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

Number 4545

Konkoly Observatory
Budapest
13 January 1998

HU ISSN 0374 – 0676

NEW VARIABLE STARS IN THE OPEN CLUSTER NGC 7654 (=M 52)

H.S. CHOI[1,2], S.-L. KIM[2], Y.H. KANG[1]

[1] Kyungpook National University, Taegu, 702-701, Korea

[2] Korea Astronomy Observatory, Taejon, 305-348, Korea

We present observational results of three newly discovered slowly pulsating B stars (SPB stars; see Waelkens *et al.* 1990) and one eclipsing binary in the open cluster NGC 7654. We report also the light variation of a low amplitude δ Scuti variable star recently discovered by Viskum *et al.* (1997).

Time-series CCD photometry of the open cluster NGC 7654 was performed over five nights from October 2 to 18, 1997 at Bohyunsan Optical Astronomy Observatory (BOAO) in order to search for variable stars, particularly, SPB stars. We also carried out UBV photometry to obtain the color-magnitude diagram of the cluster. Observation log is given in Table 1. The observations were done with a TEK 1024 CCD camera attached to the BOAO 1.8m optical telescope. The field of view of CCD image is $5\farcm8 \times 5\farcm8$ at the f/8 Cassegrain focus of the telescope.

The CCD pre-processings, such as bias subtraction and flat fielding, were performed with the IRAF/CCDRED package. We applied the point-spread function (PSF) photometry to get instrumental magnitudes, using the IRAF/DAOPHOT package (Massey & Davis 1992). The standard magnitudes and colors were obtained from a typical transformation equation (e.g., Massey & Davis 1992). The ensemble normalization technique (Gilliland & Brown 1988) was applied to standardize instrumental magnitudes of all time-series CCD frames. The detailed description about data reduction and photometric results of the open cluster NGC 7654 will be given in elsewhere (Choi *et al.* 1998).

The finding chart of the five variable stars in the observed field is shown in Figure 1. Their light curves are shown in Figure 2, where the brightness of two stars, C1 and C2, are also plotted for comparison. The brightness decrease of C2 near HJD 2450738.2 may be caused by the contamination of a nearby bright star (V1) under poor seeing condition. As seen in the figure, it is evident that V1, V2 and V3 show long-term (night to night) light variations. The brightness of V4 increases steeply by about $0\fm3$ near HJD 2450724.17 and remains constant at another time. The light curve of V4 is similar to that of an Algol-type eclipsing binary. We also detected slight light variations of V5, which was recently identified as a δ Scuti star candidate by Viskum *et al.* (1997).

Using the Fourier analysis and phase-match technique, we obtained pulsation periods of three newly discovered variable stars. The main results for the five variable stars are summarized in Table 2. The resulting period of V5 ($\simeq 0\fd278$) is in good agreement with the result of Viskum *et al.* (1997). The phase diagrams of four variable stars are shown in Figure 3.

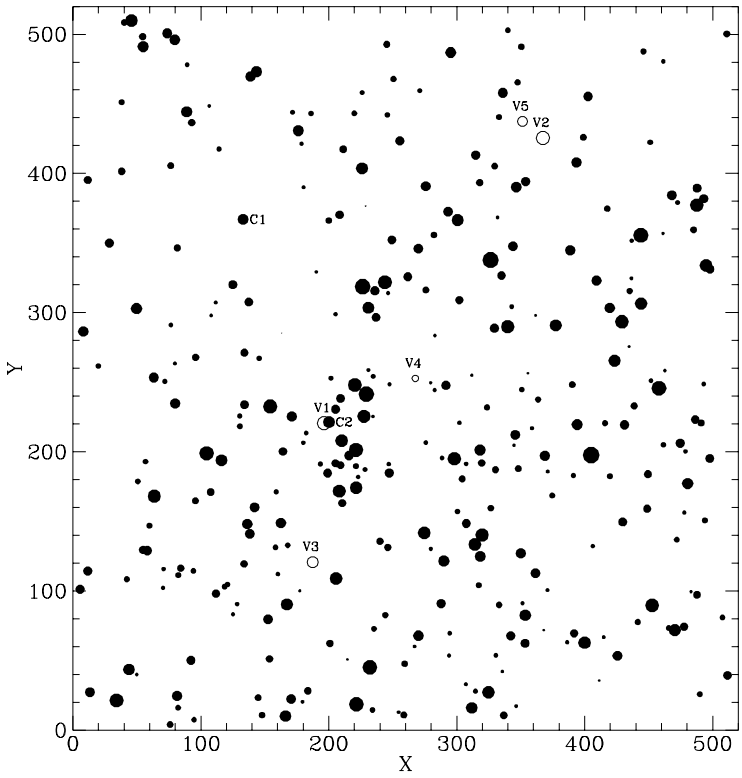

Figure 1. Observation field (5′.8 × 5′.8, 0″.68/pixel) of the open cluster NGC7654. Five variable stars (V1, V2, V3, V4 and V5) are denoted as open circles

Table 1. Observation Log

Date	Start HJD	Coverage	$N_{obs.}$	Filter	Seeing	Remark
Oct. 2	2450724.16	$4^h.8$	116	B	1″.2	clear
3	725.16	$4^h.5$	127	B	1″.5	clear
16	738.05	$6^h.9$	314	B	1″.8	cirrus
17	739.03	$3^h.8$	209	B	1″.7	cirrus
18	740.08	$6^h.8$	449	UBV	1″.3	clear

In Figure 4, we show the location of five variable stars on the C−M diagram of the cluster. Their absolute magnitudes and intrinsic colors were calculated from distance modulus of $(V - M_v)_o$=$10^m.9 \pm 0^m.2$ and interstellar reddening of E(B−V)=$0^m.62 \pm 0^m.05$ (Choi *et al.* 1998). We adopted a theoretical isochrone of log(age)=8.0 for solar metal abundance (Bertelli *et al.* 1994). Three variable stars of V1, V2 and V3 are identified as late-B type main-sequence stars located at the SPB stars instability strip (Dziembowski *et al.* 1993). The δ Scuti star V5 is located at the blue edge of δ Scuti stars instability strip (Breger 1979).

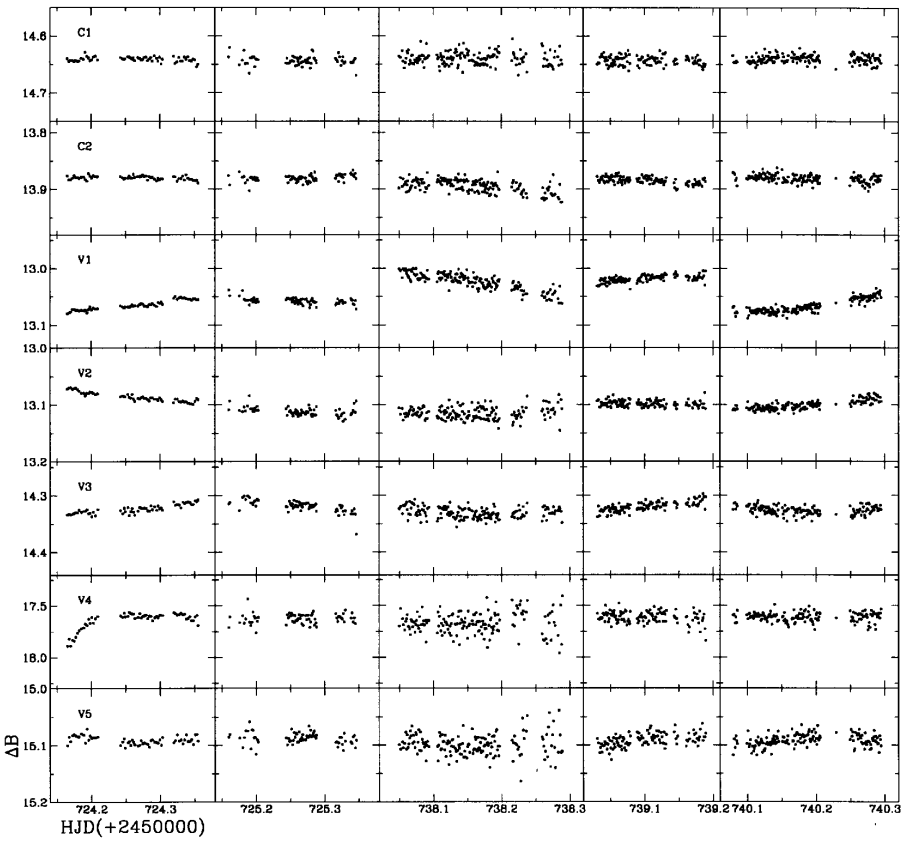

Figure 2. Light variations of five variable stars. The brightness of two stars, C1 and C2, are also plotted for comparison

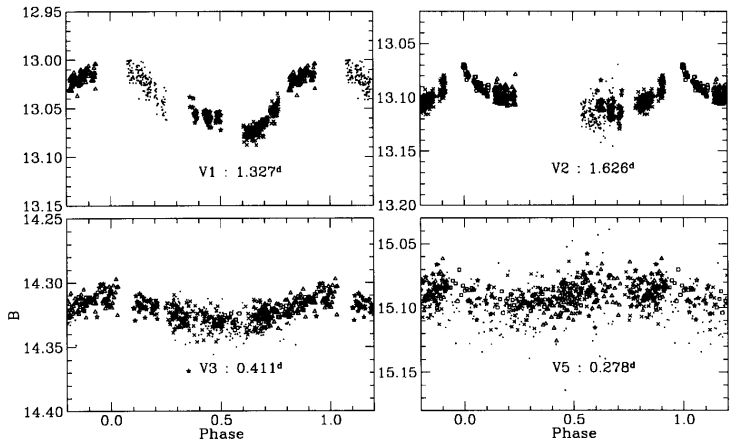

Figure 3. Phase diagrams of four variable stars. Data points are differently marked for each observation night

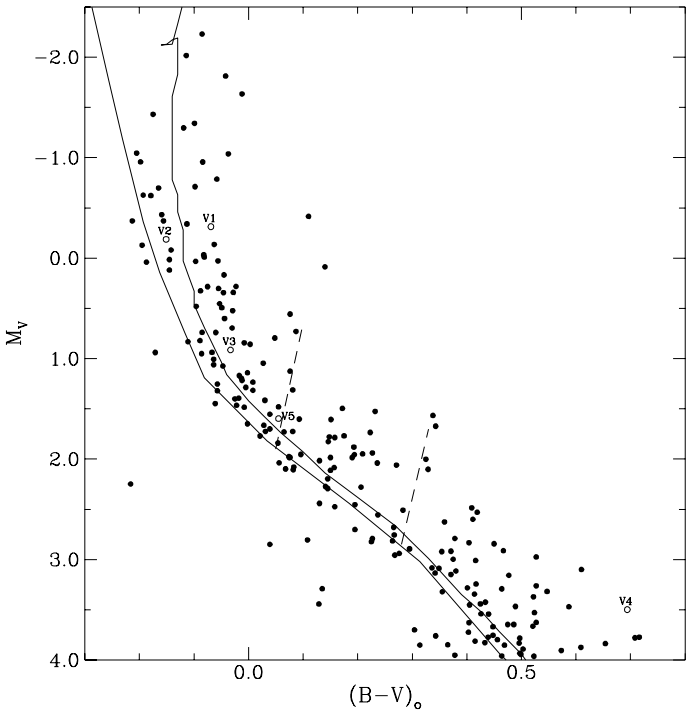

Figure 4. Five variable stars on the C−M diagram of NGC 7654 (see text in detail). The upper solid line is a theoretical isochrone of log(age)=8.0 (Bertelli *et al.* 1994) and the lower is the ZAMS (Lee & Sung 1995) for solar metal abundance. The dashed lines are the borders of δ Scuti stars instability strip given by Breger (1979). The five variable stars are denoted as open circles

Table 2. Main observational results of five variable stars in the open cluster NGC 7654

ID	RA(2000)	DEC(2000)	V	B−V	Period	ΔB	Max. epoch	Type
V1*	$23^h24^m52^s.2$	$61°36'30''$	$12^m.51$	$0^m.55$	$1^h.327$	$\sim0^m.07$	2450737.95	SPB
V2*	$23^h24^m35^s.9$	$61°38'49''$	$12^m.64$	$0^m.47$	$1^h.626$	$\sim0^m.05$	2450724.16	SPB
V3*	$23^h24^m53^s.1$	$61°35'22''$	$13^m.74$	$0^m.59$	$0^h.411$	$\sim0^m.02$	2450724.38	SPB
V4*	$23^h24^m45^s.4$	$61°36'52''$	$16^m.32$	$1^m.31$		$\sim0^m.3$		EA
V5**	$23^h24^m37^s.4$	$61°38'57''$	$14^m.42$	$0^m.68$	$0^h.278$	$\leq0^m.02$	2450740.23	δ Scuti

* : discovered in this study, ** : discovered by Viskum *et al.* (1997).

References:

Bertelli, G., Bressan, A., Chiosi, C., Fagotto, F., Nasi, E., 1994, *A&Ap Suppl.*, **106**, 275
Breger, M., 1979, *PASP*, **91**, 5
Choi, H.S., Kim, S.-L., Kang, Y.H., 1998, in preparation
Dziembowski, W.A., Moskalik, P., Pamyatnykh, A.A., 1993, *MNRAS*, **265**, 588
Gilliland, R., Brown, T.M., 1988, *PASP*, **100**, 754
Lee, S.-W., Sung, H., 1995, *J. Korea Astr. Soc.*, **28**, 45
Massey, P., Davis, L.E. 1992, *A User's Guide to Stellar CCD photometry with IRAF*
Viskum, M., Hernández, M.M., Belmonte, J.A., Frandsen, S., 1997, *A&Ap*, **328**, 158
Waelkens, C., Heynderickx, D., Degryse, K., Smeyers, P., 1990, in *Confrontation between stellar pulsation and evolution*, ASP Conf. Ser. no.11, 258