Zeitschrift für Astrophysik 68, 29—47 (1968)

# A Survey of Southern Be Stars.
## II. Photometric data*

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Received August 23, 1967

Seventy two bright southern Be stars from the list of Paper I were observed photoelectrically in the UBV system over a three years time interval. Some of them were also observed in the RI system. It was found that 33 stars display variations in V larger than $0^m.06$ and that 21 change in U—B by more than $0^m.06$. The variations are either progressive or irregular, and changes up to $0^m.3$ have been observed. The variations in V, B—V and U—B show a certain degree of correlation (Fig. 1 and 2). Combining two color diagrams it is concluded that Be stars display both an ultraviolet and an infrared excess. Comparison with other observers shows that despite the relative short time interval covered by our observations, the values found in the present paper can be regarded as a representative sample.

## Introduction

This paper follows another on the spectroscopic data of Be stars (JASCHEK, JASCHEK and KUCEWICZ, 1964, hereafter called Paper I). It is well known that the Be stars display irregular variations of brightness (UNDERHILL, 1960), but except for a few stars not very much is known about these variations, despite the fact that around one hundred Be stars distributed all over the sky are brighter than sixth magnitude, and thus easily accesible to small photometric telescopes.

We have examined photometrically most of the Be stars from Table 2 of Paper I. All these stars have some spectroscopic information regarding their emissions.

## Observations

Photoelectric observations were made from January 1963 till November 1965 with the techniques already described (FEINSTEIN, 1963). The NSF photoelectric photometer of the La Plata Observatory attached to the 32-inch reflector was used, but during three 20-days intervals (March 1964, March 1965 and November 1965) they were also observed with the 16-inch reflector of the Cerro Tololo Inter-American Observatory. The observations in the UBV system were made with the RCA 1P21 photomultiplier and standard filters, and in the RI system

* Contributions from the Cerro Tololo Inter-American Observatory, No. 20.

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Table 1. *Photoelectric observations of Be stars*

| HD | HR | Sp. MK | Date | V | B—V | U—B | n | R | R—I | n |
|---|---|---|---|---|---|---|---|---|---|---|
| 28497 | 1423 | B1 Vne | Jan 1963 | 5.49 | —0.11 | —0.95 | 3 | | | |
| | | | Dec 1964 | 5.42 | —0.15 | —1.02 | 4 | | | |
| | | | Nov 1965 | 5.41 | —0.15 | —0.96 | 4 | 5.40 | —0.12 | 2 |
| 30076 | 1508 | B2 Ve | Jan 1963 | 5.91 | —0.09 | —0.77 | 4 | | | |
| | | | Dec 1964 | 5.81 | —0.10 | —0.80 | 4 | | | |
| | | | Nov 1965 | 5.79 | —0.07 | —0.77 | 4 | 5.69 | —0.06 | 2 |
| 35165 | 1772 | B5 ne | Jan 1963 | 6.07 | —0.18 | —0.65 | 3 | | | |
| | | | Feb 1964 | 6.09 | —0.22 | —0.64 | 1 | | | |
| | | | Dec 1964 | 6.05 | —0.20 | —0.68 | 4 | | | |
| | | | Feb 1965 | | | | | 6.12 | —0.09 | 2 |
| 37775 | 1956 | B8 Ve | Jan 1963 | 2.66 | —0.12 | —0.44 | 2 | | | |
| | | | Feb 1964 | 2.66 | —0.12 | —0.37 | 8 | | | |
| | | | Dec 1964 | 2.66 | —0.11 | —0.35 | 3 | | | |
| | | | Feb 1965 | | | | | 2.62 | —0.09 | 2 |
| 41335 | 2142 | B2 IV—Ve | Jan 1963 | 5.20 | —0.07 | —0.96 | 1 | | | |
| | | | Mar/Apr 1963 | 5.22 | —0.06 | —0.86 | 2 | | | |
| | | | Feb 1964 | 5.22 | —0.10 | —0.86 | 2 | | | |
| | | | Dec 1964 | 5.22 | —0.08 | —0.84 | 4 | | | |
| | | | Feb 1965 | | | | | 5.10 | +0.03 | 3 |
| 42054 | 2170 | B3 Ve | Jan 1963 | 5.83 | —0.14 | —0.62 | 1 | | | |
| | | | Mar 1963 | 5.79 | —0.09 | —0.60 | 1 | | | |
| | | | Feb 1964 | 5.82 | —0.16 | —0.58 | 4 | | | |
| | | | Dec 1964 | 5.81 | —0.13 | —0.58 | 3 | | | |
| | | | Feb 1965 | | | | | 5.81 | —0.08 | 3 |
| | | | Mar 1965 | 5.82 | —0.12 | —0.62 | 3 | | | |
| 43544 | 2249 | B5 ne | Mar/Apr 1963 | 5.94 | —0.14 | —0.81 | 3 | | | |
| | | | Feb 1964 | 5.96 | —0.18 | —0.78 | 2 | | | |
| | | | Dec 1964 | 5.87 | —0.15 | —0.83 | 3 | | | |
| | | | Feb 1965 | 5.89 | —0.17 | —0.83 | 1 | 5.95 | —0.10 | 3 |
| | | | Mar 1965 | 5.91 | —0.15 | —0.81 | 3 | | | |
| 44458 | 2284 | B1 Vpe | Jan 1963 | 5.63 | +0.01 | —0.79 | 1 | | | |
| | | | Mar/Apr 1963 | 5.54 | —0.01 | —0.88 | 3 | | | |
| | | | Dec 1964 | 5.58 | —0.02 | —0.87 | 1 | | | |
| | | | Feb 1965 | 5.49 | —0.02 | —0.85 | 1 | 5.38 | +0.04 | 2 |
| | | | Mar 1965 | 5.64 | 0.00 | —0.81 | 3 | | | |
| | | | Nov 1965 | 5.57 | +0.01 | —0.82 | 4 | 5.33 | +0.16 | 2 |
| 48917 | 2492 | B2 Ve | Jan 1963 | 5.25 | —0.11 | —0.90 | 1 | | | |
| | | | Mar/Apr 1963 | 5.28 | —0.13 | —0.97 | 2 | | | |
| | | | Feb 1964 | 5.31 | —0.14 | —0.89 | 1 | | | |
| | | | Dec 1964 | 5.33 | —0.16 | —0.88 | 1 | | | |
| | | | Feb 1965 | 5.34 | —0.19 | —0.90 | 1 | 5.43 | —0.14 | 1 |
| | | | Mar 1965 | 5.39 | —0.18 | —0.87 | 3 | | | |

Table 1 (Cont.)

| HD | HR | Sp. MK | Date | | V | B—V | U—B | n | R | R—I | n |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 50013 | 2538 | B2 Vp | Jan | 1963 | 3.97 | —0.22 | —0.88 | 2 | | | |
| | | | Mar | 1963 | 3.96 | —0.22 | —0.90 | 1 | | | |
| | | | Feb | 1964 | 3.92 | —0.24 | —1.00 | 2 | | | |
| | | | Feb | 1965 | 3.86 | —0.24 | —1.01 | 1 | 3.96 | —0.16 | 1 |
| | | | Mar | 1965 | 3.91 | —0.22 | —0.96 | 6 | | | |
| 50820 | 2577 | B3 Ve +K2 II | Jan | 1963 | 6.28 | +0.25 | —0.26 | 1 | | | |
| | | | Mar/Apr | 1963 | 6.28 | +0.45 | —0.33 | 3 | | | |
| | | | Feb | 1965 | | | | | 4.90 | +0.64 | 1 |
| 52437 | 2628 | B4 Ven | Mar | 1963 | 6.48 | —0.15 | —0.88 | 2 | | | |
| | | | Feb | 1964 | 6.52 | —0.19 | —0.86 | 2 | | | |
| | | | Dec | 1964 | 6.60 | —0.21 | —0.83 | 1 | | | |
| | | | Feb | 1965 | 6.53 | —0.20 | —0.88 | 1 | 6.63 | —0.16 | 1 |
| | | | Mar | 1965 | 6.52 | —0.18 | —0.84 | 3 | | | |
| 54309 | 2690 | B1 Ve | Mar/Apr | 1963 | 5.90 | —0.14 | —0.93 | 4 | | | |
| | | | Mar | 1964 | 5.88 | —0.16 | —0.86 | 2 | | | |
| | | | Dec | 1964 | 5.91 | —0.17 | —0.83 | 1 | | | |
| | | | Feb | 1965 | | | | | 5.84 | —0.12 | 1 |
| | | | Mar | 1965 | 5.81 | —0.13 | —0.90 | 4 | | | |
| | | | Nov | 1965 | 5.89 | —0.18 | —0.84 | 2 | | | |
| 56014 | 2745 | B5 V | Mar | 1963 | 4.82 | —0.22 | —0.54 | 4 | | | |
| | | | Apr | 1963 | 4.74 | —0.18 | —0.50 | 3 | | | |
| | | | Feb | 1964 | 4.61 | —0.17 | —0.66 | 5 | | | |
| | | | Mar | 1964 | 4.57 | —0.15 | —0.82 | 7 | | | |
| | | | Feb | 1965 | 4.53 | —0.18 | —0.82 | 1 | 4.62 | —0.11 | 2 |
| | | | Mar | 1965 | 4.55 | —0.17 | —0.82 | 5 | | | |
| | | | Nov | 1965 | 4.53 | —0.18 | —0.80 | 2 | 4.56 | —0.16 | 1 |
| 56139 | 2749 | B3 IVe | Mar | 1963 | 3.79 | —0.18 | —0.70 | 3 | | | |
| | | | Feb | 1964 | 3.79 | —0.16 | —0.78 | 1 | | | |
| | | | Mar | 1964 | 3.90 | —0.15 | —0.80 | 2 | | | |
| | | | Feb | 1965 | | | | | 4.06 | —0.14 | 2 |
| | | | Mar | 1965 | 3.96 | —0.17 | —0.69 | 4 | | | |
| | | | Nov | 1965 | 4.00 | —0.17 | —0.67 | 2 | | | |
| 57150 | 2787 | Be Vp | Mar | 1963 | 4.67 | —0.11 | —0.88 | 2 | | | |
| | | | Feb | 1964 | 4.58 | —0.11 | —0.81 | 2 | | | |
| | | | Mar | 1964 | 4.58 | —0.10 | —0.79 | 1 | | | |
| | | | Feb | 1965 | | | | | 4.55 | —0.06 | 1 |
| | | | Mar | 1965 | 4.65 | —0.09 | —0.78 | 4 | | | |
| 58155 | 2819 | B3 IV | Mar | 1963 | 5.46 | —0.20 | —0.72 | 2 | | | |
| | | | Feb | 1964 | 5.40 | —0.18 | —0.66 | 3 | | | |
| | | | Feb | 1965 | | | | | 5.52 | —0.12 | 2 |
| | | | Mar | 1965 | 5.42 | —0.16 | —0.69 | 4 | | | |

Table 1 (Cont.)

| HD | HR | Sp. MK | Date | | V | B—V | U—B | n | R | R—I | n |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 58343 | 2825 | B3 V | Apr | 1963 | 5.38 | —0.12 | —0.54 | 2 | | | |
| | | | Feb | 1964 | 5.42 | —0.12 | —0.56 | 2 | | | |
| | | | Mar | 1965 | 5.38 | —0.06 | —0.56 | 4 | | | |
| | | | Nov | 1965 | | | | | 5.33 | —0.02 | 1 |
| 58978 | 2855 | B0 IVpe | Apr | 1963 | 5.69 | —0.11 | —1.06 | 3 | | | |
| | | | Feb | 1964 | 5.60 | —0.14 | —1.04 | 1 | | | |
| | | | Mar | 1965 | 5.55 | —0.10 | —1.02 | 4 | | | |
| | | | Nov | 1965 | | | | | 5.50 | —0.04 | 1 |
| 60606 | 2911 | B3 Ve | Mar/Apr | 1963 | 5.39 | —0.12 | —0.80 | 2 | | | |
| | | | Feb | 1964 | 5.39 | —0.14 | —0.72 | 2 | | | |
| | | | Mar | 1964 | 5.41 | —0.10 | —0.76 | 3 | | | |
| | | | Feb | 1965 | | | | | 5.37 | —0.06 | 1 |
| | | | Mar | 1965 | 5.44 | —0.09 | —0.74 | 4 | | | |
| | | | Nov | 1965 | 5.54 | —0.10 | —0.69 | 2 | | | |
| 61925 | 2968 | B3 IV | Apr | 1963 | 6.02 | —0.08 | —0.41 | 2 | | | |
| | | | Feb | 1964 | 6.01 | —0.06 | —0.37 | 2 | | | |
| | | | Mar | 1965 | 6.02 | —0.04 | —0.42 | 4 | | | |
| | | | Nov | 1965 | | | | | 5.92 | +0.05 | 1 |
| 63462 | 3034 | B0 Vpe | Mar/Apr | 1963 | 4.49 | —0.12 | —1.06 | 3 | | | |
| | | | Feb | 1964 | 4.49 | —0.21 | —1.05 | 2 | | | |
| | | | Mar | 1964 | 4.47 | —0.08 | —1.02 | 4 | | | |
| | | | Nov | 1965 | | | | | 4.37 | —0.02 | 1 |
| 65875 | 3135 | | Mar/Apr | 1963 | 6.48 | —0.09 | —0.79 | 3 | | | |
| | | | Feb | 1964 | 6.48 | —0.12 | —0.72 | 2 | | | |
| | | | Mar | 1965 | 6.50 | —0.09 | —0.79 | 4 | | | |
| 66194 | 3147 | B3 V | Apr | 1963 | 5.72 | —0.09 | —0.83 | 1 | | | |
| | | | Mar | 1964 | 5.82 | —0.08 | —0.77 | 2 | | | |
| | | | Mar | 1965 | 5.84 | —0.08 | —0.77 | 3 | | | |
| 67888 | 3195 | B5 III | Mar/Apr | 1963 | 6.42 | —0.12 | —0.50 | 4 | | | |
| | | | Feb | 1965 | | | | | 6.25 | 0.00 | 1 |
| | | | Mar | 1965 | 6.35 | —0.04 | —0.55 | 4 | | | |
| 68980 | 3237 | B3 ne | Mar | 1963 | 4.60 | —0.15 | —0.99 | 4 | | | |
| | | | Feb | 1965 | | | | | 4.59 | —0.07 | 1 |
| | | | Mar | 1965 | 4.70 | —0.10 | —0.97 | 3 | | | |
| 72067 | 3356 | B3 V | Mar/Apr | 1963 | 5.82 | —0.18 | —0.76 | 4 | | | |
| | | | Feb | 1965 | | | | | 5.89 | —0.15 | 1 |
| | | | Mar | 1965 | 5.83 | —0.17 | —0.74 | 4 | | | |
| 75311 | 3498 | B2 V | Mar/Apr | 1963 | 4.43 | —0.15 | —0.86 | 4 | | | |
| | | | Mar | 1965 | 4.49 | —0.17 | —0.73 | 4 | | | |

Table 1 (Cont.)

| HD | HR | Sp. MK | Date | V | B—V | U—B | n | R | R—I | n |
|---|---|---|---|---|---|---|---|---|---|---|
| 77320 | 3593 | B2.5 V | Mar/Apr 1963 | 6.08 | —0.22 | —0.80 | 5 | | | |
| | | | Mar 1965 | 6.06 | —0.15 | —0.79 | 6 | | | |
| 78764 | 3642 | B2 Ve | Mar/Apr 1963 | 4.78 | —0.19 | —0.81 | 4 | | | |
| | | | Mar 1964 | 4.67 | —0.13 | —0.84 | 1 | | | |
| | | | Mar 1965 | 4.69 | —0.15 | —0.81 | 4 | | | |
| 83953 | 3858 | B5 V | Mar 1963 | 4.75 | —0.11 | —0.56 | 4 | | | |
| | | | Mar 1964 | 4.75 | —0.11 | —0.58 | 1 | | | |
| | | | Feb 1965 | 4.73 | —0.08 | —0.56 | 1 | 4.73 | —0.06 | 2 |
| | | | Mar 1965 | 4.76 | —0.10 | —0.58 | 5 | | | |
| 86612 | 3946 | | Mar/Apr 1963 | 6.22 | —0.13 | —0.67 | 4 | | | |
| | | | Mar 1964 | 6.19 | —0.10 | —0.68 | 1 | | | |
| | | | Feb 1965 | 6.19 | —0.10 | —0.65 | 1 | | | |
| | | | Mar 1965 | 6.24 | —0.10 | —0.66 | 3 | | | |
| 86661 | 4009 | B2 e | Mar 1963 | 5.63 | —0.08 | —0.93 | 4 | | | |
| | | | Feb 1964 | 5.63 | —0.08 | —0.94 | 3 | | | |
| | | | Mar 1964 | 5.67 | —0.07 | —0.89 | 4 | | | |
| | | | Mar 1965 | 5.67 | —0.06 | —0.90 | 4 | | | |
| 88825 | 4018 | B5 Vnne | Mar 1963 | 6.09 | —0.09 | —0.50 | 4 | | | |
| | | | Mar 1964 | 6.13 | —0.08 | —0.50 | 1 | | | |
| | | | Mar 1965 | 6.10 | —0.07 | —0.50 | 4 | | | |
| 91465 | 4140 | B5 Vp | Mar 1963 | 3.34 | —0.14 | —0.70 | 2 | | | |
| | | | Feb 1964 | 3.31 | —0.10 | —0.74 | 1 | | | |
| | | | Feb 1965 | 3.37 | —0.07 | —0.69 | 1 | | | |
| | | | Mar 1965 | 3.29 | —0.11 | —0.72 | 4 | | | |
| 92964 | 4198 | B3 Ia | Mar 1963 | 5.39 | +0.22 | —0.68 | 3 | | | |
| | | | Feb 1964 | 5.37 | +0.24 | —0.65 | 1 | | | |
| | | | Mar 1964 | 5.38 | +0.26 | —0.67 | 1 | | | |
| | | | Mar 1965 | 5.38 | +0.25 | —0.66 | 4 | | | |
| | | | May 1965 | | | | | 5.08 | +0.24 | 2 |
| 102776 | 4537 | | Mar/Apr 1963 | 4.39 | —0.19 | —0.57 | 3 | | | |
| | | | Feb 1964 | 4.38 | —0.14 | —0.69 | 1 | | | |
| | | | Mar 1964 | 4.33 | —0.16 | —0.63 | 2 | | | |
| | | | Jun 1964 | 4.33 | —0.11 | —0.58 | 1 | | | |
| | | | Mar 1965 | 4.34 | —0.15 | —0.62 | 5 | | | |
| | | | May 1965 | | | | | 4.38 | —0.14 | 2 |
| 105435 | 4621 | B2 Ve | Mar/Apr 1963 | 2.55 | —0.13 | —0.97 | 2 | | | |
| | | | May/Jun 1963 | 2.55 | —0.12 | —0.90 | 2 | | | |
| | | | Mar 1964 | 2.59 | —0.13 | —0.92 | 2 | | | |
| | | | Mar 1965 | 2.58 | —0.13 | —0.91 | 4 | | | |
| | | | May | | | | | 2.52 | —0.14 | 2 |

Table 1 (Cont.)

| HD | HR | Sp. MK | Date | V | B—V | U—B | n | R | R—I | n |
|---|---|---|---|---|---|---|---|---|---|---|
| 105521 | 4625 | | Mar/Apr 1963 | 5.52 | —0.11 | —0.74 | 3 | | | |
| | | | May/Jun 1963 | 5.54 | —0.12 | —0.70 | 2 | | | |
| | | | Mar 1964 | 5.55 | —0.08 | —0.63 | 3 | | | |
| | | | Mar 1965 | 5.56 | —0.10 | —0.62 | 5 | | | |
| | | | May 1965 | | | | | 5.56 | —0.08 | 2 |
| 106911 | 4674 | B5 IV | Mar 1964 | 4.25 | —0.13 | —0.54 | 4 | | | |
| | | | Mar 1965 | 4.24 | —0.13 | —0.54 | 3 | | | |
| | | | May 1965 | | | | | 4.24 | —0.08 | 1 |
| 110432 | 4830 | B1 p | Apr 1963 | 5.39 | +0.16 | —0.88 | 3 | | | |
| | | | Mar 1964 | 5.35 | +0.23 | —0.83 | 3 | | | |
| | | | Mar 1965 | 5.33 | +0.23 | —0.84 | 4 | | | |
| | | | May 1965 | | | | | 4.94 | +0.21 | 1 |
| 112078 | 4897 | B5 Vn | Apr 1963 | 4.61 | —0.19 | —0.59 | 1 | | | |
| | | | Jun 1963 | 4.63 | —0.18 | —0.64 | 2 | | | |
| | | | Mar 1964 | 4.63 | —0.14 | —0.63 | 4 | | | |
| | | | Mar 1965 | 4.63 | —0.15 | —0.62 | 5 | | | |
| | | | May 1965 | | | | | 4.67 | —0.15 | 2 |
| 112091 | 4899 | B5 Ve | Jun 1963 | 4.99 | —0.08 | —0.62 | 2 | | | |
| | | | Mar 1964 | 5.00 | —0.05 | —0.61 | 3 | | | |
| | | | Mar 1965 | 5.04 | —0.06 | —0.62 | 3 | | | |
| 113120 | 4930 | B1 Vne | Apr 1963 | 5.98 | —0.02 | —0.96 | 1 | | | |
| | | | Jun 1963 | 6.04 | —0.01 | —0.96 | 2 | | | |
| | | | Mar 1964 | 6.02 | +0.01 | —0.92 | 3 | | | |
| | | | Mar 1965 | 5.93 | +0.04 | —0.87 | 4 | | | |
| 115842 | 5027 | B0.5 Iab | May/Jun 1963 | 6.06 | +0.28 | —0.77 | 3 | | | |
| | | | Mar 1964 | 6.04 | +0.27 | —0.70 | 4 | | | |
| | | | Mar 1965 | 6.02 | +0.28 | —0.71 | 4 | | | |
| | | | May 1965 | | | | | 5.72 | +0.22 | 2 |
| 120307 | 5190 | | May/Jun 1963 | 3.43 | —0.20 | —0.91 | 3 | | | |
| | | | Mar 1964 | 3.42 | —0.23 | —0.90 | 5 | | | |
| | | | Mar 1965 | 3.41 | —0.22 | —0.89 | 4 | | | |
| | | | May 1965 | | | | | 3.52 | —0.25 | 2 |
| 120324 | 5193 | B3 Ve | Jun 1963 | 3.08 | —0.13 | —0.96 | 3 | | | |
| | | | Mar 1964 | 3.32 | —0.14 | —0.97 | 4 | | | |
| | | | Mar 1965 | 3.37 | —0.17 | —0.93 | 4 | | | |
| | | | May 1965 | | | | | 3.37 | —0.16 | 2 |
| 120991 | 5223 | | Jun 1963 | 6.14 | —0.13 | —0.94 | 3 | | | |
| | | | Mar 1964 | 5.92 | —0.02 | —0.96 | 4 | | | |
| | | | Mar 1965 | 6.09 | —0.07 | —0.92 | 5 | | | |
| | | | May 1965 | | | | | 6.24 | —0.10 | 2 |

Table 1 (Cont.)

| HD | HR | Sp. MK | Date | | V | B—V | U—B | n | R | R—I | n |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 124367 | 5316 | B3 Ve | Jun | 1963 | 5.08 | —0.08 | | 2 | | | |
| | | | Mar | 1964 | 5.05 | —0.07 | —0.62 | 4 | | | |
| | | | Mar | 1965 | 5.01 | —0.04 | —0.62 | 4 | | | |
| | | | Apr | 1965 | 5.02 | —0.03 | —0.64 | 1 | | | |
| | | | May | 1965 | | | | | 4.90 | +0.04 | 2 |
| | | | Jul | 1965 | 4.97 | —0.05 | —0.62 | 1 | | | |
| 127972/3 | 5440 | B1.5 Vne | Jun | 1963 | 2.38 | —0.24 | —0.86 | 2 | | | |
| | | | Mar | 1964 | 2.36 | —0.22 | —0.87 | 4 | | | |
| | | | Mar | 1965 | 2.36 | —0.21 | —0.85 | 2 | | | |
| | | | Apr | 1965 | 2.41 | —0.19 | —0.89 | 1 | | | |
| | | | May | 1965 | | | | | 2.45 | —0.23 | 1 |
| | | | Jul | 1965 | 2.37 | —0.20 | —0.87 | 1 | | | |
| 131492 | 5551 | B3 Ve | Jun | 1963 | 5.23 | —0.05 | —0.84 | 3 | | | |
| | | | Mar | 1964 | 5.21 | —0.02 | —0.76 | 4 | | | |
| | | | Mar | 1965 | 5.02 | —0.01 | —0.77 | 3 | | | |
| | | | Apr | 1965 | 5.04 | 0.00 | —0.79 | 1 | | | |
| | | | May | 1965 | | | | | 4.87 | +0.08 | 2 |
| | | | Jul | 1965 | 5.04 | —0.02 | —0.80 | 2 | | | |
| 137387 | 5730 | B3 IV | Jun | 1963 | 5.58 | —0.16 | —0.74 | 2 | | | |
| | | | Mar | 1964 | 5.50 | —0.12 | —0.73 | 4 | | | |
| | | | Mar | 1965 | 5.50 | —0.12 | —0.80 | 2 | | | |
| | | | Apr | 1965 | 5.44 | —0.08 | —0.86 | 1 | | | |
| | | | May | 1965 | | | | | 5.45 | —0.02 | 1 |
| | | | Jul | 1965 | 5.43 | —0.13 | —0.87 | 2 | | | |
| 142983 | 5941 | B pe | Jun | 1963 | 4.94 | —0.09 | —0.09 | 3 | | | |
| | | | Mar | 1964 | 4.90 | —0.09 | —0.09 | 5 | | | |
| | | | Mar | 1965 | 4.94 | —0.08 | —0.09 | 3 | | | |
| | | | Apr | 1965 | 4.88 | —0.08 | —0.02 | 1 | | | |
| | | | May | 1965 | | | | | 4.89 | 0.00 | 2 |
| | | | Jul | 1965 | 4.91 | —0.10 | —0.02 | 1 | | | |
| 148184 | 6118 | B2 IV | Jun | 1963 | 4.44 | +0.23 | —0.88 | 3 | | | |
| | | | Mar | 1964 | 4.53 | +0.25 | —0.80 | 3 | | | |
| | | | Mar | 1965 | 4.59 | +0.22 | —0.79 | 3 | | | |
| | | | Apr | 1965 | 4.51 | +0.22 | —0.84 | 1 | | | |
| | | | May | 1965 | | | | | 4.18 | +0.20 | 2 |
| | | | Jul | 1965 | 4.53 | +0.20 | —0.82 | 1 | | | |
| 148379 | 6131 | B2 Ia | Jun | 1963 | 5.38 | +0.48 | —0.52 | 2 | | | |
| | | | Mar | 1964 | 5.34 | +0.54 | —0.45 | 4 | | | |
| | | | Mar | 1965 | 5.32 | +0.55 | —0.45 | 2 | | | |
| | | | Apr | 1965 | 5.29 | +0.52 | —0.50 | 1 | | | |
| | | | May | 1965 | | | | | 4.78 | +0.47 | 2 |
| | | | Jul | 1965 | 5.39 | +0.52 | —0.49 | 1 | | | |

Table 1 (Cont.)

| HD | HR | Sp. | MK | Date | | V | B—V | U—B | n | R | R—I | n |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 148688 | 6142 | B1 | Ia | Jun | 1963 | 5.31 | +0.29 | —0.72 | 2 | | | |
| | | | | Mar | 1964 | 5.32 | +0.35 | —0.65 | 4 | | | |
| | | | | Mar | 1965 | 5.32 | +0.34 | —0.65 | 2 | | | |
| | | | | Apr | 1965 | 5.24 | +0.32 | —0.70 | 1 | | | |
| | | | | May | 1965 | | | | | 4.92 | +0.30 | 2 |
| 149404 | 6164 | O9 | I | Jun | 1963 | 5.42 | +0.36 | —0.72 | 2 | | | |
| | | | | Mar | 1964 | 5.46 | +0.38 | —0.64 | 4 | | | |
| | | | | Mar | 1965 | 5.47 | +0.39 | —0.63 | 2 | | | |
| | | | | Apr | 1965 | 5.44 | +0.38 | —0.72 | 1 | | | |
| | | | | May | 1965 | | | | | 5.01 | +0.35 | 2 |
| 152235 | 6261 | B1 | I | Mar | 1964 | 6.33 | +0.51 | —0.48 | 3 | | | |
| | | | | Jun | 1964 | 6.38 | +0.46 | —0.52 | 2 | | | |
| | | | | Aug | 1965 | 6.36 | +0.47 | —0.52 | 1 | | | |
| 152236 | 6262 | B1 | Ia | Jun | 1963 | 4.72 | +0.47 | —0.62 | 2 | | | |
| | | | | Mar | 1964 | 4.72 | +0.48 | —0.56 | 3 | | | |
| 152667 | 6283 | B0 | Ip | Mar | 1964 | 6.69 | +0.08 | —0.85 | 1 | | | |
| 154090 | 6334 | B1 | II—III | Jun | 1963 | 4.84 | +0.22 | —0.76 | 2 | | | |
| | | | | Mar | 1964 | 4.87 | +0.25 | —0.70 | 2 | | | |
| | | | | May | 1965 | | | | | 4.59 | +0.17 | 1 |
| 155806 | 6397 | O8 | e | Jun | 1963 | 5.47 | —0.01 | —1.00 | 1 | | | |
| | | | | Mar | 1964 | 5.53 | —0.01 | —0.97 | 2 | | | |
| | | | | Jul | 1965 | 5.52 | —0.01 | —1.04 | 1 | | | |
| 157042 | 6451 | B3 | ne | Jun | 1963 | 5.25 | —0.16 | —0.87 | 1 | | | |
| | | | | Mar | 1964 | 5.21 | —0.10 | —0.86 | 3 | | | |
| | | | | Aug | 1965 | | | | | 5.12 | —0.08 | 1 |
| 158427 | 6510 | B2.5 | Ve | Mar | 1964 | 2.93 | —0.16 | —0.72 | 2 | | | |
| | | | | Jun | 1964 | 3.00 | —0.18 | —0.69 | 2 | | | |
| | | | | Aug | 1965 | 2.86 | —0.14 | —0.73 | 1 | | | |
| 167128 | 6819 | B3 | V | Mar | 1964 | 5.31 | —0.03 | —0.72 | 1 | | | |
| | | | | Jun | 1964 | 5.32 | —0.08 | —0.70 | 2 | | | |
| | | | | Jul | 1965 | 5.35 | —0.05 | —0.72 | 2 | | | |
| | | | | Aug | 1965 | 5.36 | —0.06 | —0.68 | 3 | 5.29 | —0.05 | 1 |
| 173948 | 7074 | B1 | Ve | Mar | 1964 | 4.18 | —0.15 | —0.88 | 1 | | | |
| | | | | Jun | 1964 | 4.26 | —0.18 | —0.88 | 2 | | | |
| | | | | Jul | 1964 | 4.23 | —0.13 | —0.84 | 1 | | | |
| | | | | Jul | 1965 | 4.22 | —0.15 | —0.92 | 2 | | | |
| | | | | Aug | 1965 | 4.16 | —0.16 | —0.89 | 3 | 4.15 | —0.17 | 1 |

Table 1 (Cont.)

| HD | HR | Sp. | MK | Date | | V | B—V | U—B | n | R | R—I | n |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 178175 | 7249 | B2 | Ve? | Jun | 1964 | 5.38 | —0.04 | —0.73 | 1 | | | |
| | | | | Jul | 1964 | 5.36 | —0.04 | —0.66 | 1 | | | |
| | | | | Jul | 1965 | 5.59 | —0.04 | —0.68 | 2 | | | |
| | | | | Aug | 1965 | 5.60 | —0.07 | —0.66 | 3 | 5.57 | —0.07 | 1 |
| 205637 | 8260 | B3 | Vep | Aug | 1965 | 4.65 | —0.18 | —0.60 | 2 | | | |
| | | | | Sep | 1965 | 4.67 | —0.20 | —0.59 | 1 | 4.66 | —0.10 | 2 |
| | | | | Oct | 1965 | 4.68 | —0.19 | —0.59 | 1 | | | |
| 209014 | 8386 | | | Dec | 1964 | 5.33 | —0.12 | —0.30 | 2 | | | |
| | | | | Aug | 1965 | 5.42 | —0.08 | —0.29 | 2 | 5.42 | —0.03 | 1 |
| | | | | Sep | 1965 | 5.44 | —0.11 | —0.29 | 1 | 5.40 | —0.10 | 1 |
| | | | | Oct | 1965 | 5.43 | —0.09 | —0.31 | 1 | | | |
| 209409 | 8402 | B5 | V | Aug | 1965 | 4.72 | —0.10 | —0.37 | 1 | 4.66 | —0.03 | 1 |
| | | | | Sep | 1965 | 4.73 | —0.13 | —0.39 | 2 | 4.71 | —0.03 | 1 |
| | | | | Oct | 1965 | 4.68 | —0.10 | —0.38 | 1 | | | |
| 209522 | 8408 | B5 | Vn | Dec | 1964 | 5.89 | —0.19 | —0.65 | 1 | | | |
| | | | | Aug | 1965 | 5.99 | —0.18 | —0.63 | 1 | 5.96 | —0.12 | 1 |
| | | | | Sep | 1965 | 5.96 | —0.18 | —0.66 | 2 | 6.03 | —0.16 | 1 |
| | | | | Oct | 1965 | 5.92 | —0.16 | —0.66 | 1 | | | |
| 214748 | 8628 | | | Dec | 1964 | 4.12 | —0.10 | —0.28 | 4 | | | |
| | | | | Aug | 1965 | 4.16 | —0.08 | —0.29 | 2 | 4.13 | —0.07 | 1 |
| | | | | Sep | 1965 | 4.24 | —0.10 | —0.31 | 1 | 4.18 | —0.13 | 1 |
| | | | | Oct | 1965 | 4.17 | —0.09 | —0.30 | 1 | | | |

with an RCA 7102 photomultiplier and the filters Schott OG 5 plus Corning 3965 for R, and Schott RG 8 plus Corning 2540 for I. The standard stars which define the UBV system (JOHNSON and MORGAN, 1953; JOHNSON and HARRIS, 1954) were always used. The standard stars for R and I were also taken from Johnson's lists (JOHNSON, 1964; IRIARTE et al., 1965).

In Table 1 are listed 72 stars with the mean values obtained by averaging the measures made during the month they were observed. We prefer to discuss the montly averages instead of the individual values, because in this way the observed measures are smoothed, and we thus expect that the fluctuations due to errors in the observations will be smaller.

The accuracy of each measure is about $\pm 0^{m}.025$ (m.e.) for each observation obtained during 1963, but decreases to about $\pm 0^{m}.015$ in 1965, because of the improvement of the observational techniques. We may estimate therefore that the monthly averages given in Table 1

have a mean error not larger than $\pm 0^m.020$. We expect thus that differences between two averages larger than $0^m.06$ are due principally to real variations in the star.

The reduction of the photoelectric observations obtained in 1964 and 1965 were carried our with the IBM 1620 computer of the La Plata University, with a program prepared by Dr. J. GORDON. The residuals of the standard stars in V, B−V and U−B were given for each night by the computer, and it was found that they are always much smaller than $0^m.06$, in agreement with the above mentioned conclusion.

## Discussion

Our first aim is to single out the different types of variation.

### *A. Types of variation*

As may be seen in Table 1 an appreciable number of Be stars displays variations in the V magnitude, or in the color U−B, or in both, magnitude and color. On the other hand a very few stars have also a slight variation in B−V. An examination of Table 1 reveals that some Be stars like 27 CMa (HD 56014) show a different trend as HD 44458. In some cases the variations in V or in U−B are monotonous, i.e. either decreasing or increasing continuously without reaching a point where this variation reverses its sense. We will call this "progressive variation" ($V_p$). Thus, a star with a difference between the first and the last average which is larger than $0^m.06$, and larger also than any other difference between two intermediate values, belongs to this kind of variation.

There is another group of stars which shows irregular variations with sudden changes in the brightness V, or in the color U−B. It is not possible in these particular cases to obtain an idea of the period involved, and a star in which two values differ by more than $0^m.06$ (except the first and the last), is assumed to have an "irregular variation" ($V_i$).

Table 2. *Kind of variation according to magnitude and color*

| | V | B—V | U—B |
|---|---|---|---|
| $V_p$ | 14 | 4 | 9 |
| $V_i$ | 19 | 7 | 12 |

In Table 2 are tabulated the numbers of stars according to their type of variation (progressive or irregular) and to the measured quantity in which the variation occurs (V, B−V or U−B). It should be remembered that in all cases listed, the variation is larger than $0^m.06$. A given star may appear in more than one column of Table 2 for the same kind of variation.

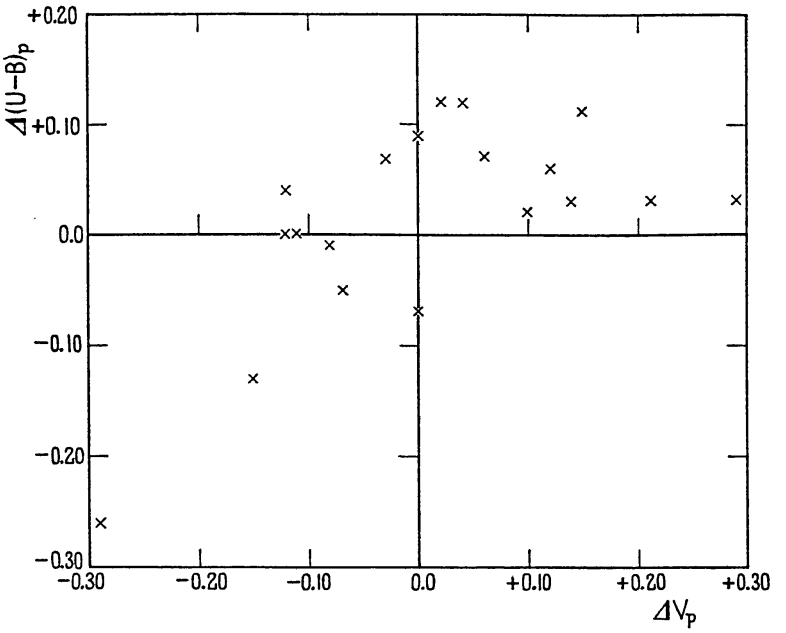


Fig. 1. Variation in V and in U—B for stars with differences larger than $0^m.06$ between the first and the last measure (progessive variations)

Evidently the photometric variation on the Be stars is mainly in V and U−B, except a very few cases in which the B−V color also varies. This indicates that the variation in the B magnitude has the same amount as in V, and that on the other hand there is a large and different variation in U, since U−B is changing some times in a different way than V.

The amounts of variation in V versus the change in U−B for the stars which vary progressively are plotted in Fig. 1. It may be seen that the points are scattered all over the diagram, with the exception of the fourth quadrant. The behaviour in the first and third quadrant (increase/decrease of U−B with increase/decrease in V) seems quite natural. Due to the presence of the envelope, when the star becomes fainter, the U becomes also fainter.

The case when the visual magnitude becomes brighter and the ultraviolet magnitude fainter, may be explained by an increase of the stellar radiation with the simultaneous ejection of matter. In this case it may happen that this ejection increases the optical depth of the envelope, and thus decreases the U radiation emitted by it. On this basis it could be expected that there should be no events in which U increases and V decreases, and this is borne out by the observations.

The same conclusion obtained from $V_p$ was also found for the $V_i$ stars, as we see in Fig. 2. There is only one case (HD 214478) with V decreasing and U−B increasing, but even this exception can probably be blamed upon the mean error of one measure, which is around $\pm 0^m.020$.

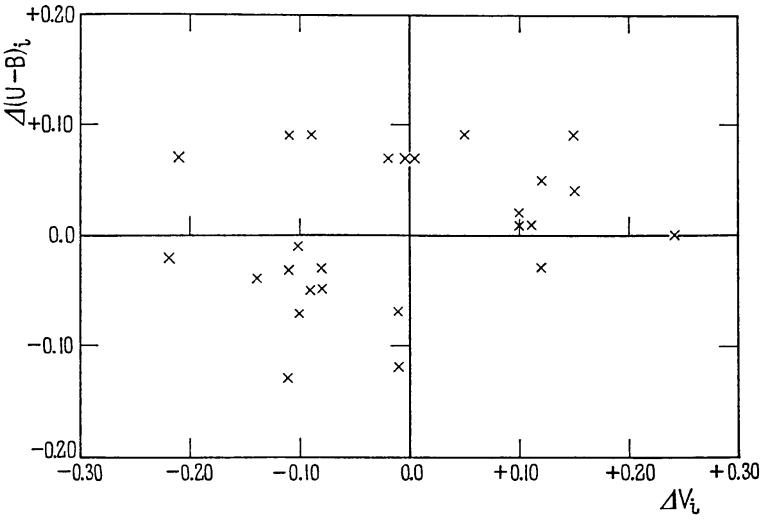


Fig. 2. Variation in V and in U—B for stars with differences larger than $0^m.06$ between two extreme values (irregular variations)

Since the behaviour of both groups in the (V, U−B) diagram is the same, one is tempted to think that both types of variation belong to the same phenomenon. The only difference being the lenght of the period or cycle involved in each case with respect to the time interval during which the observations were made.

### *B. Variation according to magnitude and colors*

The frequency of the largest observed magnitude differences in V, B−V, and U−B, for all the stars listed in Table 1 are shown in Fig. 3, 4 and 5.

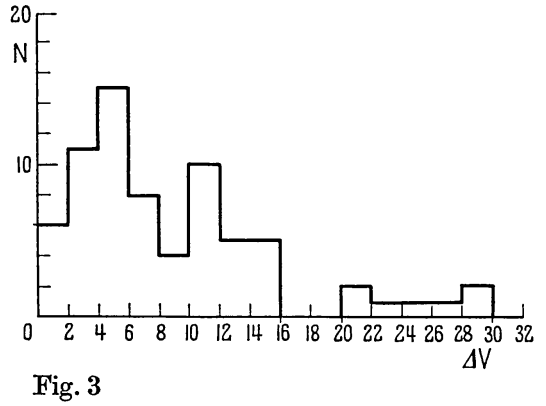


Fig. 3

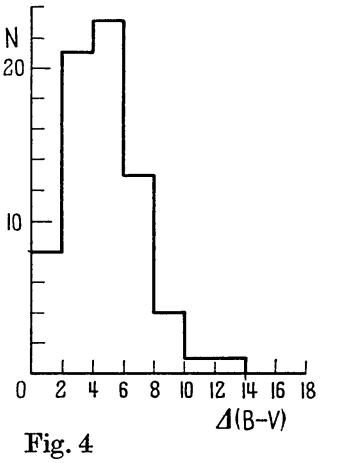


Fig. 4

Fig. 3. Frequency diagram of the range in V of individual stars. Abscissa: $\Delta V$ in $0^m.01$; ordinate: number of stars

Fig. 4. Frequency diagram of the range in B—V of individual stars. Abscissa: $\Delta$(B—V) in $0^m.01$; ordinate: number of stars

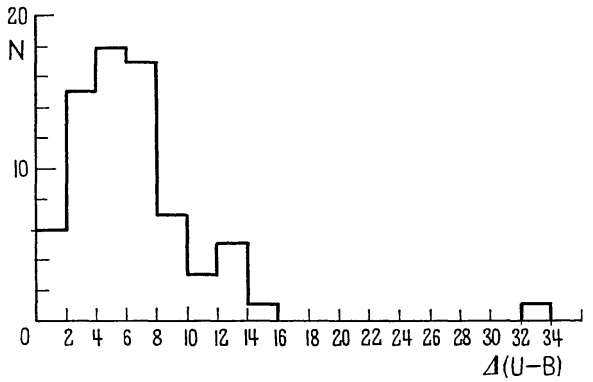


Fig. 5. Frequency diagram of the range in U—B of the individual stars. Abscissa: $\Delta$(U—B) in $0^m.01$; ordinate: number of stars

Fig. 3, which gives the distribution according to the magnitude V, shows a peak around $0^m.04$, and perhaps another peak at $0^m.12$. In the B−V and U−B colors (Fig. 4 and 5), both have the maximum at the same value: $0^m.04$.

From these three figures it is easy to conclude that the range in variation is larger in V than in U−B, which is also larger than one in B−V.

Fig. 4, which gives the frequency of the largest difference in B−V, shows the distribution of what we expect for constant stars, since only 13 stars out of the 71 stars listed in Table 1 have differences larger than $0^m.06$ (11 stars have $0^m.08$ and 2 larger values), which is the value we adopt as a limit of the errors. Obviously, at least some of the stars with differences larger than $0^m.06$ are variable stars.

## Color-color diagrams

Fig. 6 to 9 give the color-color diagrams for all the observed Be stars. The supergiant and main sequence as defined by JOHNSON, 1965, are also indicated. As most of the stars have just one observation in R and I, we made the differences V−R and V−I with the V, B−V and U−B values of the nearest date to the corresponding measures in R and R−I.

In Fig. 6 the (B−V, U−B) shows that most of the Be stars are distributed between the main sequence and the supergiant sequence, with the exception of some few stars which are farther to the right of the supergiant branch. On the other hand the position of the supergiant stars in the diagram indicates that they are subject to considerable reddening. Fig. 7 gives the (U−V, V−I) array, in which the Be stars are also above the main sequence. If we remove the ultraviolet band as we do in the (B−V, V−I) diagram (Fig. 8), the stars come closer to the main sequence

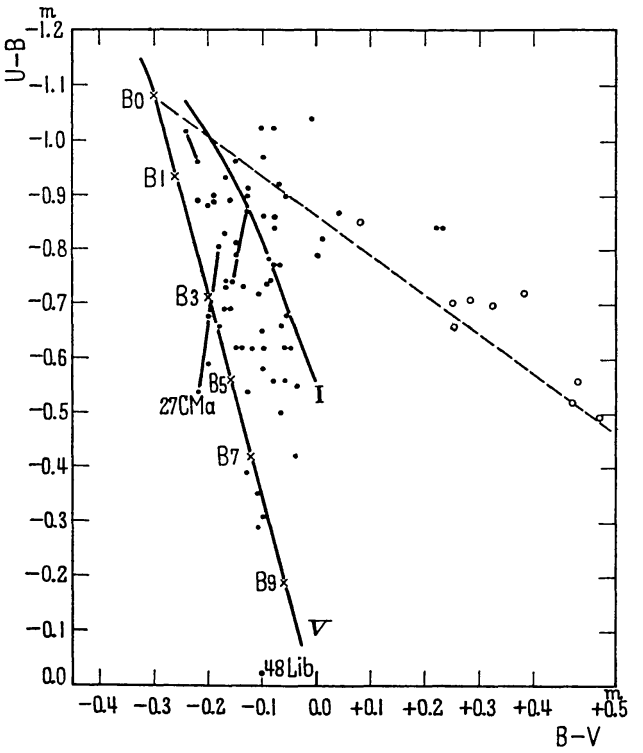


Fig. 6. (B—V, U—B) array for all the Be stars. Main sequence and supergiant sequence are indicated. The reddening line (broken line) is also shown. Dots stand for stars classified as dwarfs, and circles for giant or supergiant stars. The variation of 27 CMa (HD 56014) and other two stars are indicated

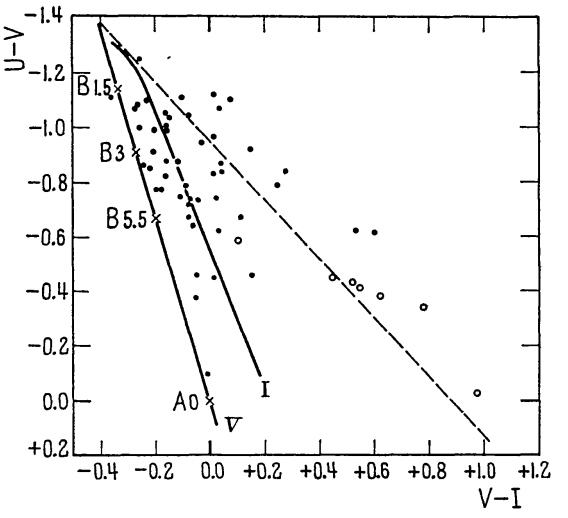


Fig. 7. (U—V, V—I) array for all the Be stars

(with the exception of only 5 stars which are below it). If we then eliminate the infrared band (Fig. 9) which gives the (B−V, V−R) diagram, the distribution of the points has less dispersion in the V−R. All these

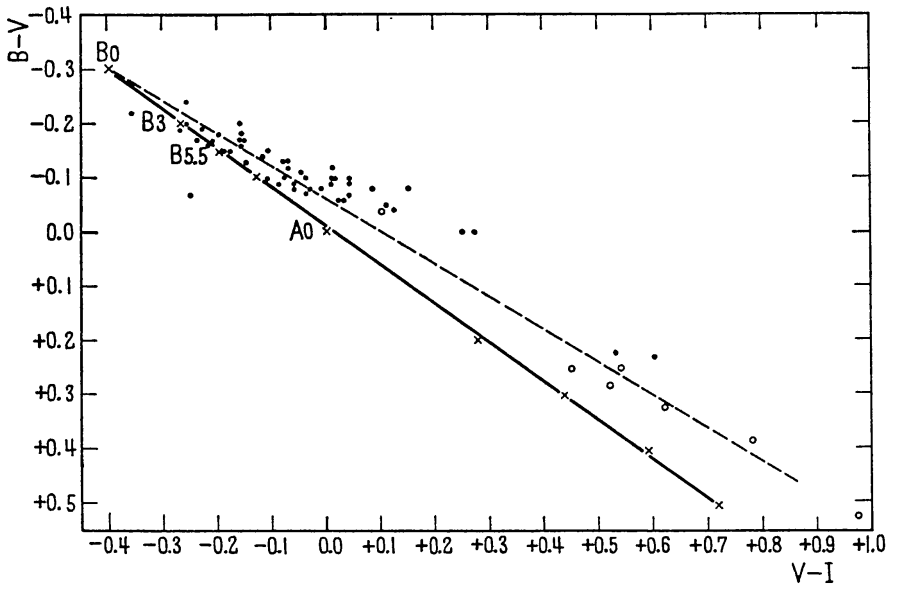


Fig. 8. (V—I, B—V) array for all the Be stars

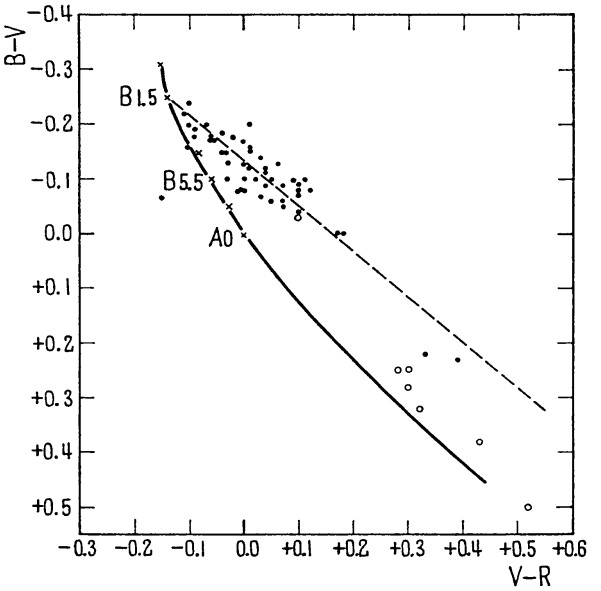


Fig. 9. (V—R, B—V) array for all the Be stars. The main sequence is indicated. The broken line gives the direction of reddening lines

results imply that a large percentage of the Be stars have both an ultraviolet and an infrared excess. In the ultraviolet, the Balmer jump is lower than in the normal stars due to the fact that the continuum is in emission. It is very possible that in the region of the shorter wavelengths of the infrared pass band (around 8200 Å) the continuum could also be in emission; therefore the Paschen jump could be smaller than in normal

stars. This peculiar energy distribution may be a result of the envelope which also produces the $H_\alpha$ emission.

The occurence of a shell around the Be stars originates a radiation which modifies the radiation of a normal star, and one is inclined to think that it is very probably of similar characteristics as to what happens in the Wolf-Rayet stars but, obviously, on a much smaller scale.

## Shell stars

Some of the Be stars that we have measured are known as shell stars, and it would be of interest to obtain the light curves of some of them. Combining our observations with the ones given by the observers of the JOHNSON group at the Catalina and Tonantzintla Observatories (JOHNSON et al., 1966) we obtained some information on those four stars of this type which have the largest number of observations.

In the four diagrams of Fig. 10, we plotted our V values of HD 50013 ($\varkappa$ CMa), 56014 (27 CMa), 56139 ($\omega$ CMa) and 120324 ($\mu$ Cen), and those obtained by JOHNSON, 1966. The agreement of all the values seems to be quite acceptable.

The star HD 50013 according to our classification of the kind of variation, is indicated as having an irregular variation, but the uniform light curve does not support this conclusion. The other three were

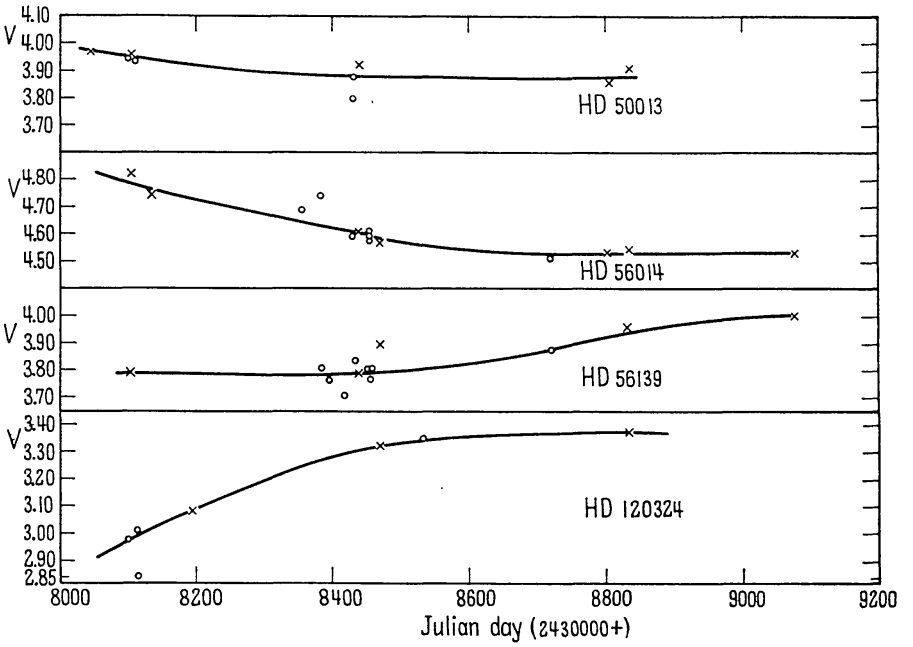


Fig. 10. Observations of the V magnitude of four shell stars. Crosses indicate our observations and circles JOHNSON's, 1966, measures

classified as stars with progressive variations which agree with their curves.

The light curves of all four objects indicate that besides the long period variations, there are also short periodic ones.

## Comparison with measures made by other observers

A large number of Be stars was observed photoelectrically and spectroscopically by MENDOZA, 1958. An examination of the southern stars of his list shows that we have in common twelve objects, which are listed in Table 3. It gives respectively the mean of our measurements

Table 3. *Comparison of photoelectric measurements taken from* FEINSTEIN *(present paper) and* MENDOZA, *1958*

| | FEINSTEIN | | | MENDOZA | | | Difference: FEINSTEIN-MENDOZA | | |
|---|---|---|---|---|---|---|---|---|---|
| HD | V | B—V | U—B | V | B—V | U—B | $\Delta$V | $\Delta$(B–V) | $\Delta$(U–B) |
| 28497 | 5.44 | —0.14 | —0.98 | 5.90 | —0.20 | —0.89 | —0.46 | +0.06 | —0.09 |
| 30076 | 5.84 | —0.09 | —0.78 | 5.92 | —0.11 | —0.83 | —0.08 | +0.02 | +0.05 |
| 41335 | 5.22 | —0.08 | —0.88 | 5.24 | —0.09 | —0.83 | —0.02 | +0.01 | —0.05 |
| 44458 | 5.58 | 0.00 | —0.84 | 5.64 | —0.02 | —0.85 | —0.06 | +0.02 | +0.01 |
| 58343 | 5.39 | —0.10 | —0.55 | 5.33 | —0.05 | —0.60 | +0.06 | —0.05 | +0.05 |
| 65875 | 6.49 | —0.10 | —0.77 | 6.63 | —0.08 | —0.86 | —0.14 | —0.02 | +0.09 |
| 83953 | 4.75 | —0.10 | —0.57 | 4.68 | —0.14 | —0.56 | +0.07 | +0.04 | —0.01 |
| 120324 | 3.26 | —0.15 | —0.95 | 3.47 | —0.22 | —0.81 | —0.21 | +0.07 | —0.14 |
| 127972/3 | 2.38 | —0.22 | —0.87 | 2.35 | —0.22 | —0.80 | +0.03 | 0.00 | —0.07 |
| 148184 | 4.52 | —0.22 | —0.83 | 4.57 | —0.22 | —0.74 | —0.05 | 0.00 | —0.09 |
| 178175 | 5.48 | —0.05 | —0.68 | 5.54 | —0.11 | —0.78 | —0.06 | +0.06 | +0.10 |
| 205637 | 4.67 | —0.19 | —0.59 | 4.60 | —0.18 | —0.69 | +0.07 | —0.01 | +0.10 |

from Table 1 and the values obtained by MENDOZA. The last columns display the differences FEINSTEIN-MENDOZA for each star. From the 12 stars in both lists, 6 have magnitude differences in V larger than $0^m.06$, 7 have U−B differences larger than $0^m.06$ and only one star has a B−V difference larger than $0^m.06$ according to Table 3. On the other hand only the stars HD 58343, 127972/3 and 205637 seem to be non-variable according to Table 1, but the difference FEINSTEIN-MENDOZA shows that the last star is variable, since its color difference is $\Delta$(U−B) $= 0^m.10$.

COUSINS, 1965, published a list of bright southern stars which according to his photoelectric measures obtained over a decade, are variable in magnitude. In Table 4 are tabulated 15 stars which we have in common.

Table 4. *Comparison with Cape measures*

| HR | HD | Range ($P_g$) | Range (V) |
|---|---|---|---|
| 2745 | 56014 | $0^m.24$ | $0^m.29$ |
| 2749 | 56139 | 0.16 | 0.21 |
| 2787 | 57150 | 0.1 | 0.09 |
| 3237 | 68980 | 0.11 | 0.10 |
| 3498 | 75311 | 0.10 | 0.06 |
| 3642 | 78764 | 0.06 | 0.11 |
| 4140 | 91465 | 0.17 | 0.08 |
| 4621 | 105435 | 0.04 | 0.00 |
| 5193 | 120324 | 0.2 | 0.29 |
| 5440 | 127972/3 | 0.14 | — |
| 5941 | 142983 | 0.19 | 0.06 |
| 6262 | 152236 | 0.10 | — |
| 7074 | 173948 | 0.14 | 0.10 |
| 8260 | 205637 | 0.26 | — |
| 8402 | 209409 | 0.3 | — |

The two columns of Table 4 give: the range of variation in the blue listed by COUSINS, and the range in the visual according to us. If no value is given in the last column (4 stars), it means that we did not find the star to be variable, but in these 4 cases the stars have perhaps an insufficient number of measures to detect their variations. The values appearing in both columns of Table 4 are rather similar.

As a conclusion, if we compare our observations with those of MENDOZA, 1958, we find large difference between these two lists for half of the 12 stars in common. This result is compatible with the variation we had obtained from Table 1 for the same stars. On the other hand, the ranges of variation we got are similar to those given by COUSINS, 1965, for the same stars. All these agreements suggest that the time interval of three years is long enough to derive significant conclusions.

## Conclusion

The variation we found in V and/or U−B for half of the Be stars imply that the envelope whose existence is demonstrated by the $H_\alpha$ emission, is not in steady state. In most of the Be stars the changes occur on a slow time scale, but superimposed on these there are irregular variations over a very short time scale.

In order to obtain a more detailed picture, the author hopes to undertake in the future a similar study including more red and infrared observations. It is hoped that this information will be useful for a better understanding of the behaviour of this kind of stars.

I appreciate very much many suggestions given to me by Dr. C. JASCHEK. I am also indebted to Dr. J. GORDON of the Computing Center of the University of La Plata, who programmed the reduction of our photometric observations. The facilities offered to me by the Cerro Tololo Interamerican Observatory are especially acknowledged.

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