

## Two New Cool Variable Stars in the Field of NGC 659

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**Abstract** From data taken in the course of a program to monitor variations in H $\alpha$  emission by hot, massive stars, we report the incidental finding that the very red stars USNO-B1.0 1508-0065037 and USNO-B1.01507-0066512 are irregular variables with brightness ranges to date of 0.2 and 0.8 magnitude, respectively.

### 1. Introduction

Since summer 2010 we have been monitoring variations in H $\alpha$  emission in early type stars in open cluster fields by means of narrowband photometry (Souza *et al.* 2011). While our focus is on Be and other hot stars, the temporal coverage and homogeneity of the observations provide opportunities for discovery of variables of other types. NGC 659 is a young ( $\sim 35$  MY) open cluster in Cassiopeia at a distance of  $\sim 4,900$  pc (WEBDA; Inst. Astron., Univ. Vienna 2012). As home to at least five Be stars, it is a prime target of the program.

### 2. Observations and reduction

As a result of this monitoring, two stars have shown themselves to be irregular variables. USNO-B1.0 1508-0065037 (R.A.  $01^{\text{h}} 44^{\text{m}} 37.56^{\text{s}}$ , Dec.  $+60^{\circ} 49' 53.5''$  (J2000)), has a brightness range of 0.2 magnitude. USNO-B1.0 1507-0066512, (R.A.  $01^{\text{h}} 44^{\text{m}} 26.90^{\text{s}}$ , Dec.  $+60^{\circ} 44' 35.3''$  (J2000)), has a brightness range of 0.8 magnitude. Basic observational data for both stars, designated Star 1 and Star 2, are given in Table 1, and a finding chart for NGC 659 is provided in Figure 1. Observations were obtained with an Apogee U9000 CCD on the 0.6-m DFM Engineering telescope at Williams College, through matched 5 nm-wide 645-nm continuum and 656-nm H $\alpha$  filters from Astrodon Imaging. The NGC 659 field was observed on twenty-six nights during 2010–2012. Useful data are obtained for stellar objects down to  $R \approx 15$ . Each observation consists of multiple exposures to enable removal of cosmic ray artifacts.

We employ a semi-automated reduction pipeline described in Souza *et al.* (2013). Since photometric nights are extremely rare at our location, corrections for seeing, transparency, and airmass variations are critical. We use inhomogeneous ensemble photometry (Bhatti *et al.* 2010; Richmond 2012),

which employs all stars in the field, except those identified as variable, as reference stars. The magnitude scale is roughly set by determining an offset between mean measured narrowband magnitudes for a nonvariable early B star in the field and its R magnitude (from NOMAD; USNO 2012). This offset is then applied to all other objects in the field. While reasonable for early-type stars, this method—along with the possibility that H $\alpha$  may be in emission in any given star—renders the narrowband magnitudes reported here unsuitable for comparison with other observations, for these cool stars.

### 3. Results and discussion

Figure 2 is the light curve for Star 1. Since the 645-nm and 656-nm light curves track each other well and differ only by a constant offset ( $656 \text{ nm} - 645 \text{ nm} = -0.055 \pm 0.028$ ), we plot the mean of 645-nm and 656-nm magnitudes as a function of Heliocentric Julian Date (HJD). Uncertainties are estimated by Ensemble 0.7 (Richmond 2012) from nonvariable stars of similar magnitude. Experience indicates that these error bars correspond to roughly  $\pm 2$  standard deviations. Brightening occurs at about  $\text{HJD} - 2450000 = 5650, 5850,$  and  $6220$ . The brightness range over the observed period is  $\sim 0.2$  magnitude, and there is no evidence of periodicity.

Figure 3 is the light curve for Star 2, plotted similarly. Both stars are plotted with a magnitude range of 1.0 so that they may be more directly compared. For Star 2,  $656 \text{ nm} - 645 \text{ nm} = -0.104 \pm 0.062$ . Brightening occurs at about  $\text{HJD} - 2450000 = 5650$  and  $6010$ , and there is an overall dimming trend. The brightness range over the observed period is  $\sim 0.8$  magnitude, and there is again no evidence of periodicity.

For both stars, variability over the observed period is significant and irregular. Brightening of both stars near  $\text{HJD} - 2450000 = 5650$  is coincidental. A few of the  $\sim 330$  stars measured in the field show such a feature, with no positional dependence and consistent with chance. Neither star is identified as variable in the GCVS, the VSX database, or elsewhere as found using VizieR identifier and positional searches. Star 1 has been classified as a carbon star (Aaronson *et al.* 1990), and with  $(B-V) \approx 2.7$ , it is very red. Star 2, with  $(B-V) \approx 2.3$ , is also very red, but has not been spectrally classified. Similarities in color and variability between this star and Star 1 make it tempting to speculate that it may also be a carbon star.

It is very unlikely that either of these stars is a member of NGC 659. From their colors and apparent magnitudes they must be much less distant than the cluster, so the  $\sim 0.65$  magnitude of interstellar reddening at the cluster (WEBDA 2012) is not likely to be a major factor affecting their colors. If they are indeed carbon stars or stars of other evolved moderate- to low-mass type, NGC 659 is far too young to have produced them.

#### 4. Acknowledgements

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This work made use of the following software and resources: astrometry.net (Lang *et al.* 2010); Aperture Photometry Tool 2.1.8 (Laher *et al.* 2012); Ensemble 0.7 (Richmond 2012); GCVS online edition (Samus *et al.* 2012); VSX AAVSO Variable Star Index (Watson *et al.* 2012); VizieR catalog access tool, CDS, Strasbourg, France (<http://vizier.u-strasbg.fr>); WEBDA database, Institute for Astronomy, University of Vienna (<http://www.univie.ac.at/webda>); NOMAD catalog, U.S. Naval Observatory (<http://www.nofs.navy.mil/nomad>).

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Table 1. Identifications and basic observational data. Identifications and positions are from VizieR; magnitudes are from NOMAD (USNO 2012) as accessed through VizieR.

<i>Parameter</i>	<i>Star 1</i>	<i>Star 2</i>
USNO B1.0 identifier	1508-0065037	1507-0066512
NOMAD identifier	1508-0067389	1507-0069147
GSC 2.3 identifier	NAJ5009439	NAJ5008235
R.A. (J2000)	01 <sup>h</sup> 44 <sup>m</sup> 37.56 <sup>s</sup>	01 <sup>h</sup> 44 <sup>m</sup> 26.90 <sup>s</sup>
Dec. (J2000)	+60° 49' 53.5"	+60° 44' 35.3"
B	17.90	17.21
V	15.21	14.97
R	13.98	13.95

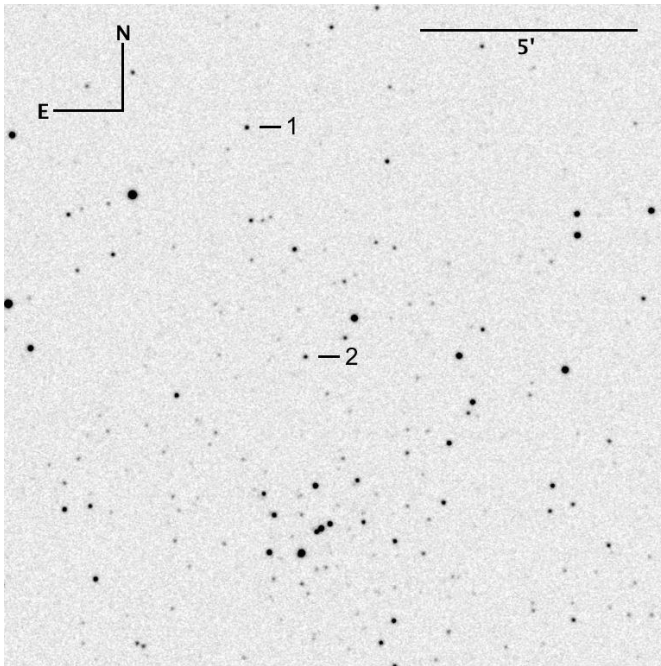


Figure 1. The field of NGC 659, from a 656-nm image taken 11 December 2011. The positions of Star 1 and Star 2 are indicated.

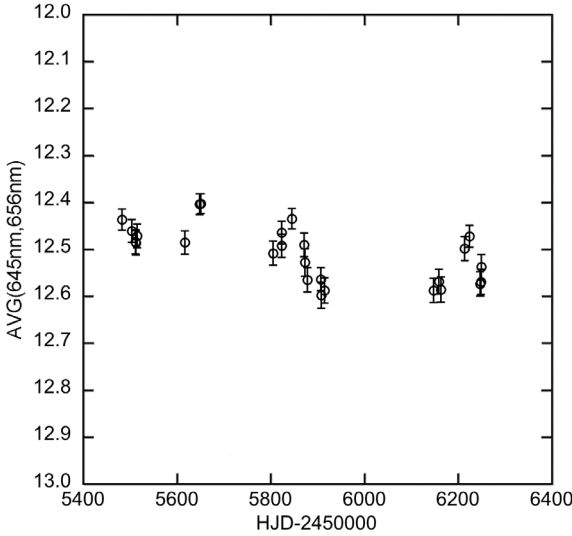


Figure 2. The light curve for Star 1 (USNO-B1.0 1508-0065037), plotted as the average of narrowband (5-nm wide) magnitudes at 645 nm and 656 nm. Figures 2 and 3 are plotted with the same 1.0 magnitude range so that they may be more directly compared.

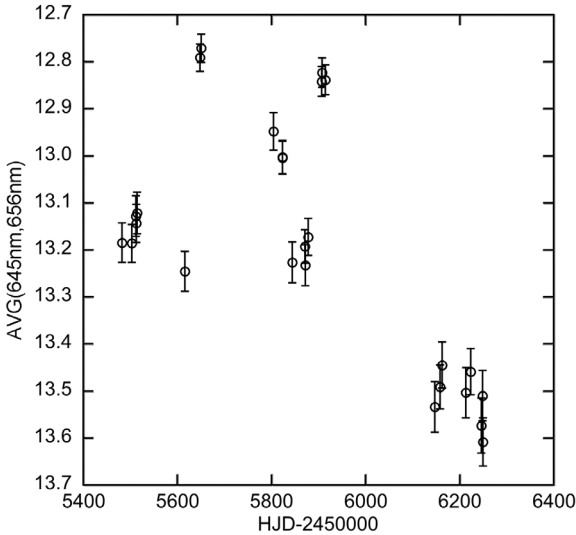


Figure 3. The light curve for Star 2 (USNO-B1.0 1507-0066512), plotted as in Figure 2.