Malaysian Journal of Science **26** (2): 143 – 149 (2007)

REPORT

Helium λ 4009.27 Å Phase Variation in Alpha Virginis

Sharifah Fetom Syed Zain, Nazhatulshima Ahmad and **Mohd Zambri Zainuddin***

Physics Department, Faculty of Science, University of Malaya, 50603 Kuala Lumpur, Malaysia
* mzz1@um.edu.my (corresponding author)
Received 14th March 2006, accepted in revised form 22nd August 2007.

Abstract The spectroscopic observations have been carried out with the SBIG Self-guided spectrograph attached to the Celestron CG-14 which utilizes the Schmidt-Cassegrain design of the University of Malaya observatory. The spectra of spica, α Vir (67 Virginis, HIP 65474, HR 5056, HD 116658, BD -10 3672, SAO 157923) were obtained on four nights that is 28th and 30th August 2005, 1st September 2005 and 21st February 2006. The medium-resolution (R_{min} ~ 3710.349) spectrum was taken in the λ range of 3900 to 4700 Å. Phase variation of He I λ_0 4009.27Å has been studied and shows the spectroscopic binary characteristic of the Spica with variable velocity between -344.0 ± 2.25 to -140.0 ± 2.25 km/s.

Abstrak Cerapan spektroskopik telah dilakukan dengan menggunakan spektrograf SBIG-SGS yang tersambung ke Teleskop Celestron CG-14 yang berasaskan rekabentuk Schmidt-Cassegrain di balai cerap Universiti Malaya. Spektra bagi Spica, α Vir (67 Virginis, HIP 65474, HR 5056, HD 116658, BD -10 3672, SAO 157923) telah diambil pada empat malam iaitu 28hb dan 30hb Ogos 2005, 1hb September 2005 dan 21hb Febuari 2006. Spektrum dengan resolusi sederhana (R_{min} ~ 3710) telah diambil pada julat λ antara 3900 dan 4700 Å. Perubahan fasa bagi He I λ_0 4009.27Å telah dikaji dan menunjukkan cirri-ciri spektroskopik Spica dengan nilai halaju jejarian yang berubah-ubah iaitu di antara -344.0 ± 2.25 dan -140.0 ± 2.25 km/s.

(Spectroscopic, eclipsing binary, variable velocity, Doppler effect, resolution)

INTRODUCTION

The spectroscopic and eclipsing binary star α Vir (67 Virginis, HIP 65474, HR 5056, HD 116658, BD-10 3672, SAO 157923) known as Spica (RA: 13h 25m 32.242s; DEC: -11° 11' 46.538") with apparent magnitude varies between +0.92 and +0.98 and period of 4.0142 days which has been determined by Vogel and Baker [1]. Spica has been identified as a double-line spectroscopic binary since 1890 and confirmed by the work of Struve and Ebbighausen [2], Shobbrook *et al.* [3] and Meisel and Berg [4]. Spica has been known to have a variable velocity for over 100 years confirmed by Baker [1] and Walker [5]. Struve *et al.* [6] described Spica as a system with two components of about the same spectral type but with very different line profiles which the line of primary component (blue B1 III-IV type sub-giant or giant) are broad, those of the secondary (blue B2V type main sequence) are relatively narrow and much weaker. Struve and Ebbighausen [2] found a remarkable periodic change in the relative intensities of the two absorption components of Spica. Struve *et al.* [6] pointed out that the rotational broadening of the lines in both primary and the secondary indicate rotational velocities for both stars and the absorption line of the primary showed a variable structure at all orbital phase.

In the spectroscopic binary, the motion of the two stars around their common center of mass alternatively moving toward and away from the observer. The spectrum of each star will alternatively change their places due to the Doppler effect. Spica as a double-line spectroscopic binary will show the periodically

shifted of each wavelength since both the primary and the companion have the same characteristic absorption line which is B type. The relative movement between the primary and the companion shows the shifting in each wavelength and Spica can be seen as a blue and red Spica at the same time due to the orbital motion [7]. Here the phase variation of He I λ_0 4009.27Å will be studied and shows the spectroscopic binary characteristic of the Spica as discovered by Ikeda [7] and with its variable velocity as discovered by Baker [1] and Walker [5].

OBSERVATIONS

The spectroscopic observations have been carried out with the SBIG Self-guided spectrograph attached to the Celestron CG-14 which utilizes the Schmidt-Cassegrain design of the University of Malaya observatory. A high resolution of grating has been used in collecting the spectra of Spica that gives 1.07 angstroms per pixel dispersion with a resolution of about 2.4 angstroms when used with narrow slit and the spectral range is about 750 angstrom which is adequate to detect the spectroscopic binaries, according to Holmes [8].

The spectra of Spica, α Vir (67 Virginis, HIP 65474, HR 5056, HD 116658, BD -10 3672, SAO 157923) were obtained on four nights, that is 28th and 30th August 2005, 1st September 2005 and 21st February 2006 (Table 1). The detector was a CCD ST-7E with conversion factor, g, 2.71 ± 0.08 e/ADU and read-out noise values, σ_{ron} 6 ± 1 electrons rms. The medium-resolution (R_{min} ~ 3710.349) spectrum was taken in the λ range between 3900 to 4700 Å with the signal to noise ratio > 100 due to the sky condition.

PHASE VARIATION OF He I λ_0 4009.27Å

Figure 1 shows He I λ_0 4009.27Å, at λ 4001.277Å with Δλ= -8.021 and FWHM value 8.177 Å in phase ϕ_1. Figure 2 shows He I λ_0 4009.27 Å at λ 4005.533 Å with Δλ= -3.737 and FWHM value 7.421 Å in phase ϕ_2. Figure 3 shows He I λ_0 4009.27Å, at λ 4007.016Å with Δλ= -2.254 and FWHM value 6.938 Å in phase ϕ_3. All the first three phases shows the blue Spica with decreasing value of FWHM. The bulge on both sides of He I λ_0 4009.27 Å in phase ϕ_1 show the both components, the primary and the companion. With the value of λ 4005.533 Å and Δλ= -3.737 shows the shifting of the wavelength to the red region which the bulge on the right side of He I λ_0 4009.27Å can be recognized as the development of red Spica. In phase ϕ_3 He I λ_0 4009.27Å clearly shows Spica A and Spica B in the splitting features. Table 2 shows the value of shifted wavelength, Δλ and FWHM.

Table 1: Phase and the observation time for Spica

PHASE	DAY	OBSERVATION DATE	OBSERVATION TIME (LOCAL TIME)	UNIVERSAL TIME	EXPOSURE TIME
ϕ_1	0.0	28th August 2005	20:21:13	12:21:13	290s
ϕ_2	0.96	30th August 2005	19:23:21	11:23:21	290s
ϕ_3	1.95	1st September 2005	19:14:55	11:14:55	290s

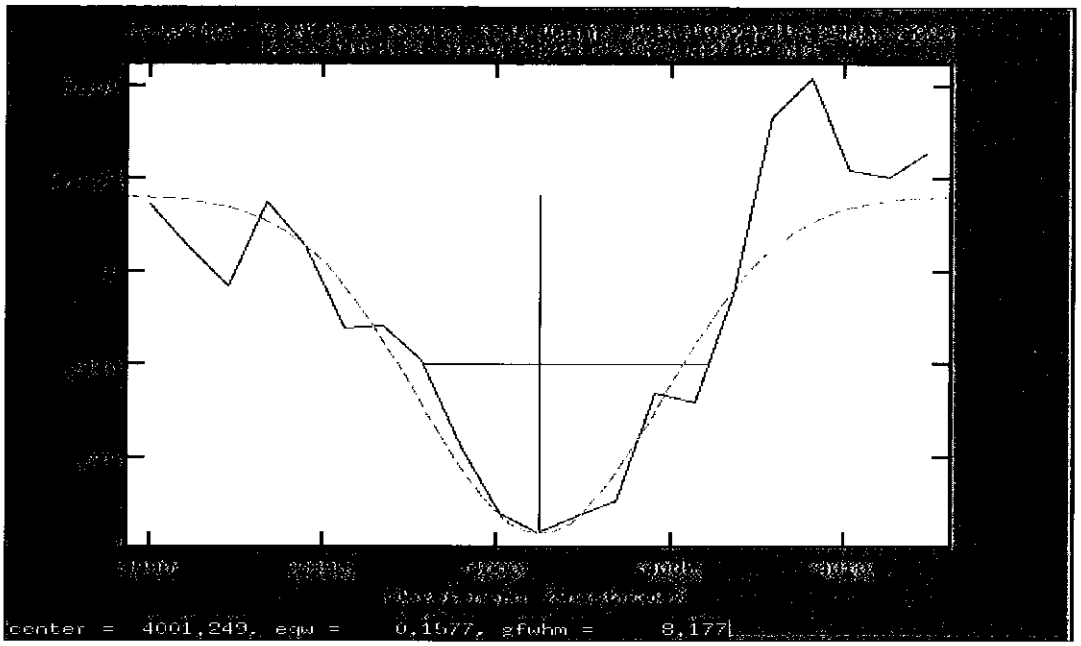

Figure 1. The relative intensity as a function of wavelength for He I λ_0 4009.27Å in phase ϕ_1

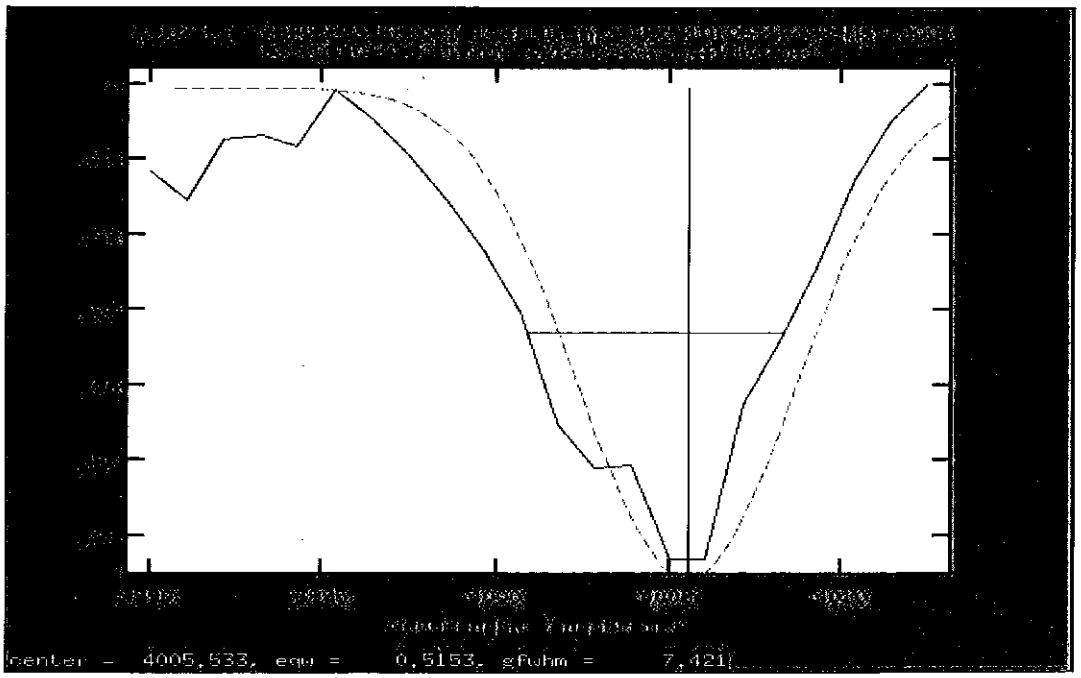

Figure 2. The relative intensity as a function of wavelength for He I λ_0 4009.27Å in phase ϕ_2

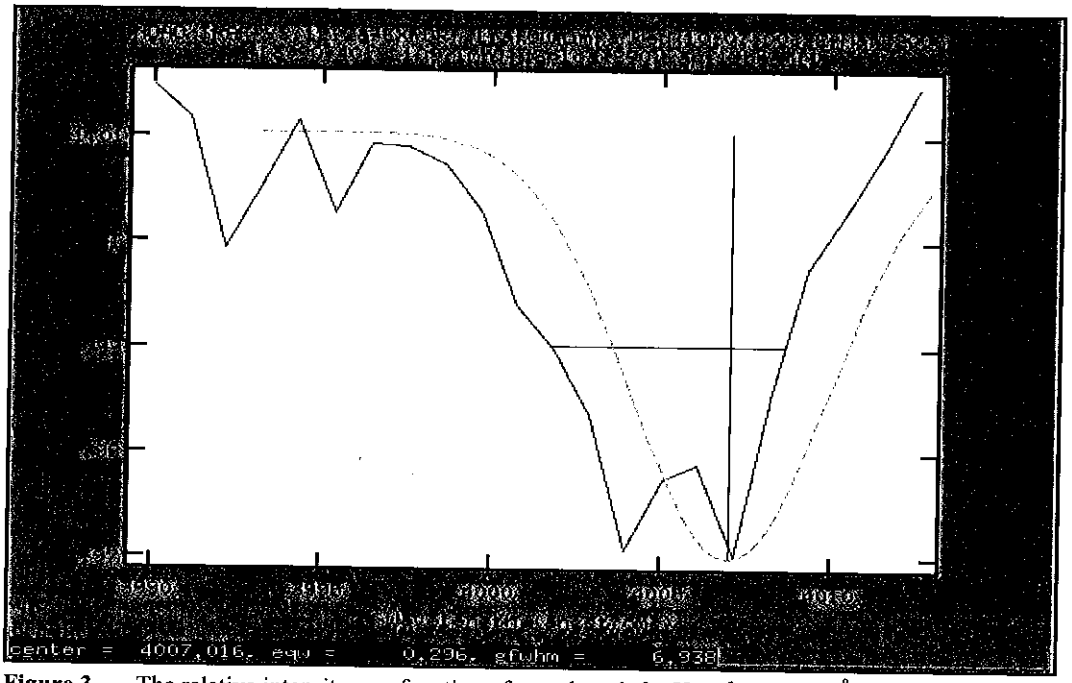

Figure 3. The relative intensity as a function of wavelength for He I λ_0 4009.27Å in phase ϕ_3

Table 2. He I λ 4009.27Å

LINE	PHASE	WAVELENGTH (λ) Å ± 0.03	$\Delta\lambda$ ($\lambda - \lambda_0$)	FULL WIDTH HALF MAXIMUM (Å) ± 0.01
2 (λ_0=4009.27)	ϕ_1	4001.249	-8.021	8.177
	ϕ_2	4005.533	-3.737	7.421
	ϕ_3	4007.016	-2.254	6.938

Figure 4 shows the relative intensity as a function of radial velocity for the first three days of observation (28th, 30th August and 1st September 2005) shows the moving features of the Spica (zero velocity has been set at the rest wavelength).

Figure 5 shows the spectral series for He I λ 4009.27 Å that has been obtained on the 21st February 2006 (zero velocity has been set at the rest wavelength). Table 3 shows the related time and phase on the day of the observation.

The moving features as described by Fraser *et al.* [9] obviously can be seen which consists of the blue shifted and the red shifted in the spectral series that has been plotted for the seven phase. He I λ 4009.27Å shows variable velocity between -344.0 ± 2.25 to -140.0 ± 2.25 km/s (Table 4).

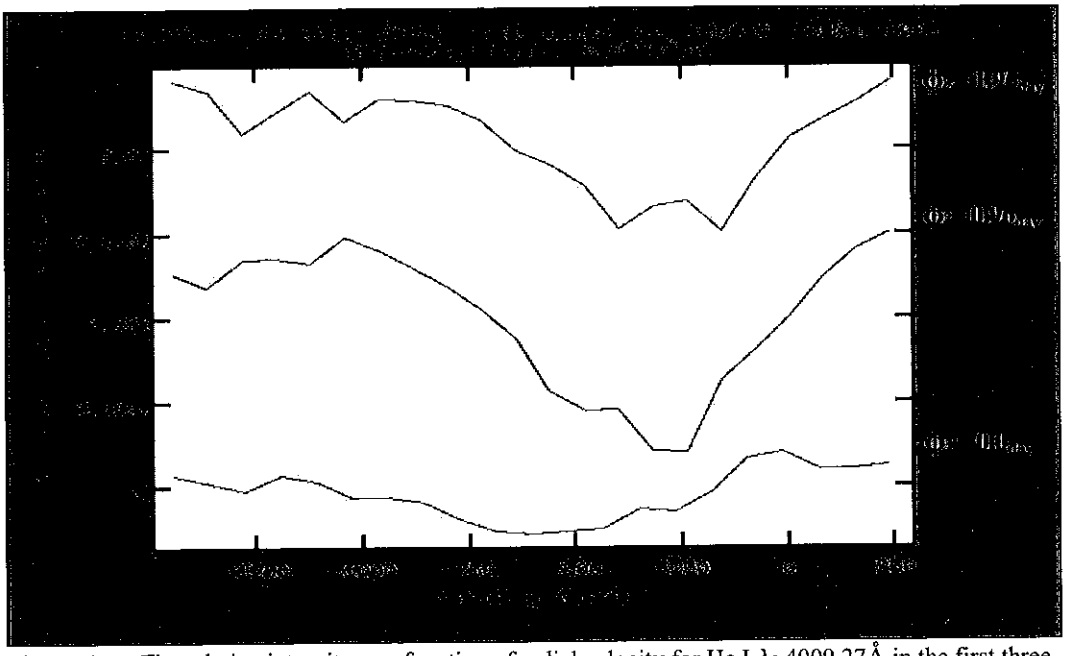

Figure 4. The relative intensity as a function of radial velocity for He I λ_0 4009.27Å in the first three days of observations.

Table 3. Time and phase of the observation on the 21st February 2006

PHASE	TIME (U.T.)	HOURS
Φ_1	18:16:54	0.00
Φ_2	18:54:52	0.63
Φ_3	19:09:50	0.88
Φ_4	19:55:07	1.65
Φ_5	20:09:27	2.87
Φ_6	21:45:45	3.48
Φ_7	21:55:05	3.65

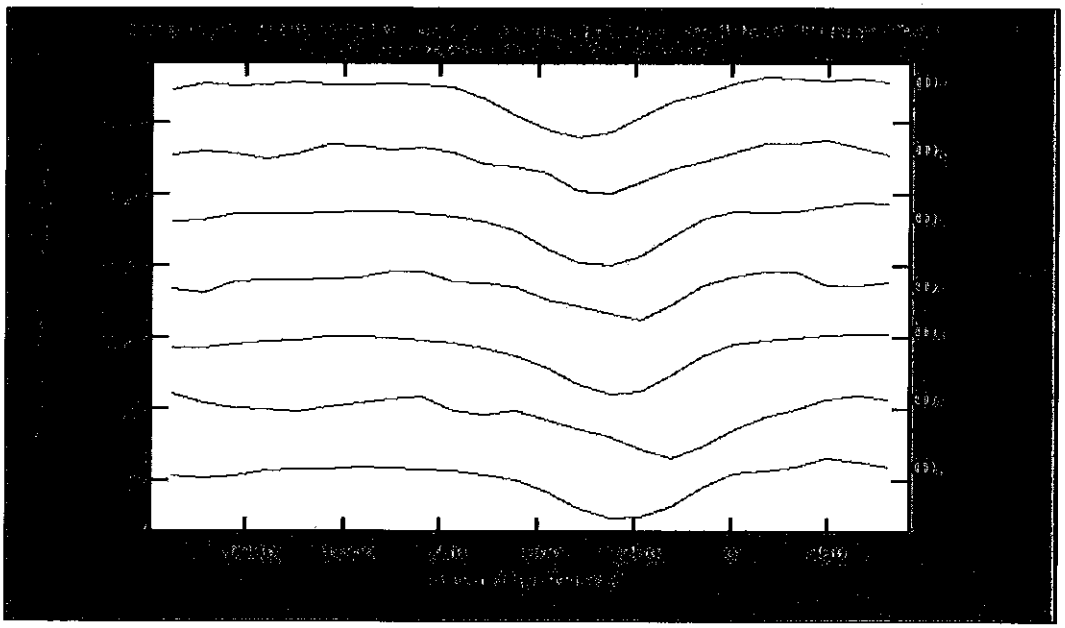

Figure 4. Seven phases of the relative intensity as a function of radial velocity for He I λ_0 4009.27Å on the 21st February 2006.

Table 4. He I λ 4009.27Å, phase variation

PHASE	WAVELENGTH (λ) Å± 0.03	RADIAL VELOCITY (km/s) ± 2.25	FWHM (Å) ± 0.01
Φ_1	4005.342	-219.2286	4.974
Φ_2	4007.134	-140.8298	5.952
Φ_3	4005.376	-245.4689	5.123
Φ_4	4005.87	-171.4005	5.211
Φ_5	4004.753	-314.2343	4.818
Φ_6	4004.695	-323.2006	4.988
Φ_7	4004.043	-343.7856	5.119

DISCUSSION

The selected characteristic lines of Spica showed both the blue and the red Spica in the same phase due to the stars rotation and the orbital motion caused by the gravitational effects between the primary and the companion (Baker [1]; Struve and Ebbighausen [2]; Struve *et al.* [6]; Shobbrook *et al.* [3]; Fraser *et al.* [9]; Ikeda and Tamura [7]). The moving features as described by Fraser *et al.* [9] obviously can be seen which consists of the blue shifted and the red shifted in the spectral series that has been plotted for the seven phases.

He I λ 4009.27Å shows variable velocity between -344.0 ± 2.25 to -140.0 ± 2.25 km/s and this enhanced the evidence of the spectroscopic binary characteristic of Spica the α Virginis.

The spectrum of Spica which contains a component due to the companion, have complicated profiles which shows the moving features [9]. The relative movement between the primary and the companion shows the shifting in each wavelength and Spica can be seen as a blue and red Spica at the same time due to the orbital motion [7]. This research needs more photometry

and spectroscopy data to enhance the evidence and to solve the complicated problem due to the complex feature of the spectra of Spica which shows variable radial velocity and variable absorption lines structure.

REFERENCES

1. Baker, R. H. (1909). The orbits of the spectroscopic components of α Virginis. *Publications of the Allegheny Observatory.* Vol. 1, No. 10.
2. Struve, O. and Ebbighausen, E. (1934). The spectroscopic Binary α Virginis. American Astronomical Society 365 - 376.
3. Shobbrook, R. R., Lomb, N. R. and Herbison-Evans, D. (1972). The short period light and velocity variations in Alpha Virginis. *MNRAS* **156**: 165 - 180.
4. Meisel, D. D. and Berg, R. A. (1975). Helium λ10830 in Alpha Virginis A and B. *The Astrophysical Journal* **198**: 551 - 553.
5. Walker, G. A. H., Moyles, K., Yang, S. and Fahlman, G. G. (1982). The line profile variations of Spica. *Publications of the Astronomical Society of the Pacific* **94**: 143 - 148.
6. Struve, O., Sahade, J., Huang, S. S. and Zebergs, V. (1958). The spectroscopic binary Alpha Virginis (Spica). *The Astrophysical Journal* **128**: 310 - 327.
7. Ikeda, Y. and Tamura, S. (2000). Spectroscopic diagnostic of symbiotic stars. III. Radial velocity analyses of HBV 475. *PASJ* **52**: 589 - 599.
8. Holmes, A. (2001). *Operating Instructions for the Santa Barbara Instrument Group Self Guided Spectrograph (SGS) and Spectra Analysis Software.*
9. Fraser, G., Yang, S. and Walker, G. A. H. (1983). The line profile variations of Spica. Hvar Observatory. Faculty of Geodesy. UDC 524.312.7-355.3. Conference paper pp. 231 – 239.