

## Research Note

# Adaptive Optics Observations of Arcturus using the Mount Wilson 100 Inch Telescope

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**ABSTRACT.** Upon inspection of the multiple-star results in the *Hipparcos* catalog, the flag for entry number 69673 particularly stands out; it is Arcturus, for which no companion has been reported previously. The *Hipparcos* companion is reported to be at a separation of  $0''.255 \pm 0''.039$  with a magnitude difference in a broadband filter (peaked near 460 nm) of  $3.33 \pm 0.31$ . We present recent results using the natural guide star adaptive optics system on the Mount Wilson 100 inch telescope showing Arcturus to be a single star.

## 1. INTRODUCTION

The *Hipparcos* catalog (European Space Agency 1997) has reported the existence of a companion to Arcturus (HR 5340) at a separation of  $0''.255 \pm 0''.039$  and a magnitude difference of  $3.33 \pm 0.31$  (J1991.25). The fit to two components has been given a grading of “A”—a good or reliable solution that was obtained by combining two first-class solutions in good mutual agreement. No companion to Arcturus is indicated in a recent spectroscopic binary catalog (Batten, Fletcher, & MacCarthy 1989), 20 foot (6.1 m) beam interferometer on the Mount Wilson 100 inch (2.5 m) telescope (Merrill 1922) or by speckle interferometry with the Palomar 200 inch (5 m) telescope (Blazit et al. 1977). Finally, a companion is not listed in the Washington Double Star (WDS) catalog,<sup>1</sup> a very comprehensive compilation of visual multiple-star detections and measurements. If Arcturus were a double, its historic use as a radial velocity standard (Griffin 1998) and photometric standard (Johnson et al. 1966) would cast into doubt some of the conclusions of archival data. A history of Arcturus as a radial velocity standard and its historical duplicity status is given in Griffin (1998).

In 1994 January construction began on a natural guide star adaptive optics (NGS-AO) system at the Cassegrain

focus of the Mount Wilson 100 inch telescope. The system features a Shack-Hartmann wavefront sensor driving an ITEK 241 actuator deformable mirror. The heart of the wavefront sensor is a front-side illuminated,  $32 \times 32$  CCD array with 32 skipper output amplifiers. This arrangement allows frame rates up to 3.3 kHz. The wavefront sensor processing chain employs eight Texas Instruments 320-C40 digital signal processors hosted in a Pentium class machine running OS/2. The user interface allows complete, remote operation of all adjustable optics and electronics and is designed for one-person operation. Further details can be found in Shelton et al. (1995). With installation of a liquid nitrogen cooled  $1024 \times 1024$  CRAF-Cassini CCD at the corrected output in 1994 July, the NGS-AO system became routinely operational. In 1997 March, the CRAF-Cassini CCD was upgraded to a more sensitive and cosmetically clean front-side-illuminated CCD.

## 2. REDUCTION OF DATA

The data for Arcturus were taken on the night of 1998 July 27 UT using an  $H\alpha$  filter. The seeing conditions at the time of data collection were on the subarcsecond level. The observation procedure consisted of taking 50 short-exposure images (0.05 s) in rapid succession (about 2 s delay) to minimize the tip-tilt errors in the system. The frames were debiased and flat-fielded and a weighted shift-and-add algorithm was used to remove any frame-to-frame

<sup>1</sup> The Washington Double Star catalog is available on the World Wide Web at <http://aries.usno.navy.mil/ad/wds/wds.html>.

tip-tilt errors. The weighted shift-and-add algorithm (ten Brummelaar et al. 1998) is a modification of the traditional image stacking algorithm which takes the seeing conditions in each individual frame into account. The frames with the higher peak values (and therefore the better seeing) influence the final image more than the frames with the lower peak values. A contour plot of the resulting image is shown in Figure 1. The image scale is  $0''.0216 \text{ pixel}^{-1}$ . The units of the axes are arcseconds with the zero point in the center of the image.

To show the capabilities of the system, we have included an image of the bright component of Albireo (HR 7417 = ADS 12540 Aa = MCA 55 Aa) taken with the same system approximately 2 years earlier under similar seeing conditions. The data were taken on the night of 1996 July 1 UT using an *R*-band filter. In the case of this object, the separation was determined to be  $0''.40 \pm 0''.02$  with a magnitude difference of  $3.47 \pm 0.26$ . A contour plot of the resulting image is shown in Figure 2. The contours shown in Figure 2 are in the same proportion to the peak value as those shown in Figure 1.

### 3. CONCLUSION

Because magnitude difference detection limits of multiple stars vary with primary brightness and primary-secondary separation, we have taken a further step to characterize the detection limits of the NGS-AO system with respect to Arcturus. We characterized the noise in an annulus about Arcturus. The radius was set to the separation stated in the *Hipparcos* catalog with an average width of 2 pixels. We calculated the standard deviation of the noise in the annulus and determined that we should be able to detect a companion 4.5 mag dimmer than Arcturus with  $3\sigma$  certainty. In practice, we have been able to detect companions closer to the  $1\sigma$  limits. Clearly, there is no companion to Arcturus meeting the description stated in the *Hipparcos* catalog.

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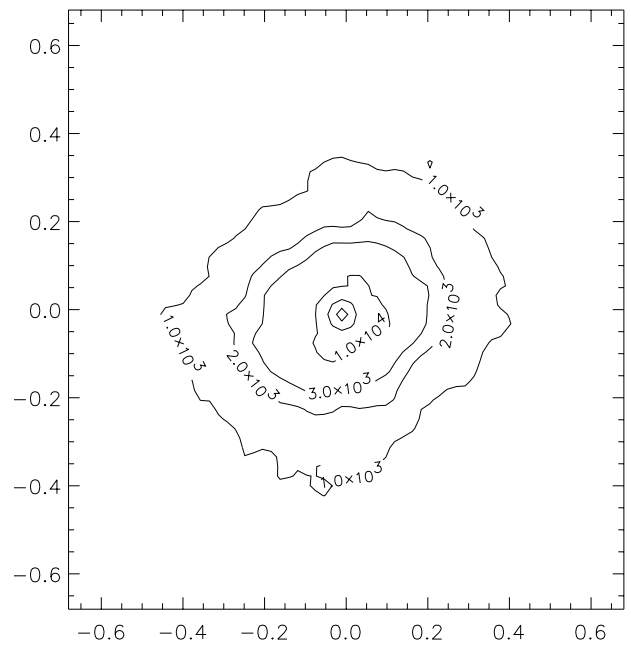


FIG. 1.—Contour plot of Arcturus. The units of the axes are arcseconds. North is up, and east is to the left.

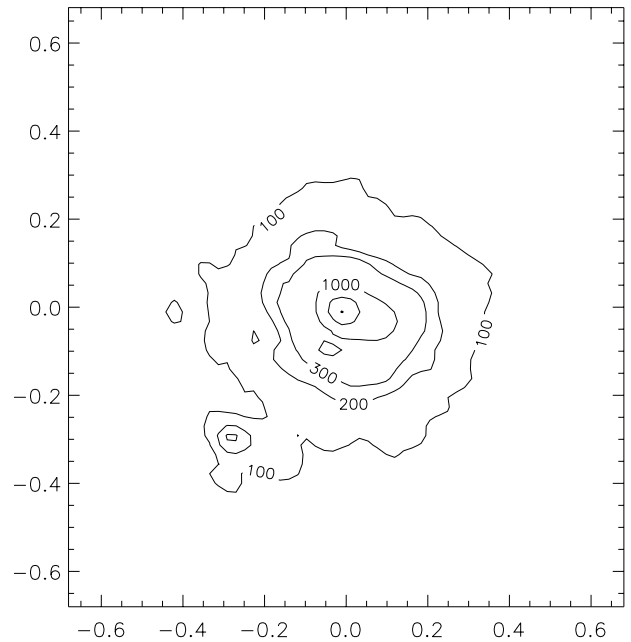


FIG. 2.—Contour plot of the bright component of Albireo, showing a definite companion. The companion is of a magnitude difference and separation similar to that predicted by *Hipparcos* for Arcturus. The contour lines shown are in the same proportion to the peak value as those in Fig. 1. The units of the axes are arcseconds. North is up, and east is to the left.

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