

Adaptive Optics Observations of Arcturus using the Mount Wilson 100-inch Telescope

Nils H. Turner

Mount Wilson Institute and
Center for High Angular Resolution Astronomy
Georgia State University

Theo A. ten Brummelaar

Center for High Angular Resolution Astronomy
Georgia State University

and

Brian D. Mason

United States Naval Observatory

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ABSTRACT

Upon inspection of the multiple star results in the *HIPPARCOS* catalog (European Space Agency, 1997), 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 ± 0.039 arcsec with a magnitude difference in a broadband filter (peaked near 460 nm) of 3.33 ± 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.

Subject headings: stars: individual (Arcturus, Albireo) — techniques: adaptive optics

1. INTRODUCTION

The *HIPPARCOS* catalog has reported the existence of a companion to Arcturus (HR 5340) at a separation of 0.255 ± 0.039 arcsec and a magnitude difference of 3.33 ± 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 the most recent compilation of lunar occultation doubles (Mason, 1995), a recent spectroscopic binary catalog (Batten et al., 1989), 20-foot beam interferometer on the Mount Wilson 100-inch telescope (Merrill, 1922), or by speckle interferometry with the Palomar 200-inch telescope (Blazit et al., 1977). Finally, a companion is not listed in the Washington Double Star (WDS) catalog (available on the World Wide Web at <http://aries.usno.navy.mil/ad/wds/wds.html>), 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 very thorough history of Arcturus as a radial velocity, photometric, and spectro-photometric standard and its historical duplicity status is given in Griffin (1998).

In January of 1994, 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, 32×32 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 1024×1024 CRAF-Cassini CCD at the corrected output in July 1994, the NGS-AO system became routinely operational. In March 1997, 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 27 July 1998 UT using an $H\alpha$ filter. The seeing conditions at the time of data collection were sub-arcsec. The observation procedure consisted of taking 50 short exposure images (0.05 seconds) in rapid succession (about 2 seconds 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 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 arcsec per pixel. The units of the axes are arcsec 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 1 July 1996 UT using an R-band filter. In the case of this object, the separation was determined to be 0.40 ± 0.02 arcsec with a magnitude difference of 3.47 ± 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 two 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 three sigma certainty. In practice, we have been able to detect companions closer to the one sigma limits. Clearly, there is no companion to Arcturus meeting the description stated in the *HIPPARCOS* catalog.

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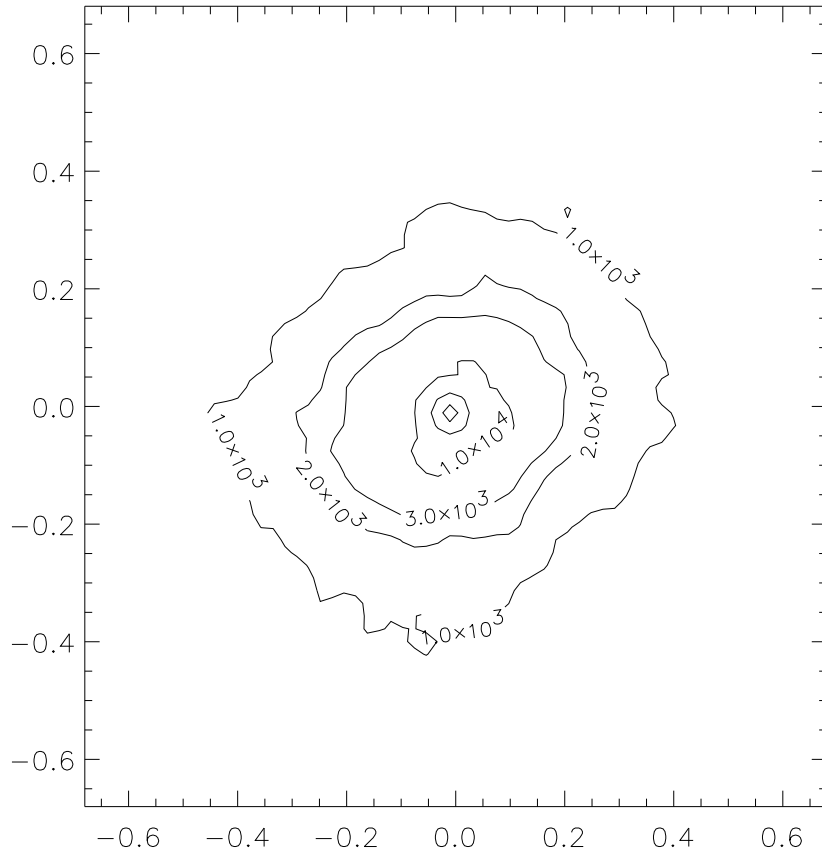


Fig. 1.— This is a contour plot of Arcturus. The units of the axes are seconds of arc. North is up and east is to the left.

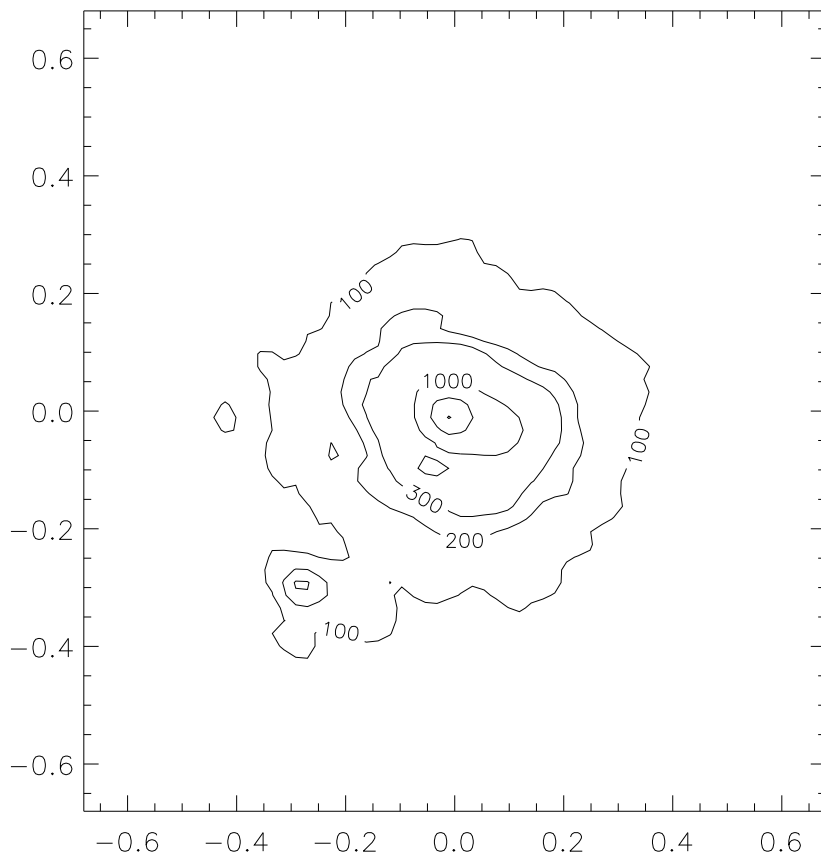


Fig. 2.— This is a contour plot of the bright component of Albireo, showing a definite companion. The companion is of a magnitude difference and separation similar to that predicted by *HIPPARCOS* for Arcturus. The contour lines shown are in the same proportion to the peak value as those in Figure 1.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