Pixel Scale and Orientation of Pharo Determined from the Binary Star HD 165341

1. Observations and Analysis

The binary star HD 165341 was observed with the Palomar 200-inch telescope using Pharo + AO at the f/29.91 focal ratio on 2002 Jun 23 for the purposes of determining the plate scale and the location along the cass ring of true north. HD 165341, a bright (V=4 mag) $4''.55$ binary, has an accurately determined orbit (grade 1) with orbital parameters listed in both Pourbaix (2000, A&AS, 145, 215) and the 6th Catalogue of Visual Orbits. The observations were obtained using the Brγ filter in combination with a 1% neutral-density filter. Twenty-eight exposures were obtained in different positions around the array, although not in a strict grid. Exposure times were $\sim$ 1.8 seconds each. The observations range in airmass from 1.59 to 1.75.

The relative positions of the binary components are determined via the centering algorithm "gauss" of the "daophot" package in IRAF. The gauss algorithm determines the centers by fitting a 1D Gaussian function along both the x and y axes within a specified box size, using a fixed full-width at half-maximum value. Based on visual inspections of radial fits to the diffraction cores of the binary components, we adopt a box size of 5 pixels and a full-width at half-maximum of 3.7 pixels. The measured separations and orientations are then compared with the predicted values (from the orbital solution at this epoch) to determine both the pixel scale and ring rotation of true north.

2. Results

Pixel Scale (Figure 1) - Based on 28 measurements of HD 165341, the average plate scale is 25.168 ± 0.034 mas/pix, with a standard deviation of 0.083 mas/pix. The uncertainty in the plate scale is determined by adding the uncertainty in the mean and the uncertainty in the binary's semi-major axis ($0''.0052$, Pourbaix 2000; normalized by the separation of 172.24 pixels) in quadrature. The measured plate scale is 2.0σ or 0.8 standard deviations greater than the value quoted in Hayward et al. (2001, PASP, 113, 105; 25.10 mas/pixel).

Ring Angle of North (Figure 2) - Based on 28 measurements of HD 165341, the average ring angle of north is 334.034 ± 0.099 degrees, with a standard deviation of 0.093 degrees. The uncertainty in the angle is determined by adding the uncertainty in the mean and the uncertainty in the binary's ascending node (0.097 degrees, Pourbaix 2000) in quadrature.

The determined value of north is significantly different from both the nominal value (335.0) and the value suggested by the evening staff (e.g. R. Burruss) on 2002 Jun 23 (335.8). The evening staff suggest the uncertainty in the ring angle of north is 0.5 degrees.

Positional Dependent Solutions (Figures 3 & 4) - The multiple measurements of HD 165341 reveal a positional dependence on the array in both the pixel scale and the ring angle of north. The position of each measurement is set as the mid-point between the 2 binary star components. Larger pixel scale values (by $\sim 1\sigma$) are found in the upper-left corner of the array (small x, large y), while smaller pixel scale values (by $\sim 1\sigma$) are found in the lower-right corner of the array. The ring angle of north exhibits a similar spatial dependence, of comparable magnitude.

Linear Fits to the Positional Dependence (Figure 5) - Linear least squares fits are determined for the pixel scale and ring angle of north as functions of the distance along an axis connecting the upper-left and lower-right corners of the array. The best fit relations are $scale = -0.000358 \times d + 25.370$ mas/pixel, and $north = -0.000357 \times d + 333.833$ degrees, where d is the distance along the diagonal axis. From corner to corner, these relations predict a variation in the pixel scale and north rotation angle of 0.5 mas/pixel and 0.5 degrees, respectively.

3. Interpretation

These results were discussed at the Caltech/JPL Adaptive Optics group meeting on 2002 July 9. The general opinion was that the nominal pixel scale and ring angle of north values have only been determined theoretically, not empirically. Thus, additional observations of astrometric fields (e.g. binary stars or clusters) would be helpful in establishing these values and determining their long-term reliability.

Although the positional dependence of the pixel scale and ring angle of north are not understood, the may be caused by optical distortions in the light path. Observations of astrometric fields at different ring rotations could help isolate the distortions, depending on whether the positional dependences rotate with the field-of-view or not. Optical distortions should also be more prominent using the wider field-of-view (i.e. f/18.69 focal ratio).

Given that the observations described here took $\sim 20 - 30$ minutes to acquire, it is suggested that observers interested in accurate astrometry across the full field of PHARO obtain similar data during their observing run.

- Russel White (July 9, 2002)

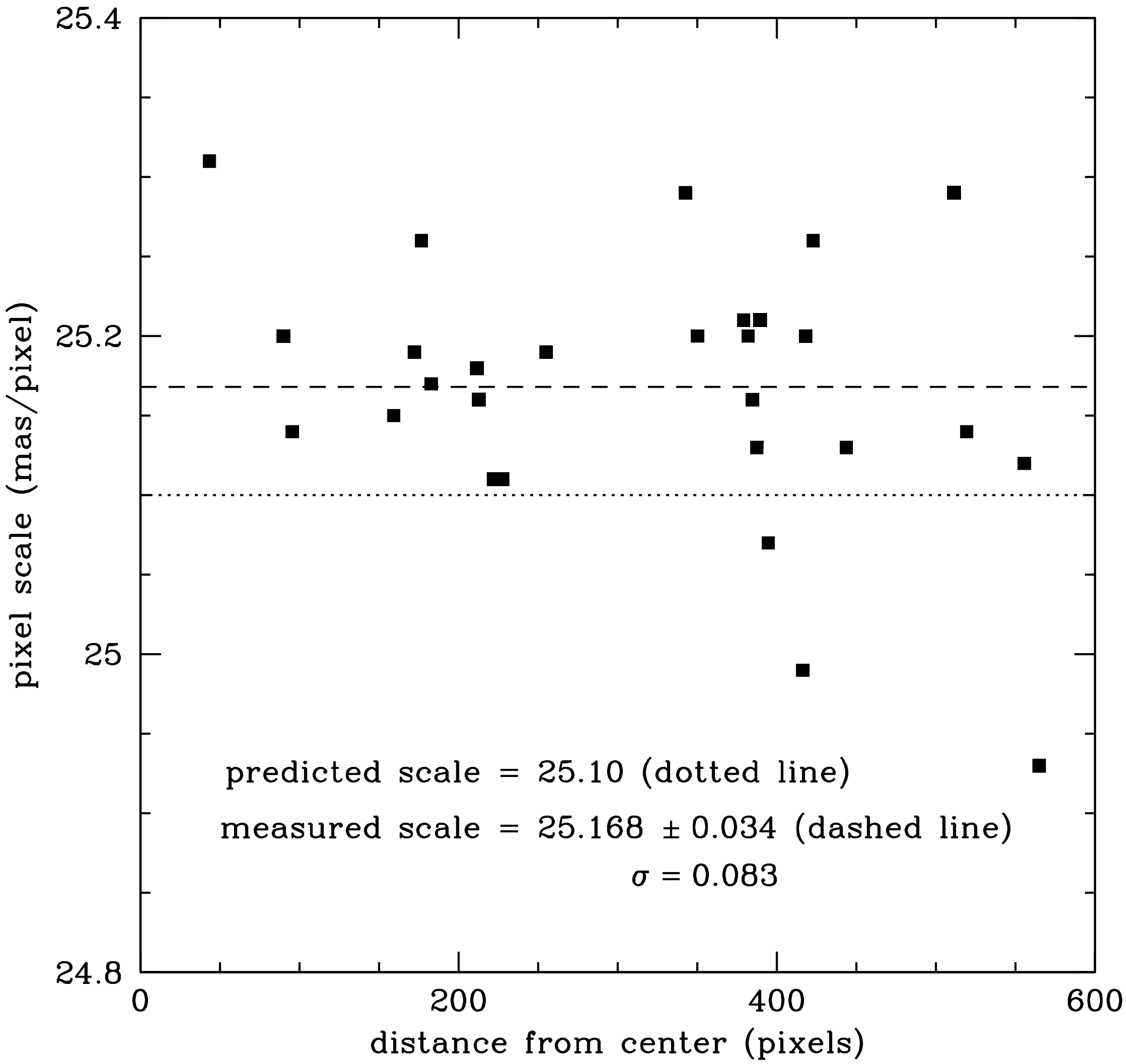

Fig. 1.— Pixel scale determined from 28 measurements the binary star HD 165341 versus distance from the center of the array to the mid-point of the binary separation.

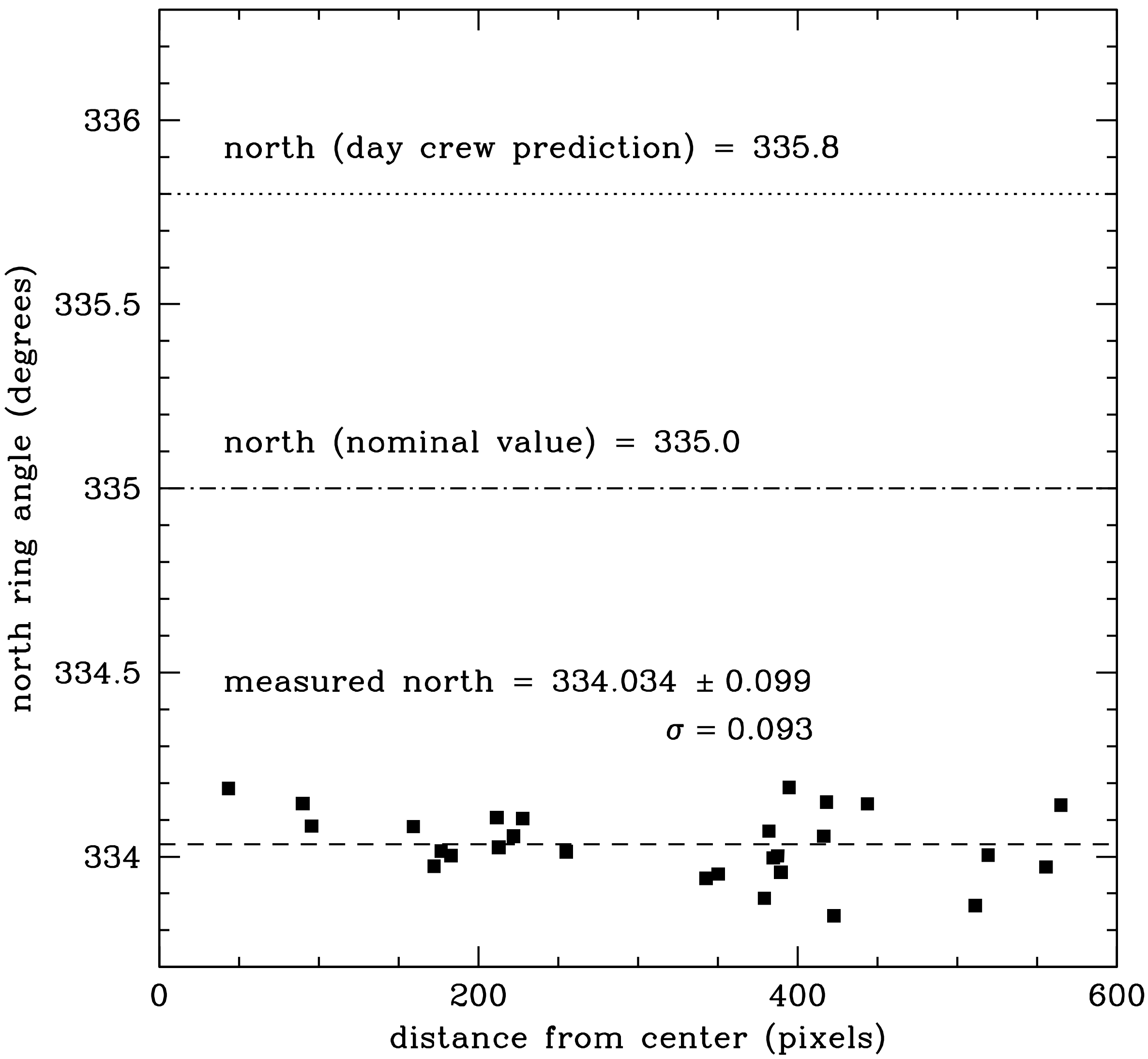

Fig. 2.— Ring rotation of north determined from 28 measurements of the binary star HD 165341 versus distance from the center of the array to the mid-point of the binary separation.

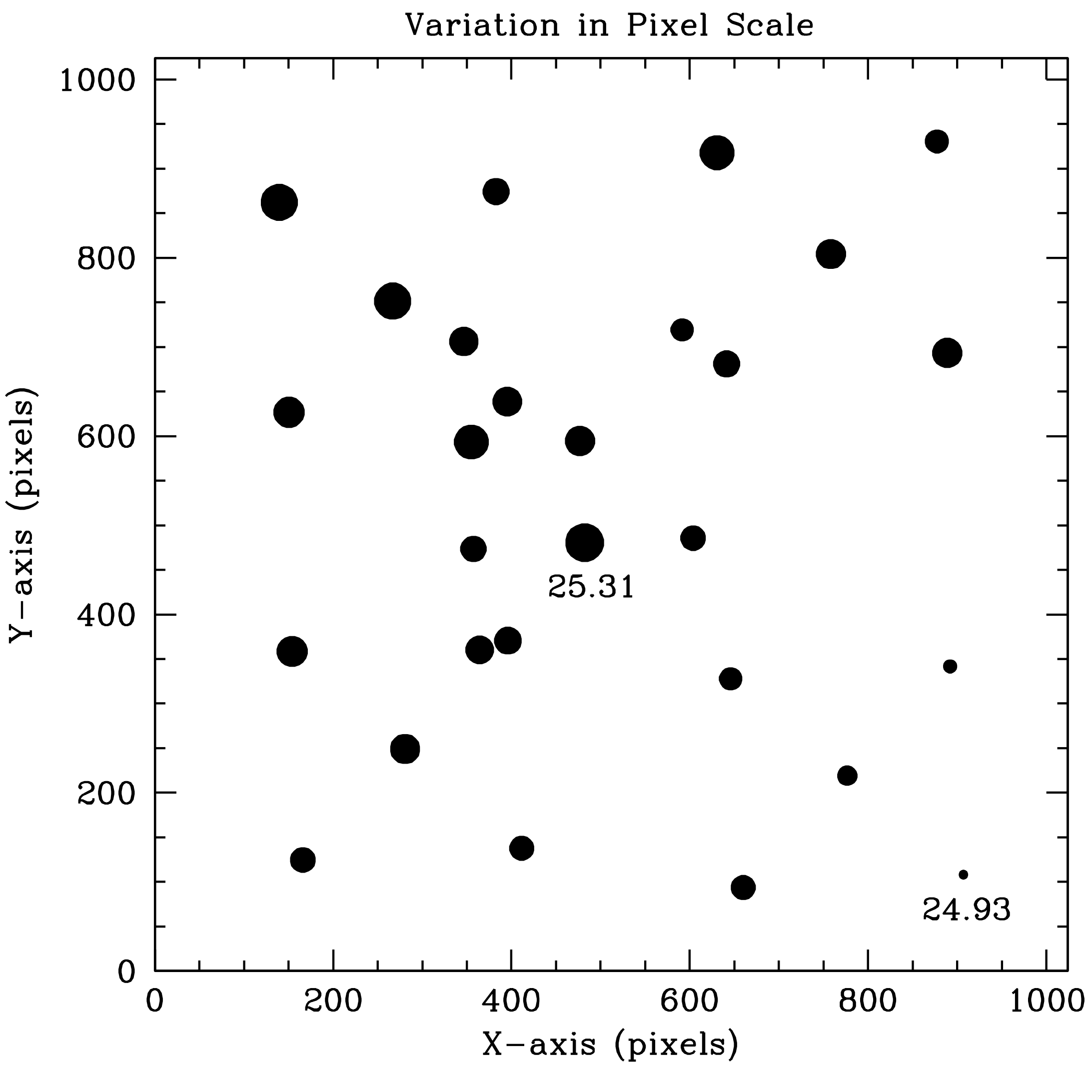

Fig. 3.— Positional dependence of the pixel scale. The point size indicates the pixel scale, decreasing linearly from the largest value of 25.31 mas/pixel (*largest circle*) to the smallest value of 24.93 (*smallest circle*).

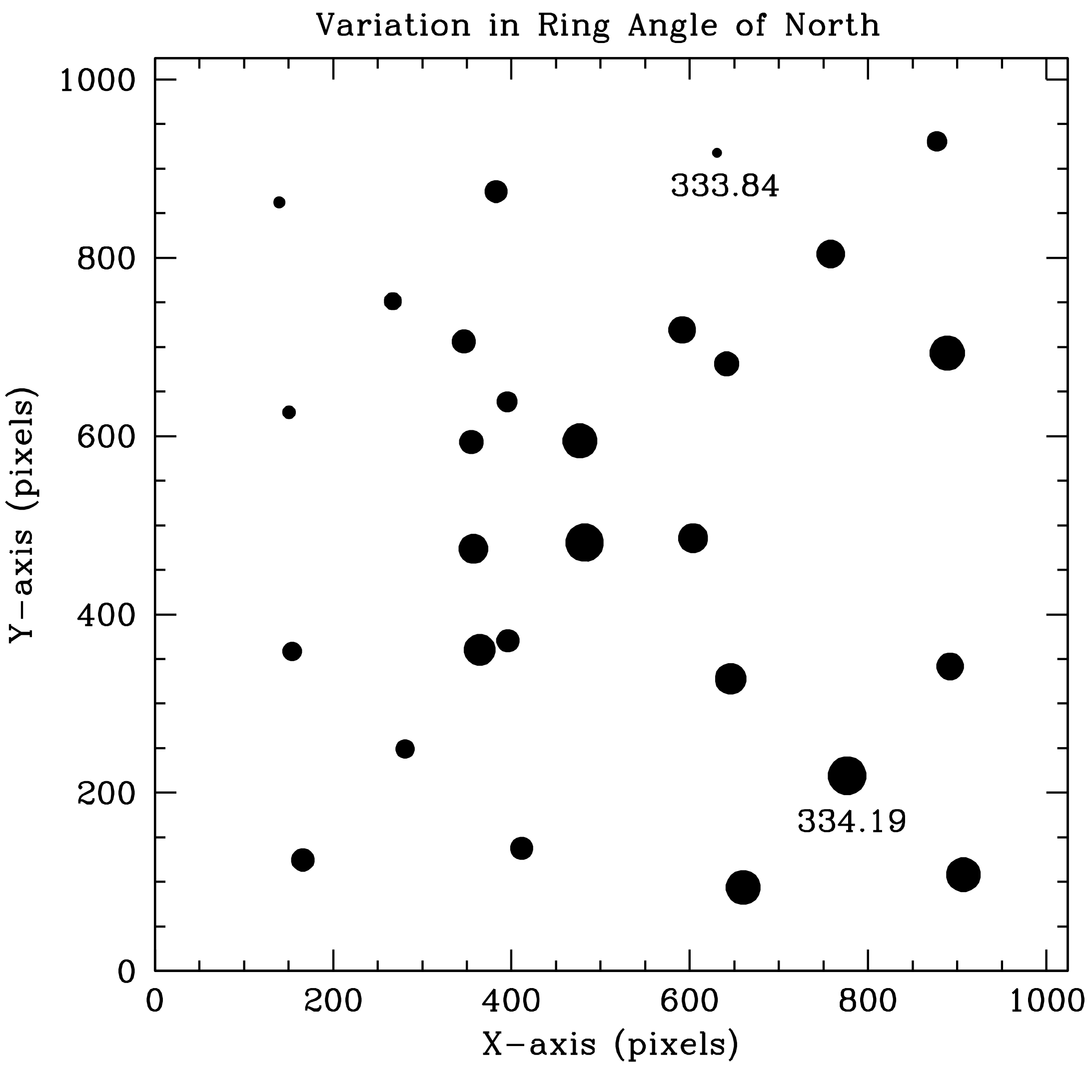

Fig. 4.— Positional dependence of the ring angle of north. The point size indicates the variation in the angle, changing linearly from one end at 333.84 degrees (*smallest circle*) to the other end at 334.19 degrees (*largest circle*).

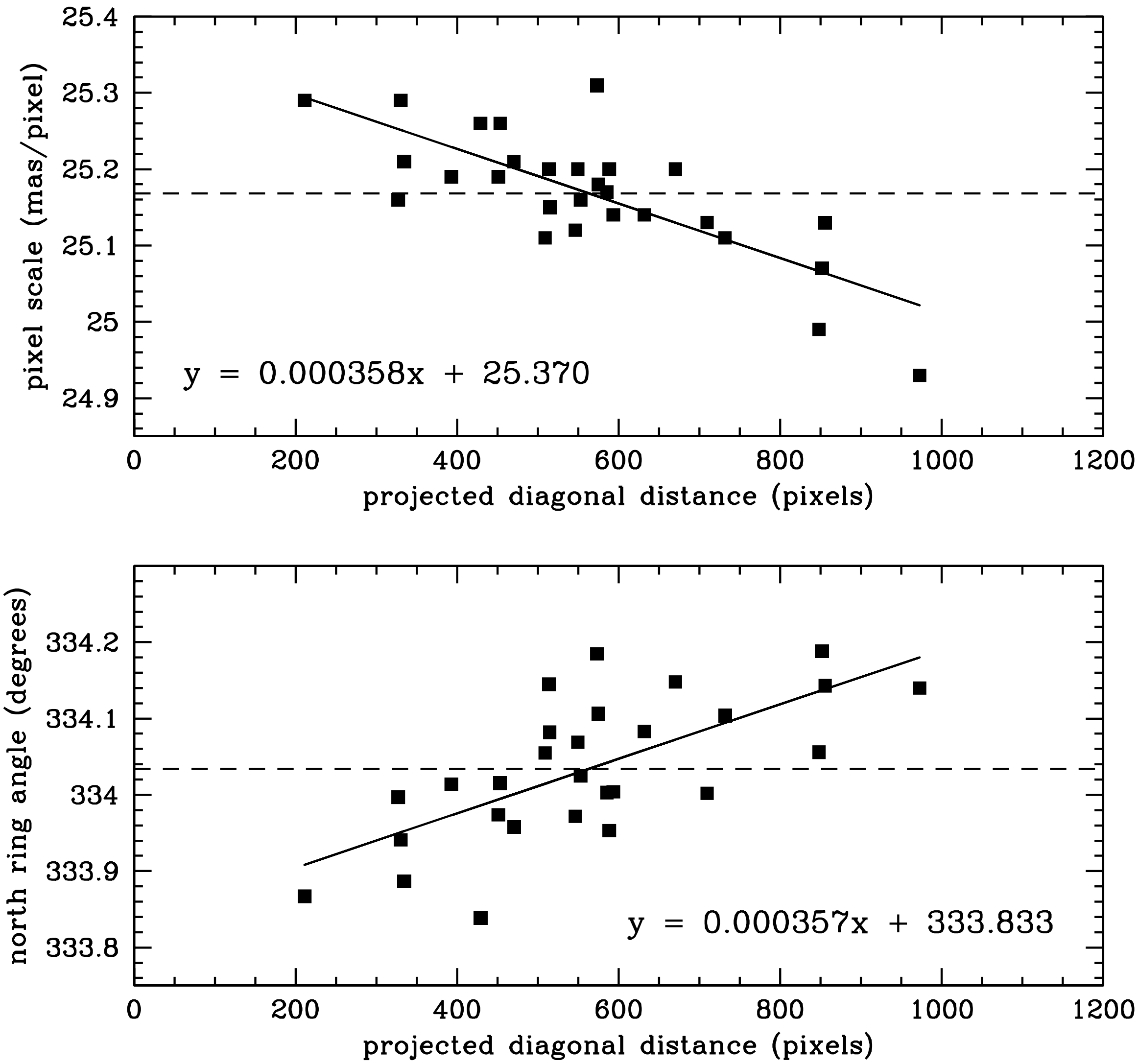

Fig. 5.— Linear least squares fits for the pixel scale (*top panel*) and the ring angle of north (*bottom panel*) as functions of the distance along an axis connecting the upper-left and lower-right corners of the array.