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THE STRUCTURE AND THE DISTANCE OF COLLINDER 121 FROM *HIPPARCOS* AND PHOTOMETRY: RESOLVING THE DISCREPANCY

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ABSTRACT

We present further arguments that the *Hipparcos* parallaxes for some of the clusters and associations represented in the *Hipparcos* catalog should be used with caution in the study of the Galactic structure. It has already been shown that the discrepancy between the *Hipparcos* and ground-based parallaxes for several clusters including the Pleiades, Coma Ber, and NGC 6231 can be resolved by recomputing the *Hipparcos* astrometric solutions with an improved algorithm diminishing correlated errors in the attitude parameters. Here we present new parallaxes obtained with this algorithm for another group of stars with discrepant data—the galactic cluster Cr 121. The original *Hipparcos* parallaxes led de Zeeuw et al. to conclude that Cr 121 and the surrounding association of OB stars form a relatively compact and coherent moving group at a distance of ≃550–600 pc. Our corrected parallaxes reveal a different spatial distribution of young stellar populace in this area. Both the cluster Cr 121 and the extended OB association are considerably more distant (750–1000 pc), and the latter has a large depth probably extending beyond 1 kpc. Therefore, not only are the recalculated parallaxes in complete agreement with the photometric *uvbyβ* parallaxes, but the structure of the field they reveal is no longer in discrepancy with that found by the photometric method.

Subject headings: Galaxy: structure — open clusters and associations: individual (Collinder 121) — stars: distances

1. INTRODUCTION

Obtaining reliable knowledge about the structure and distance of nearby OB associations plays a critical role in the overall study of the Milky Way morphology near the Sun. Unlike the external galaxies where the star-forming fields are generally evident from direct imaging, the study of the spiral structure of our own Galaxy is largely grounded in distance determinations of young stellar tracers. At present, sufficiently accurate astrometric data (parallaxes and proper motions) are available for few star-forming regions within ≃500 pc. More comprehensive and representative studies of the local history and dynamics of star formation have to rely on the photometric method of distance determination and stellar evolution theory.

The completion of the *Hipparcos* catalog (ESA 1997) offered a possibility for a major improvement of the membership of young moving groups near the Sun and refining the distance scale to nearby open clusters and OB associations. However, the mean *Hipparcos* parallaxes for some galactic clusters are in disagreement with ground-based determinations by various methods. Statistically significant discrepancies between the *Hipparcos* trigonometric and traditional photometric, spectroscopic, and interferometric results have been reported in the literature for selected small-scale fields, most notably for the Pleiades open cluster (Pinsonneault et al. 1998; Soderblom et al. 1998, 2005; Narayanan & Gould 1999; Stello & Nissen 2001; Makarov 2002; Pan et al. 2004; Percival et al. 2005). Platais et al. (2007) found a similar offset in the *Hipparcos* mean parallax for the young open cluster IC 2391. A discrepancy was reported by Kaltcheva et al. (2005) for the open cluster IC 2602 as well. The cause for these inconsistencies is most likely due to a faulty data reduction algorithm used in *Hipparcos*, which allowed highly correlated errors of along-scan attitude parameters to propagate into the fitted astrometric parameters. An alternative data reduction approach has been suggested and successfully tested by Makarov (2002, 2003).

The region of Cr 121 is another example of this discrepancy. Since the discovery of a compact group at l, b = (234.98°, −10.21°) by Collinder (1931), both the cluster and the larger 10° × 10° field have been extensively studied by UBV and *uvbyβ* photometry. This area includes one of the 12 OB associations within 1 kpc of the Sun with fairly detailed kinematical information and membership determined from *Hipparcos*. The *Hipparcos* proper motions reveal a moving group of 103 stars between l = 227° and 245°, identifying the compact cluster Cr 121 with an unbound extended OB association at a distance of 592 ± 28 pc, similar to Sco OB2 (de Zeeuw et al. 1999). Robichon et al. (1999) selected 13 *Hipparcos* members of Cr 121 and found a mean *Hipparcos* parallax of 1.80 ± 0.24 mas (556 ± 74 pc). In contrast to these results from *Hipparcos*, the latest *uvbyβ* photometric study (Kaltcheva 2000) concluded that a compact stellar group apparently identical to the genuine cluster (Cr 121) is situated at 1085 ± 41 pc, and the closest members of the loose association are found at an average distance of 660–730 pc, in agreement with most of the previous photometric investigations. Since the *uvbyβ* photometry is arguably the best photometric system in use to provide accurate photometric distances, the origin of the discrepancy was suggested to be in the *Hipparcos* parallaxes for the Cr 121 members. Burningham et al. (2003) studied the low-mass pre–main-sequence stars toward Cr 121 and also came to conclusions consistent with the photometric distance determinations.

In this Letter, we consider a sample of probable members of the extended association around Cr 121 selected by de Zeeuw et al. (1999) for which accurate *uvbyβ* photometry is available. The astrometric parameters of these stars are recomputed from the *Hipparcos* Intermediate Astrometry Data by the method proposed by Makarov (2002). The recomputed parallaxes allow us to resolve the controversy about the distance and dimensions of the OB association in this field.

2. RESULTS AND DISCUSSION

Our sample contains all 44 early-type stars with *Hipparcos* parallaxes listed by de Zeeuw et al. (1999) as probable members of the Cr 121 moving group for which *uvbyβ* photometry is available. Homogeneous photometric *uvbyβ* distances are calculated for 43 of them (Kaltcheva 2000). Table 1 presents the sample, where the *Hipparcos* identification numbers are given in the first column, followed by the *Hipparcos* parallaxes and their errors, recalculated parallaxes and their errors, photometric *uvbyβ* distances, and MK spectral classification. The stars are formally divided into field stars (or possible association members), spread over a 10° × 10° area around the center of Cr 121 and six photometrically selected members of the dense cluster Cr 121 (Kaltcheva 2000 and references therein). As follows from the data in Table 1 there is a statistically significant difference between the mean *Hipparcos* parallax of 1.87 ± 0.15 mas and the mean recomputed parallax of 1.29 ± 0.15 mas. The errors provided here are the formal standard deviation of the mean computed from the formal errors of parallaxes.

Figure 1 shows the original *Hipparcos* parallaxes (*left plot*) and our recomputed parallaxes (*right plot*) versus the photometric parallaxes for the sample of 43 stars in Table 1. The *Hipparcos* parallaxes are on average larger than the photometric values by 0.52 ± 0.107 mas, where the quoted error is the sample standard error of the mean. This is a statistically significant difference of the same order as those found for the Pleiades and a few other Galactic clusters. On the other hand, the agreement is excellent between the mean photometric parallax and the mean corrected parallax (0.063 ± 0.158 mas). This supports our main conclusion that the *Hipparcos* parallaxes are systematically overestimated in this area of the sky. But Figure 1 also reveals another strange property of the original parallaxes. While the recomputed parallaxes are scattered fairly symmetrically around the line of unit slope in the right plot and their dispersion is in good agreement with the measurement errors, the original parallaxes are grouped tightly around the mean (1.87 mas) with a standard deviation of only 0.61 mas. This value is much too small for the estimated formal errors (mean 0.93 mas, rms 0.96 mas). We attribute this result to a strong selection effect in the method employed by de Zeeuw et al. (1999), which preferentially accepted stars with large measured parallaxes, i.e., mostly stars with positive errors "observed minus true." In combination with the correlated error of the mean parallax, this selection bias gives rise to doubt about the completeness and reliability of the present membership list.

The significant dispersion of both photometric and recomputed parallaxes also implies a complex morphology of this moving group having a considerable depth, as opposed to the previous conjecture of an association compressed in the radial dimension, similar to the nearby Sco OB2 association, as concluded by de Zeeuw et al. (1999). The group also appears to be located at a larger distance of ≃740 pc, rather than at ≃550 pc as follows from the mean *Hipparcos* parallax of the sample in Table 1. Based on a larger photometric sample, it has already been pointed out that the loose nearby structure defined by de Zeeuw et al. (1999) to be located at 592 ± 28 pc photometrically appears to be more distant by about 100 pc (Kaltcheva 2000). The parallaxes recalculated here support the photometric findings.

Our result implies that the problem of inaccurate mean parallaxes in *Hipparcos* affects more regions, and of larger angular area, than just a few small patches occupied by dense open clusters. This is not an irreversible situation, because the method of astrometric solution of the available *Hipparcos* data used in this Letter proves once again successful in correcting this error, despite its limitations. A more systematic and thorough comparison of *Hipparcos* data with distances

TABLE 1
THE SAMPLE

HIP	π (mas)	σ_π (mas)	π_r (mas)	σ_{π_r} (mas)	r (pc)	MK
Field Stars						
31436	1.14	0.90	0.67	0.94	1812	B2/B3 V
31901	2.05	1.06	0.95	1.07	1050	B5
32084	2.63	1.18	−1.02	1.09	664	B3 V
32101	1.24	1.07	−0.21	1.11	938	B9.5 III
32591	1.42	0.97	0.14	0.98	605	B8 V
33007	1.16	0.86	1.17	0.92	475	B4 V
33092	2.02	0.70	2.37	0.78	518	B1 Ib
33165	1.74	0.76	1.33	0.85	…	WN…
33260	1.19	1.10	0.98	1.11	930	B9 Ib/II
33294	1.43	0.69	0.82	0.77	681	B2 III/IV
33316	1.51	0.64	−0.32	0.73	632	B2/B3 III
33447	2.78	0.70	1.23	0.77	766	B2 III/IV
33523	1.70	1.23	−0.41	1.25	1697	B2 V
33532	2.24	0.73	1.04	0.85	539	B2.5 III
33611	2.05	0.70	1.40	0.76	722	B2 V
33621	1.70	0.93	0.29	0.98	764	B8 II/III
33666	2.33	0.68	0.90	0.76	740	B2 III
33673	1.68	0.72	0.56	0.78	923	B4 Vn
33721	2.46	0.74	1.43	0.81	706	B3 Vnn
33769	1.26	0.80	0.25	0.85	1077	B2/B3 V
33770	2.05	0.97	1.31	1.28	630	B2 IV
33804	3.17	0.59	3.29	0.66	365	B2/B3 III/IV
33814	2.31	0.93	2.44	0.97	887	B3 V
33846	1.41	0.74	2.04	0.80	647	B3 V
33865	1.75	1.18	−0.14	1.35	648	B3 IV
33888	1.35	1.13	1.38	1.14	793	B9 V+…
34041	1.79	0.66	1.48	0.72	521	B2/B3 V
34067	1.66	0.80	2.27	0.84	853	B3 III
34074	1.10	1.10	1.82	1.13	1597	B7/B8 III
34153	2.55	1.06	1.92	1.09	535	B8 V
34167	1.44	0.91	1.45	0.94	958	B2 IV
34219	1.95	1.67	2.94	1.38	665	B6 III
34227	1.04	0.94	0.90	0.97	757	B3 V:n
34281	1.28	1.03	1.16	1.04	842	B5 V
34331	2.23	0.65	1.11	0.71	534	B2 IV-V
34579	1.78	0.60	1.64	0.68	368	B2 V
34940	2.07	1.24	3.18	0.98	676	B2 IV
35026	1.44	0.78	2.34	0.83	1435	B2 IV/V
Cr 121						
32823	1.92	1.23	2.41	1.26	944	B5 V
32911	3.49	1.02	2.75	1.05	1012	B8 IV/V
33062	1.22	0.96	0.81	1.02	947	B2 II/III
33070	2.30	1.13	0.97	1.17	1291	B3 II/III
33208	1.77	1.14	1.16	1.16	981	B3 V
33211	3.46	1.08	2.51	1.11	1131	B3 V

NOTE.—Identifications from the *Hipparcos* catalog, followed by the *Hipparcos* parallaxes π and their formal errors σ_π, the recalculated parallaxes π_r and their formal errors σ_{π_r}, the photometric *uvbyβ* distances r, and the MK classification.

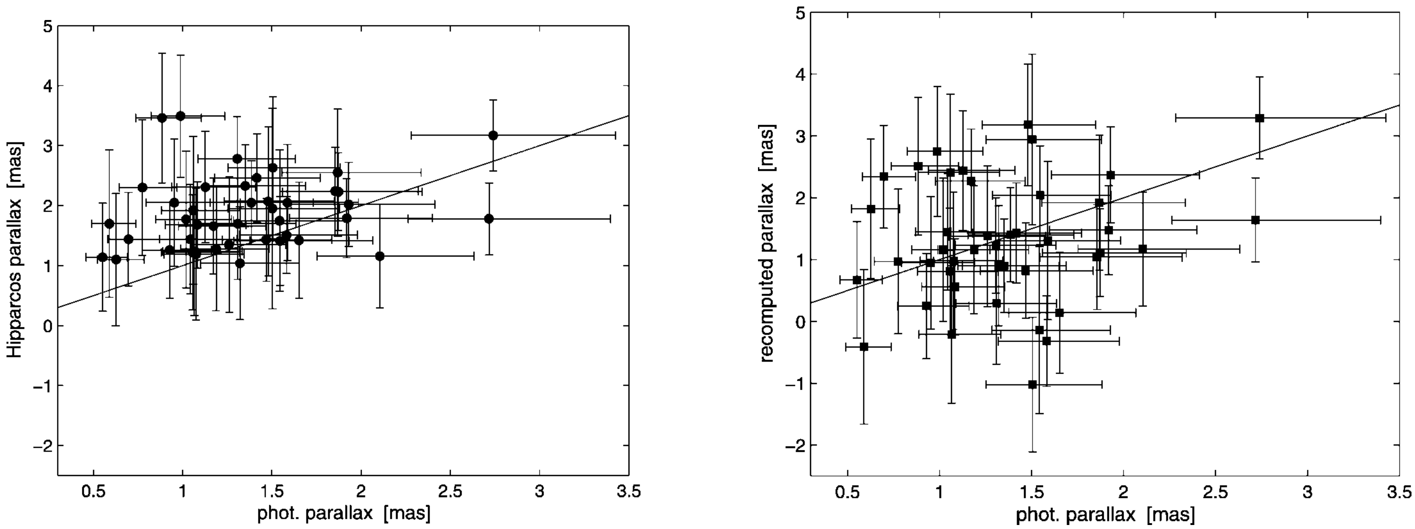

FIG. 1.—Differences between the *uvbyβ* photometric parallaxes and *Hipparcos* parallaxes (*left plot*), and the parallaxes recomputed in this Letter (*right plot*) for stars in the area of Cr 121. The error bars of the photometric parallaxes correspond to the maximum estimated error in the photometric distances of 20%.

from precision multiband photometry will probably reveal more problematic areas. It is not clear at present how widely spread the parallax error is, and whether a global astrometric solution will have a significant impact on the present knowledge of distances and morphology for many of the OB associations represented in the catalog, but it is evident that the *Hipparcos*-based census of some of the moving groups near the Sun should be critically reconsidered.

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