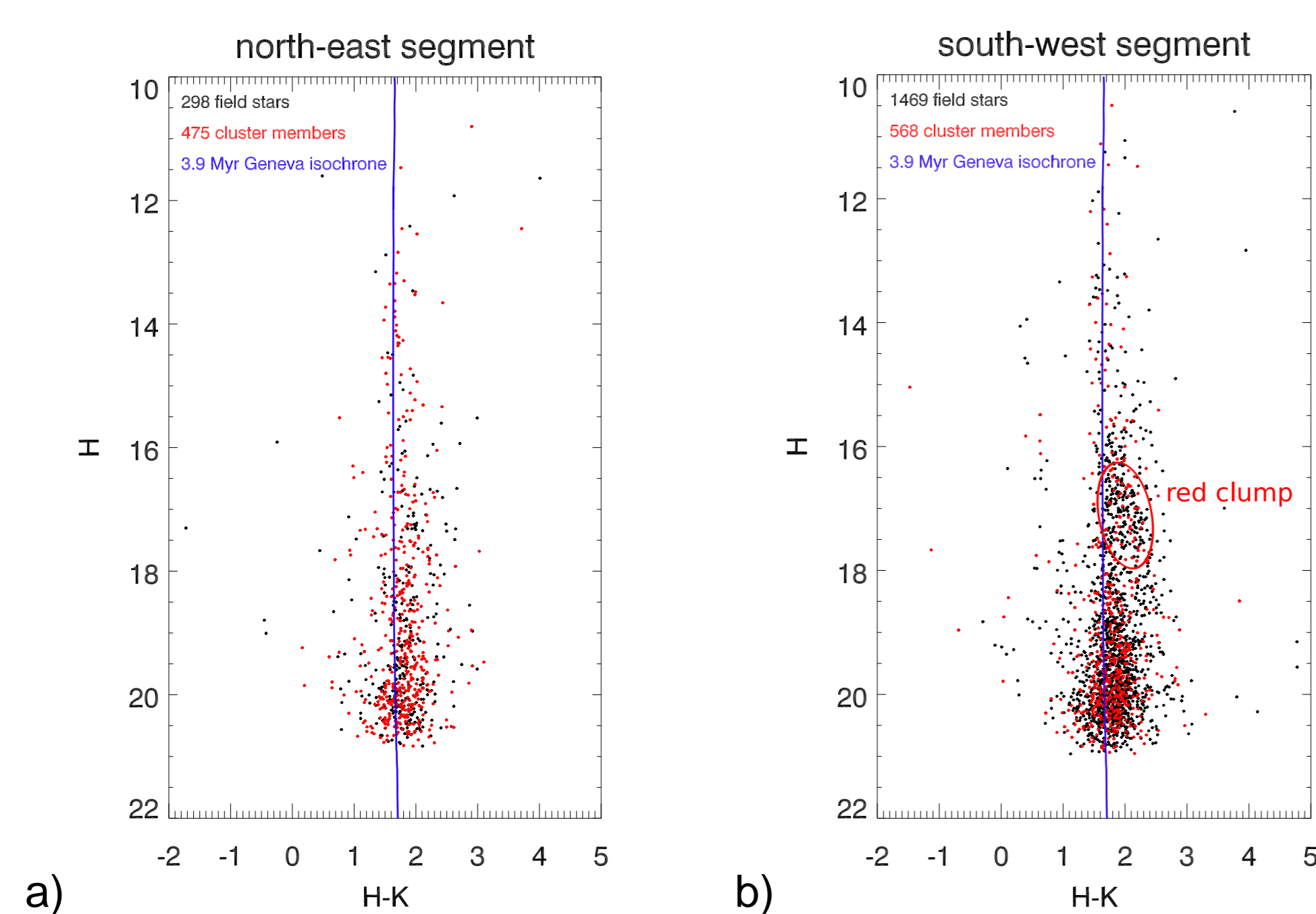


Figure 6: Color-magnitude diagrams of all stars detected and matched in H 2003, Ks 2003 and Ks 2008 for the north-east (a) and south-west segment (b) of Fig. 3. A 3.9 Myr Geneva mainsequence isochrone was fitted by eye to the bright stars on the mainsequence [6]. The stronger field contamination in the south-west segment is evident in the larger number of blue foreground stars. The datapoints in a) are more narrowly distributed along the mainsequence than b) and a prominent clustering of stars from red clump stars in the inner bulge is absent [7]. The proper motion members from the north-east segment therefore constitute a cleaner sample of cluster stars.

Data

All data used in the following analysis originate from two observing runs in 2003 and 2008 (time baseline: 5.0 yrs) and were obtained by the Very Large Telescope (VLT) with AO correction from NAOS/CONICA. The proper motion of the cluster stars was determined from two epochs of Ks-band data ($\lambda_c = 2.18 \mu\text{m}$, $\Delta\lambda = 0.35 \mu\text{m}$). For the color-magnitude diagram additionally H-band ($\lambda_c = 1.66 \mu\text{m}$, $\Delta\lambda = 0.33 \mu\text{m}$) observations from the first epoch are used.

	2003		2008
	H	Ks	Ks
number of frames	16	16	44
integration time per frame [s]	60	60	30
average seeing ["]	0.55	0.39	0.54
average FWHM ["]	0.072	0.081	0.076
field of view ["]	27.75	27.75	27.80

Table 1:

In order to reconstruct bad pixels and to cover a larger field of view the telescope was dithered. The single frames were combined using the *drizzle* algorithm [2]. For the 2003 H-, Ks-band data all frames were used, for the 2008 Ks-band data 10 frames with the largest full width half maximum (FWHM) were sorted out before creating the final image. The overlap between the two Ks datasets results in a field of view of about 39", the effective field of view for the final H-band image was about 36".

Geometric transformation

In order to determine the spatial displacement between the two epochs a geometric transformation has to be derived to map each position measured on the Ks 2003 image onto the correct position on Ks 2008. To calculate this transformation the IRAF task *geomap* was used. The determination of the transformation with the cluster as reference frame encompasses the following steps:

- rough transformation of Ks 2003 onto Ks 2008
- match the two source catalogues (matching radius: 4 pix $\hat{=}$ 21.7 mas/yr)
- select the bright (not saturated) stars as likely cluster candidates for the initial guess of the geometric transformation:
 - $11.0 \text{ mag} < m_{Ks2008} < 15.5 \text{ mag}$
 - $|m_{Ks2008} - m_{Ks2003}| \leq 0.5 \text{ mag}$, to sort out mismatches
- minimize the x,y residual displacements by iteratively removing outliers and carefully adapting the order of the transformation

As can be seen in Fig. 2 the obtained final sample of stars used for deriving the transformation is closely clustered around the origin as expected for cluster member candidates in the cluster reference frame. The final rms deviation of the polynomial transformation was 0.5 mas/yr for the x- and y-direction.

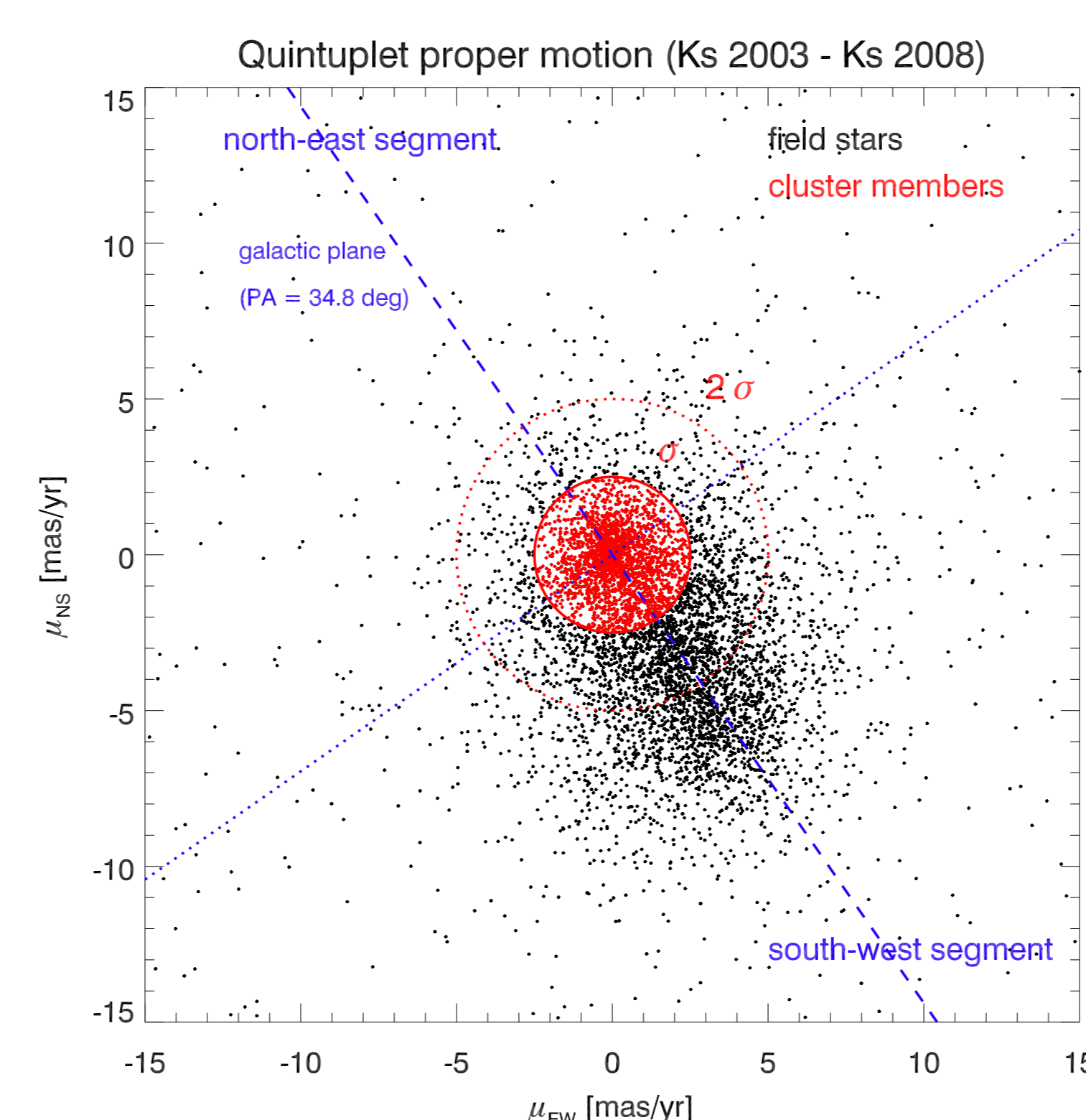


Figure 3: Proper motion diagram of the Quintuplet cluster

Outlook

The next steps towards a clean cluster member sample and a first present day mass function estimate for the Quintuplet cluster are the following:

- refine selection of proper motion members
 - detailed comparison of the two subsamples (north-east and south-west segment)
 - derive distinct σ -criteria in dependence of different magnitude bins
 - remove stars identified as blue foreground or red background objects in the color-magnitude diagrams from the list of proper motion cluster candidates
- derivation of the completeness by determining the recovery fraction of artificial stars inserted into the cluster images
- determine the present day mass function from the completeness corrected color-magnitude diagram by using a main-sequence isochrone to convert the magnitudes into masses

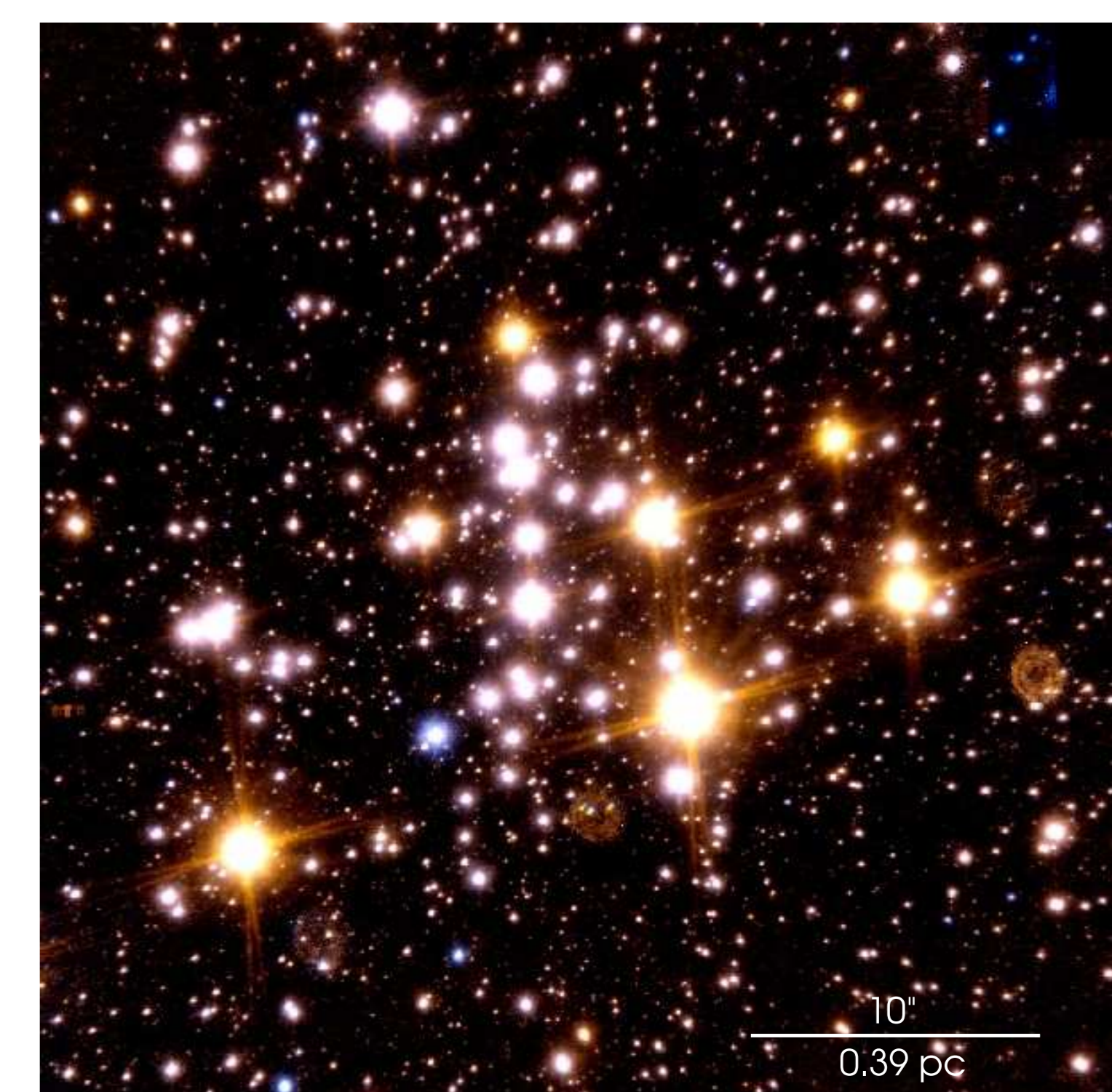


Figure 1: VLT/NACO HKs composite image of the Quintuplet cluster

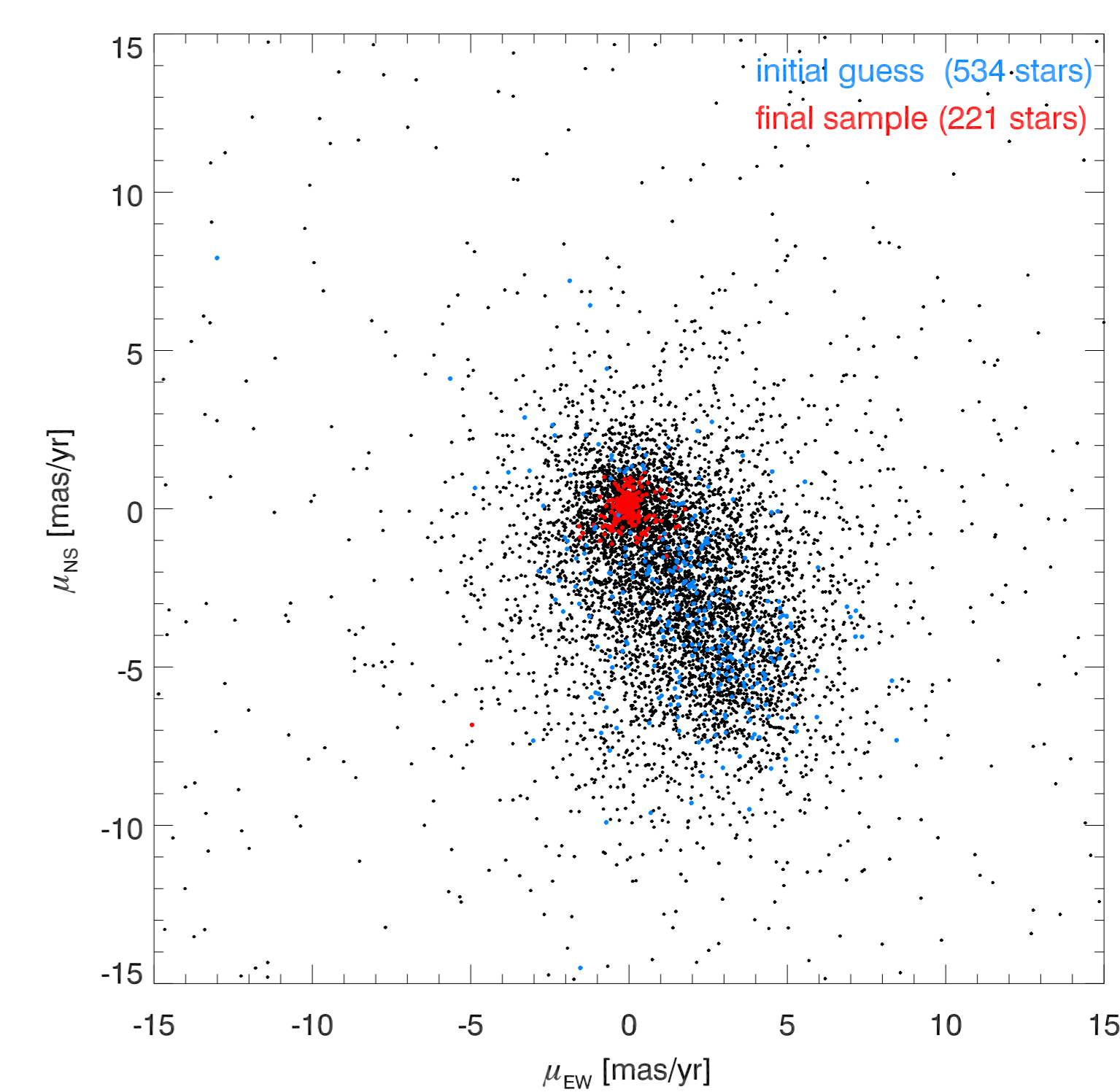


Figure 2: Stars used to calculate the *geomap* transformation: initial guess (blue and red), final sample (red)

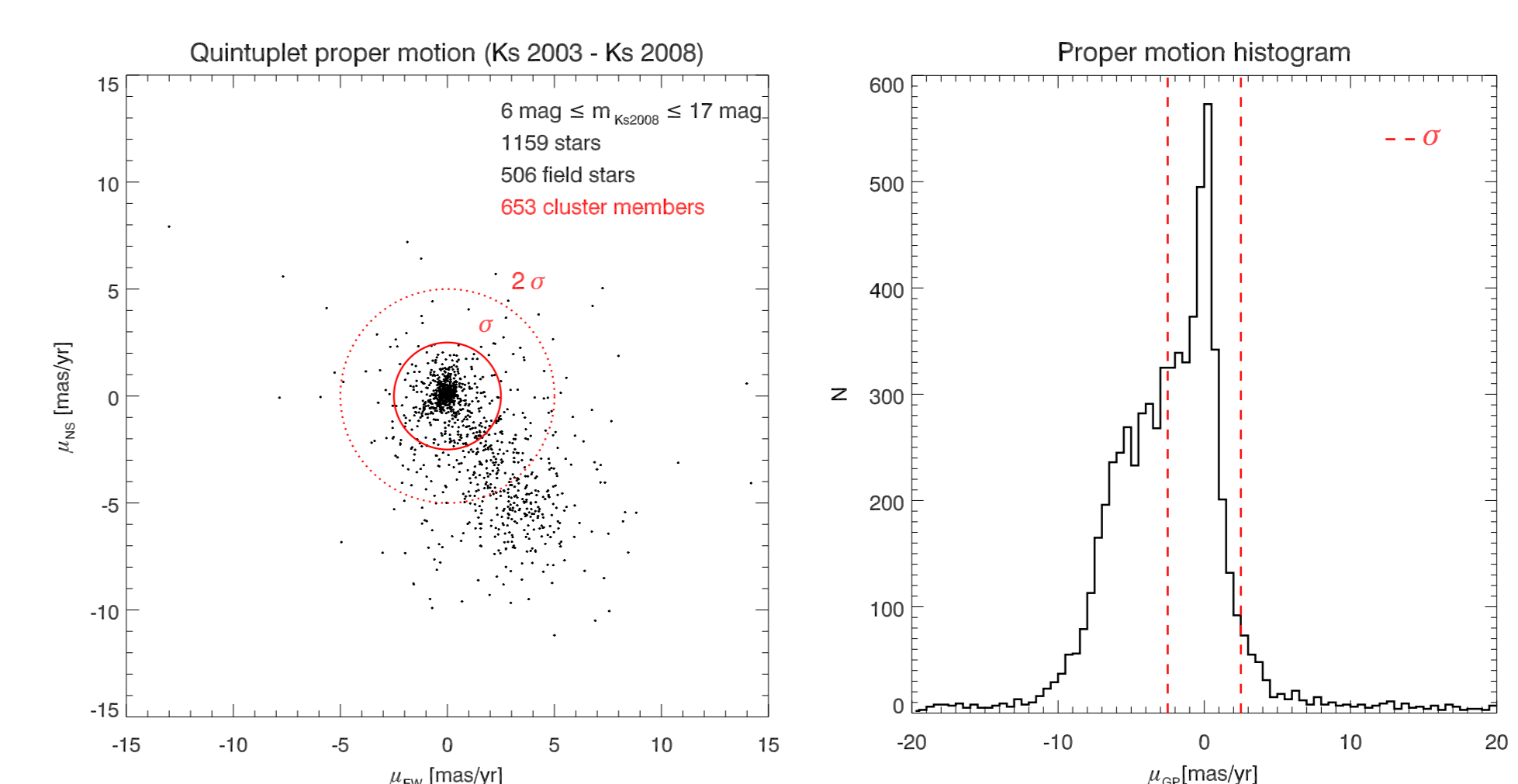


Figure 4: For bright and intermediate stars cluster and field separate well. Figure 5: Histogram plot of the proper motion parallel to the galactic plane

	north-east segment	south-west segment
detected stars	1804	4906
cluster members	1081	1324
field stars	723	3582

Table 2: Number of matched stars in Ks 2003 and Ks 2008

Acknowledgments

We acknowledge funding by the German Science Foundation Emmy Noether Programme under grant STO 496-3. Based on observations made with ESO Telescopes at the Paranal Observatories under Programme ID 081.D-0572 as well as observational data from the ESO science archive.

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