Positions of Bright Stars determined with the 1.3m Telescope and ND9 Detector

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Internal Memo

March 30, 2004

Abstract

Positions of four bright stars were determined with the 1.3m telescope and ND9 camera. (Observed - Hipparcos) differences in position range from 3 to 69 mas with a mean value of 26 mas. In only one case is the derived difference significant with respect to its formal error. Numerous improvements are possible which should enable more stars to be observed and better accuracies achieved in a future program.

1. Observations and Reductions

All the observation were taken in late February, 2004 with the 1.3-meter telescope equipped with the ND9 2048^2 (24μm pixel) camera which gives a scale of 0.960 arcsec pix^{-1}. A nine magnitude attenuating spot (130 pixels in diameter) is located at the center of the CCD which enables unsaturated images of bright stars to be observed simultaneously with much fainter stars (11 to 17 mag). Since the ND9 camera has never been on the 1.3m telescope before, one night of observing was devoted to characterizing the ND9 detector system. The best focus setting was found to be 2014, which nevertheless produced large images (FWHM $\sim$ 3 arcsec) and significant variations in the image quality across the CCD. Because of the thickness of the ND9 mounting plate, the camera could not be focused at the design focus of the telescope thereby causing the larger images and distortions. Nonetheless, good astrometry is possible if care is taken in the reductions.

The 1.3m telescope is equipped with a number of broadband filters (WR, I, R, V, B, and UCAC) which could not be used to take the observations presented in this study. In order to have unsaturated images of the bright stars, exposure times for each of these passbands would have to be under 45s, meaning each frame would be strongly affected by positional errors induced by the atmosphere. As a result, the B-filter was replaced with a narrow band R filter (NR) which enabled longer exposure times to be used. Unfortunately, the NR filter is very narrow, and exposures of 10 minutes or more would be needed for well exposed images. Since 1.3m guide errors become significant for exposures longer than 5 minutes, an exposure time of 5 min was adopted and used to take all the data presented herein.

Each star was observed generally with four 5 min exposures taken with the camera in the θ_R = -90° orientation, and then four additional frames were taken after the camera was rotated by 180°. The purpose of this procedure was to improve the systematic accuracy of the derived stellar positions by combining the direct and reversed sets of CCD frames.

Each CCD frame was reduced to positions using reference stars taken from the UCAC2 catalog and standard differential reductions. The least-squares solutions in each coordinate included eight unknowns in order to obtain a good tie in between the reference and observed stars positions. The polynomial fits do not allow for small systematic errors in position across the CCD. These were calibrated from an residual analysis and used as a look up table in the reductions. In general, the formal errors of the derived positions of bright stars were better than ±20 mas in each coordinate.

2. Positions of Bright Stars

Bright stars were observed from a list of candidates supplied by Jim Benson. Because of bad weather, only seven stars were observed, and three of these were later rejected because of duplicity. In two cases, the bright star's image was asymmetrical indicating the presence of a nearby companion. One other star, λ UMa, was later rejected, since it showed a large offset in position and, in addition, was flagged in the Hipparcos catalog as a very likely close visual double. Hence, only four stars (θ Aur, α Leo, ϵ Ori, and δ CNC) are included in this pilot study.

The results for these stars are summarized in Table 1, where columns 1 and 2 give respectively the star name and ID number in the Hipparcos catalog; columns 3 and 4 are the ICRS Hipparcos equatorial positions at J1991.25; column 5 is the visual magnitude; columns 6 and 7 are (observed - Hipparcos) differences in coordinate position at the epoch of the observations [i.e. (O - C)$_\alpha = \Delta\alpha(O-C)\cos\delta$ and (O - C)$_\delta = \Delta\delta(O-C)$]; and the last column gives the mean number of UCAC2 reference stars used in each determination. The main limitation on the accuracy is probably the number of reference stars used. With more reference stars, the polynomial fits could be better determined, and as a result, the errors in the derived positions are expected to improve. Certainly, more reference stars in the solutions are possible, since the limiting magnitude of the observations presented in Table 1 is about R $\sim$ 15.2, and the UCAC2 catalog extends another magnitude fainter. The limiting magnitude could have been extended if exposure times exceeding 5 min had been possible (see the discussion in the previous section).

The (O - C)s given in the table are generally < 50 mas, and in only one case is there a 3-σ result. The formal errors range from ± 12 to ± 30 mas. It is important to note that these (O - C) differences do not include any possible rotation in the Hipparcos coordinate system, because the UCAC2 catalog used in this study was determined differentially from the Tycho-2 star catalog which is tied into the Hipparcos coordinate system. Nonetheless, the (O - C)s give information about positional errors at the current epoch resulting from errors in the proper motions. According to the Hipparcos catalog, Hipparcos positions of bright stars should be accurate to ± 13 mas at the current epoch. The data in the table neither confirms or denies that result.

2.1. Further Improvements

The results presented herein are based only on four stars. When the 1.3m telescope becomes fully operational (and automated), many more stars could be observed thereby giving better statistical results. Moreover, the observations can be improved in a number of ways which should give better accuracies: 1) When the guider on the 1.3m telescope becomes operational, longer exposure times will be possible enabling more reference stars to be observed; 2) If the adapter plate for the ND9 camera is machined down, the image quality could be significantly improved; 3) Eventually the telescope will be able to accurately set on objects. In this study, the bright star could not be placed and keep at the center of the attenuation disk because of pointing and guiding errors. In the future, this should be possible, and as a result, there could be an improvement in the systematic accuracy of the derived positions; and 4) The small order systematic errors across the CCD could be better determined with more observations.

Table 1. (1.3 observed - Hipparcos) differences in position at epoch 2004.170

Star	HIP No.	RA	Dec	V	$(O\text{-}C)_\alpha$ (mas)		$(O\text{-}C)_\delta$ (mas)		N_{ref}
θ Aur	28380	5 59 43.23815	37 12 45.9507	2.6	–24 ±	12	3 ±	22	197
α Leo	49669	10 8 22.45938	11 58 1.9025	1.4	69	14	12	30	30
ϵ Ori	26311	5 36 12.81257	–1 12 6.9021	1.7	6	16	–29	16	137
δ CNC	42911	8 44 41.11010	18 9 17.5104	3.9	–49	18	14	28	52