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LETTERS

Discovery of Three Variable Stars in Direction toward NGC 4565 *

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Abstract We present the results of a variable star search in a field next to the edge-on galaxies NGC 4565 from the archive data of Beijing-Arizona-Taibei-Connecticut Multicolor Sky Survey. Three new variable stars were discovered. Based on spectra obtained from the 2.16 m NAOC telescope, we identify two of these as RR Lyr stars and one as a special T Tauri star.

Key words: stars: variables: RR Lyr — stars: variables: T Tauris

1 INTRODUCTION

With the large field of view of the 60/90 Schmidt telescope equipped with a 2048×2048 CCD, the BATC (Beijing-Arizona-Taibei-Connecticut Multicolor Sky Survey) program is very suitable for discovering new variable stars. Zhang et al. (2002, 2003) used the Schmidt telescope to monitor the old open clusters NGC 188 and NGC 7789. They discovered more than 30 new variable stars, thereby doubling the number of known variables in the two clusters. This reveals the capability of the Schmidt telescope in this work. In this paper, we report new discoveries of variable stars in a field next to the edge-on galaxy NGC 4565 (Wu et al. 2002) from the archive data of BATC. The observations and data reduction are described in Sect. 2. The search for variable stars and the period determination are described in Sect. 3. The results and a discussion are given in Sect. 4 and our conclusions are presented in Sect. 5.

2 OBSERVATIONS AND DATA REDUCTION

2.1 Images

The observational data of NGC 4565 were obtained with the 60/90cm Schmidt telescope at the Xinglong Station of the National Astronomy Observatories (NAOC), using a thick Ford 2048×2048 CCD. The CCD has a field of view of $58' \times 58'$ and a scale of $1.67''$ per pixel (Fan et al. 1996). The BATC i filter was used for the observations, with central wavelength 6660Å

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and bandwidth 480Å. From February 17 to February 21, 1996, 77 images were obtained with exposure times of 900 seconds (Wu et al. 2002).

Preliminary processing of the raw CCD data was performed using the IRAF package, removing the bias and dark. Correction for the dome-diffuser flat-field then ensured a photometric accuracy of 0.01 mag (Wu et al. 2002 ; Zhou et al. 2004).

2.2 Spectral Identifications

The spectra of the three new candidate variables were obtained on Feb 17, 2004 with the 2.16 m telescope at the Xinglong Station of NAOC. A Zeiss universal spectrograph was used with a Tektronix 1024×1024 CCD and a 200 Å mm^{-1} grating. He-Ar lamp was employed for wavelength calibration and three standard stars were used for flux calibration. The exposure time is 2000 seconds for each source. The spectral data were reduced using the IRAF package and the final 1-d spectra are shown in Fig. 1.

3 VARIABLES SEARCHING AND PERIOD DETERMINATION

Aperture photometry was used to obtain the objects in 77 i-band frames. The objects detected in the different frames are matched by their equatorial coordinates. Five i-band images were obtained on five photometric nights and calibrated by the four Oke & Gunn (1983) standards adopted by BATC (Zhou et al. 1999 ; Zhou et al. 2001). The calibration is accurate to 0.02 mag (Wu et al. 2002).

In order to obtain the BATC i-band magnitudes of all the sources in the 77 images, we selected 24 stars in the common region as secondary standards. All these 24 secondary standards were carefully chosen (must be bright, unsaturated and with standard deviations less than 0.01 mag). Based on these secondary standards, we recalculated the magnitude differences of the images with the five calibrated images. Then we obtained the BATC i-band magnitudes of all the sources measured above and acquired a light curve for each of the sources.

The next step is to search for variable star candidates. We considered only those sources with more than 20 observational data points and with signal-to-noise ratios above 4σ. Nearly 100 candidates were obtained. After rejecting a large number of spurious candidates that are located near bad pixels, strong cosmic rays, bright galaxies, saturated stars and the edges of the CCD frames, we were finally left with three candidates, which turned out to be all new discoveries. They are listed in Table 1 and their finding charts are shown in Fig. 1.

Table 1 Parameters of Three Newly Discovered Variable Stars

Star	GSC ID	α (2000) h m s	δ (2000) ° ′ ″	i (BATC)$_{max}$ mag	Amplitude mag	Period day	Type
V1	GSC 1990–1708	12:35:29.06	+25:54:25.2	15.035	0.154	0.6216	T Tauris
V2		12:35:30.56	+25:39:28.4	17.786	0.796	0.3430	RRab
V3	GSC 1992–0039	12:37:41.47	+26:16:14.9	15.704	0.380	0.3789	RRc

We used the method of phase dispersion minimization (PDM, Stellingwerf 1978) to analyze the light curves of the three new sources. A PDM code was employed to derive the period, maximum magnitude and amplitude of each light curve. Considering the time resolution and time base of our observations, the accuracy of the periods is around 0.003 d. These parameters are also listed in Table 1 and the phased light curves are shown in Fig. 1.

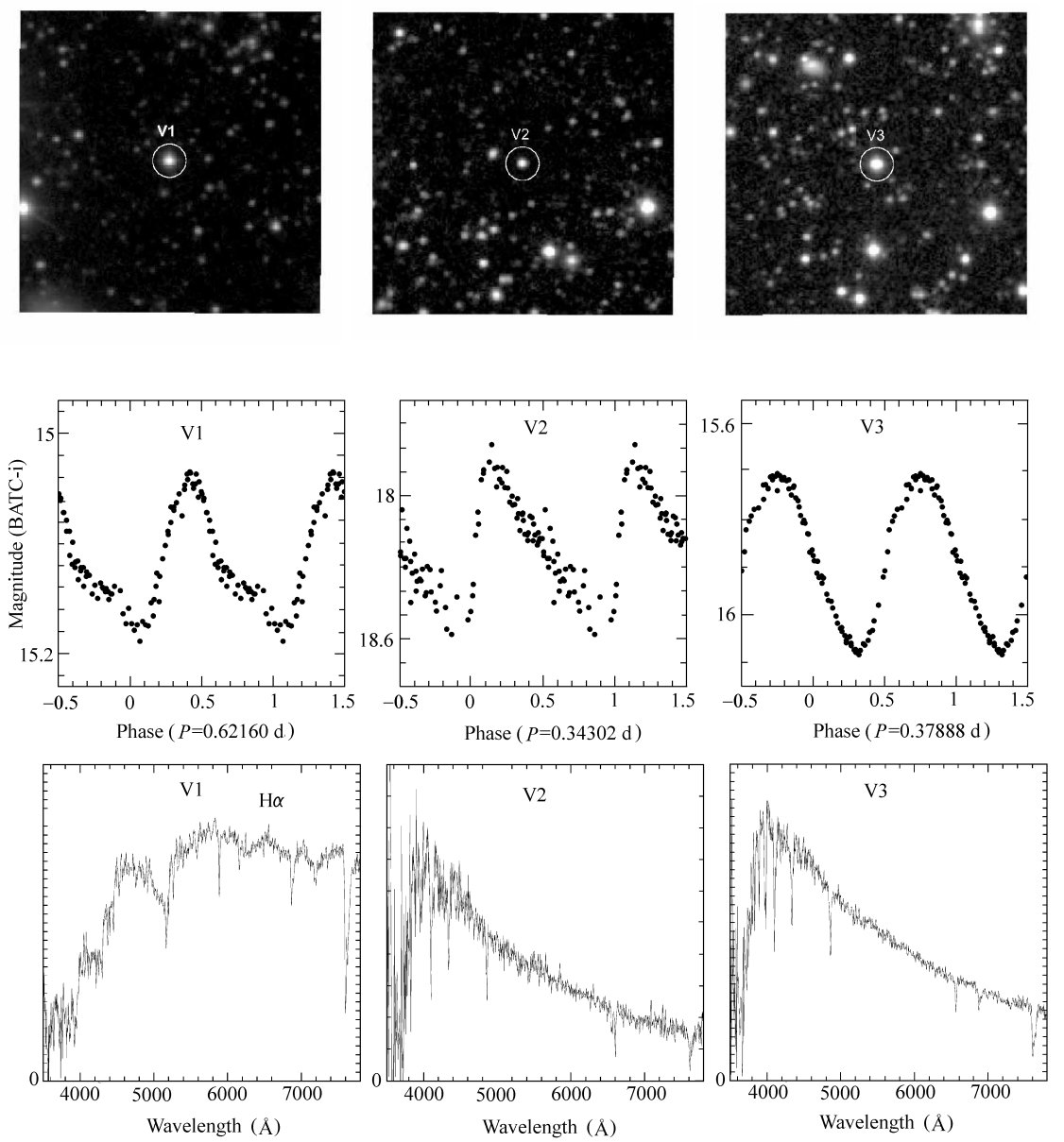

Fig. 1 Finding charts, phased light curves and spectra of three new variables. The circles in the finding charts have radius 10 arcsec.

4 RESULTS AND DISCUSSION

A systematic search for variable stars around NGC 4565 has resulted in the discovery of three new variable stars. In this section, we discuss their properties and classifications based on their light curves and spectra. The last column of Table 1 lists the their final variable type.

V1: It is the brightest one of the three. The PDM method gives two possible periods, 0.6216 d and 0.7719 d. Here we only give the results of the first, more probable period. The phased light curve shows a rapid increase, then a rapid decrease, followed by a slower decrease. Both the light curve and period are quite similar to those of RR Lyr stars, but its spectrum shows features typical of later type stars. Also, it presents a weak Hα emission line. Thus, this star should be a T Tauri star. However, its RR Lyr-like light curve and its location of high galactic latitude indicate that it is a special T Tauri star. It should be studied further.

V2: It is the faintest of the three, with magnitude about 18. Its phased light curve shows a steep rise followed by a slower decline. A period of 0.3430 d is determined. The amplitude is approximately 1 mag. Based on its spectra, it is considered as an F type star. From its spectral type, amplitude, period and asymmetry of the light curve, it belongs to the type ab of RR Lyr star.

V3: It shows a typical light curve of RR Lyr star with a period of 0.3789 d and an amplitude of 0.380 mag. It also presents an F type spectrum. Based on its roughly symmetric light curve, we classified it as a type-c RR Lyr star.

5 CONCLUSIONS

We have presented the result of our variable star search in a nearby field of NGC 4565 from the BATC archive data. We discovered three new variable stars. Based on the spectral observation with the 2.16 m telescope, two of these stars are identified as RR Lyr stars and one, as a special T Tauri star.

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