COMMISSIONS 27 AND 42 OF THE IAU
INFORMATION BULLETIN ON VARIABLE STARS
Number 4480

Konkoly Observatory
Budapest
26 May 1997

HU ISSN 0374 – 0676

ALDEBARAN: DISCOVERY OF SMALL AMPLITUDE LIGHT VARIATIONS

Aldebaran (Alpha Tau = HD 29139) is one of the nearest and brightest red giant stars. It is a standard spectroscopic star with a spectral type of K5 III; its average visual magnitude is about +0.87 mag with mean values of B−V = +1.52 and U−B = +0.90. Aldebaran has a relatively well determined parallax of 0.048 ± 0.005 arcseconds that should improve after the Hipparcos parallax is published. The star also has relatively high space motions with respect to the sun, indicating that it is an old, evolved disk star.

Because of its brightness and accessibility from both ground-based and orbiting observatories, it has been a favorite target of numerous studies. It is listed in the Bright Star Catalog (Hoffleit, 1982) and SIMBAD as a variable star and Petit (1982) classifies it as an Lb-type irregular star. In the literature the visual magnitude range is from $V \cong +0.78$ to +0.93; most of these visual magnitude measurements are from surveys. It should be noted that reported variability for bright stars such as Aldebaran can sometimes have systematic errors due to saturation effects of the detectors and the lack of nearby appropriate comparison and check stars. Hence some of the early visual magnitude values of Aldebaran should be treated with caution.

The only concerted photometric study of Aldebaran was done by Krisciunas (1992). He obtained V-band photometry over 3 observing seasons (1987/88, 1990/91, and 1991/92). However, the photometry was conducted only 4 to 5 nights per season and a total of only 13 nights of data were obtained. Krisciunas found no indication of variability of greater than 0.02 magnitude, and reported Aldebaran to be "essentially constant" within the precision of his measurements. He found mean values of $\langle V\rangle = +0.876 \pm 0.004$ magnitude and $\langle B-V\rangle = +1.549 \pm 0.026$ magnitude. The study of Krisciunas does not support the relatively large ≈ 0.1 light variations reported in the survey data, but there is not sufficient coverage or precision to discern low amplitude brightness changes. To understand and better quantify the photometric behavior of Aldebaran, we undertook a more intensive program of differential photometry of this famous, bright star.

In August 1996, Aldebaran was added to the program of photometry of cool giants and supergiants being carried out by us at Wasatonic Observatory and Villanova University Observatory. The photometry reported here was conducted from August 1996 to March 1997 at the Wasatonic Observatory (Allentown, Pennsylvania) on 31 nights using an uncooled Optec photometer attached to a 20-cm Schmidt-Cassegrain telescope. The detector employed was a silicon PIN-photodiode. Differential photometry was conducted primarily with the V-band but on several nights the star was also observed with the Wing near-IR three filter intermediate band system to measure TiO (Wing, 1992). The characteristics of the Wing three-color system are given in Table 1. The TiO index is calculated according to Wing from:

$$\text{TiO-Index} = A-B-0.13\times(B-C)$$

Table 1. The Wing filter system

Filter	Region Measured	Central Wavelength	Bandpass (FWHM)	Measurements
A	TiOγ(0,0) Band	7190 A	110 A	TiO-Index
B	IR Continuum	7540 A	110 A	B-C Color Index
C	IR Continuum	10400 A	420 A	B-C Color Index

Table 2. Photometric data

JD 2450+	Visual magnitude
324.847	+0.871
356.800	+0.868
365.881	+0.877
380.850	+0.882
402.630	+0.870
418.649	+0.872
426.553	+0.867
438.583	+0.865
455.605	+0.877
470.526	+0.882
477.658	+0.880
483.546	+0.877
504.549	+0.873
517.591	+0.875
531.520	+0.876

where A, B, and C are standardized magnitudes measured with these filters A near-IR color index is also formed from these observations, and is useful for determining the temperature of cool stars. This color index is defined as:

$$\text{IR Color Index} = \text{B}-\text{C}$$

where B and C are the magnitudes measured at 7540 A and 10,400 A, respectively, which are regions clear of molecular absorption.

The comparison star was ϵ Tau (HD 28305; V = 3.50, B$-$V = 1.04, G9.5 III), which is itself a wing IR standard star, and the check star used was π Tau (HD 28100; V = 4.69, B$-$V = 0.98, G7 IIIa). Three ten-second integrations were made for each observation using the usual sky-comparison-variable-comparison-sky sequence. Atmospheric extinction and conversion to heliocentric Julian Day number was done during data reduction. Corrections for the V-band observations to the standard UBV system was also done; IR magnitudes were standardized using magnitude values supplied by Wing (1979).

Nightly and weekly means were computed from the V-data and these are plotted against heliocentric Julian Day in Figure 1, and tabulated in Table 2. As can be seen, the light variations observed over the 6-month period are relatively small. Systematic trends in the data and spline-fits were applied to see if any regularities in the light variations could be found. As shown in Figure 1, Aldebaran appears to vary on a time-scale of about 85-95 days; the full light variation is 0.018 magnitude. To check this period analytically,

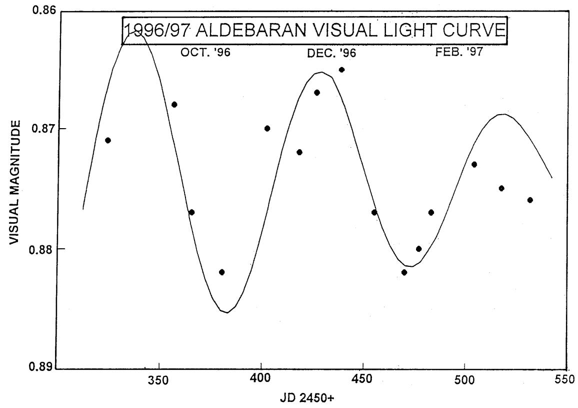

Figure 1. Aldebaran visual light curve; calendar dates are mid-month. The sine curve shown was generated using a 92-day period and varying semiamplitude

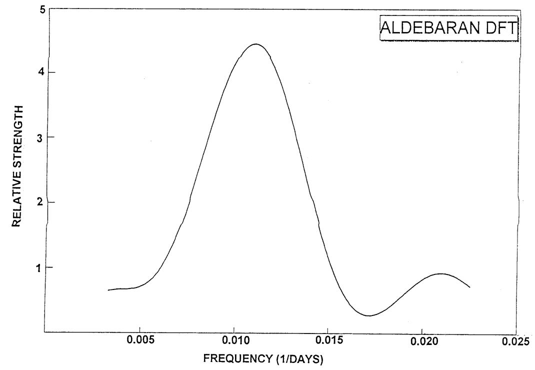

Figure 2. Aldebaran DFT; note peak intensity at frequency 0.01095 (period=91.3 days)

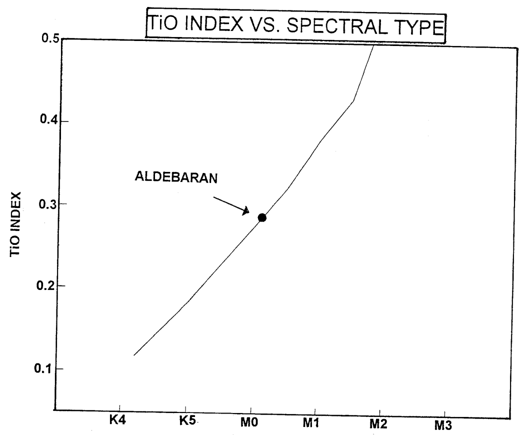

Figure 3. TiO-index - spectral type calibration, indicating Aldebaran as an M0 star

the observations were subjected to a formal period search using a Discrete Fourier Transform (DFT) of Sinnot (1988). Figure 2 shows the results of the DFT; a peak frequency of 0.01095/days was found, corresponding to an approximate 92 day period. This period is close to the photometric period found by inspection. A sine curve of decreasing semi-amplitude, from $0\overset{\mathrm{m}}{.}005$ to $0\overset{\mathrm{m}}{.}0015$, was generated using the 92-day period. This fit is shown in Figure 1. The agreement with the observations is reasonably good.

It is not certain if this period is stable with time and if there are any long-term changes in brightness. The mean brightness observed by us of $\langle V \rangle = +0.873$ magnitude is in good agreement with the $\langle V \rangle$ found earlier by Krisciunas; this indicates that the star does not have significant long-term brightness changes over the time scale of at least several years.

Based on the apparent observed period and varying amplitude, it appears that Aldebaran has photometric characteristics similar to the so-called Small Amplitude Red Variables (SARVs). SARVs are M-giants which pulsate with small light amplitudes and have periods of up to 200 days and visual amplitudes of up to 2.5 magnitudes (Percy, 1989). If so classified, Aldebaran would have the smallest observed amplitude of this class of stars.

Although we did not attempt to obtain light curves using the Wing IR filters, we did observe the star on four nights with this filter set. From these observations we determined the TiO-index and the near-IR color index to be $+0.282 \pm 0.012$ and -0.227 ± 0.009 magnitude, respectively. From over 20 cool standard stars observed with the Wing filters (Wing, 1978) a TiO-index vs. spectral type was calibrated for K and M-type stars. Part of this calibration is seen in Figure 3, where Aldebaran's TiO-index indicates it is of spectral type M0-III, which is not the usual K5 III value associated with this star. Additionally the U−B and B−V colors are more suitable for a M0 III star rather than a K5 III star.

More observations using the Wing filters are needed to further quantify the spectral type of Aldebaran and also to search for outer atmospheric TiO variations. Continued photometry is also planned to ascertain period stability and amplitude changes.

The authors wish to thank Dr. Emilia Belserene for her assistance in translating the DFT program from BASIC to FORTRAN. We also than Dr. Robert Wing for providing standard star IR data. For this research we utilized the SIMBAD database, operated by CDS, Strasbourg, France. This work was supported in part by NSF grant AST-9315365, which we gratefully acknowledge.

Rick WASATONIC
Edward F. GUINAN
Dept. of Astronomy and Astrophysics
Villanova University
Villanova, PA. 19085

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