# Search for "Lost" Variables in Carina. I. The Cape Variables

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**Abstract** We present precise positions and finder charts for probable candidates for thirteen variables found on Cape Observatory plates, part of sixty new variables near η Carinae originally published by Worssell in 1919. *BVRI* datasets are presented for eight of the stars (BE, BF, BG, BH, BM, BN, BW, and BY Car), showing that most of these stars are essentially constant. BK Car may be identical with NSV 4957.

## 1. Introduction

The Union Observatory of Johannesburg, South Africa, was originally established in 1905 for meteorological research. Under the directorship of R.T.A. Innes it later branched into positional astronomy and proper motion studies in particular. Reports on variable star studies were issued from time to time in the *Union Circulars*, but it appears that insufficient time and resources were allocated to this branch of astronomy (go to the South African Astronomical Observatory (SAAO) web site given in the reference list for more on the history of the Union Observatory). For example, Worssell (1919) listed sixty new variables near η Carinae, while recognizing that his results were very preliminary and that much work remained to be done to verify their variability. At the same time he offers reasons why his observatory was not able to investigate the stars any further. Citing from page 16, Worssell states :

> ...to pronounce definitely that a star is variable or not, requires that many plates should be examined. The labor of doing this is very great. We have at the moment twenty-five photographs of the region available, but there is no room for their simultaneous display, and their examination in small groups both greatly increases the labor and the risk of breakage.

The manner in which the new variables were reported reflects the very preliminary nature of these discoveries:

- no provisional names given (the provisional *Astronomische Nachrichten* (AN) names came later, first appearing in Anon. 1920);

- no finder charts provided;
- only rough coordinates given, even for rather faint stars.

Probably, it was hoped that another observatory would take up the challenge of studying these stars more thoroughly. Unfortunately, many of Worssell's stars could not be identified with certainty in this rich region of the Milky Way and have languished for many decades as "lost" objects, notwithstanding the fact that they were given official names in the catalogues of variable stars. The purpose of our research has been to establish the identities of the following Carina variables : BE, BF, BG, BH, BK, BM, BN, BP, BV, BW, and BY. Two other stars, TV and BC Car, also found by Worssell, had been previously found at Harvard (Pickering 1906) but they are not in doubt.

It is important to point out that this project was undertaken in the absence of the original discovery plates, which are difficult to locate and access. The aim was to see if the study of alternate plates and recent images would achieve convincing results.

## 2. Worssell's variables

Worssell (1919) lists sixty new variables in addition to almost fifty previously known or named variables. We are only concerned with his new discoveries. At first glance one might think that these new stars are a fairly homogeneous group, being found at one observatory, by one observer, etc. However, a careful reading of his report reveals that this is not the case. The Union Observatory, in its program of proper motion studies, used plates from three sites (Union, Cape, and Sydney, Australia), spanning the time interval 1892–1919. It is virtually certain that plates from different observatories, separated by time and geography would have utilized different makers and possibly plates of slightly differing characteristics, notwithstanding that all plates were photoblue in response. One of us (MM) compiled a small subset from Worssell's list, namely thirteen variables found only on a pair of Cape Observatory plates, to see if there was any underlying pattern or commonality to these stars.

Some of Worssell's Cape variables were rediscoveries of stars found on Harvard Observatory plates, and reported in the *Harvard Circular*. TV and BC Car were two such stars found on the Cape plates.

## 3. The Cape plates

Two plates of the η Carinae region had been provided to Union Obs., and blinked as part of their proper motion program. One was taken 1892 March 3, the other 1919 February 13. The elapsed time between them was 26.95 years. A byproduct of blinking the Cape plates was the detection of thirteen variables, eleven of them new. However, doubts must now inevitably arise as to the compatibility of two such

plates for photometric purposes, even rough photometry, a purpose for which they may not have been ideally suited. An exposition of how variables can be found by use of the blink microscope has been given by Capron (1973), also indicating the possible pitfalls.

## 4. Contemporary materials

With the original plates not available, MM attempted to visualize what Worssell would have most likely seen by using modern blue-light plates of the η Car region. An old Sydney Observatory plate was also used, while recent yellow and red light plates were compared to assess the color of likely stars, to get an indicative *B–V*. The atlases and plates used were:

- *A Spectral Survey of the Southern Milky Way III*. (Loden *et al*. 1976). Abbreviated Stockholm Survey;
- print of Sydney Astrographic plate, centred on η Car nebula, ca. 1895;
- *True Visual Atlas* (Papadopolous 1979);
- DSS (*Digitized Sky Survey*) images (Space Telescope Science Institute 2007).

The η Carina nebula is a very popular subject for imaging, and richly tinted images are very common in popular astronomy magazines. Whilst pleasing to the eye, these pictures have limited scientific value.

A few images have been useful for orientation, when they happen to give good definition of stars against the bright nebular background. The complexity of this region—many hot stars mingled with bright nebular background—present problems for survey catalogues based on Schmidt camera *B* and *R* plates. These catalogues have big "holes" in the η Car region. Recourse was made to other catalogues such as UCAC2 and GSC2.2 for positional data close to the heart of the nebula.

## 5. Identification of candidates

Worssell's original positions (equinox 1875) were looked up and precessed forward to J2000. Each star's surroundings were studied using a GUIDE8 display, but as these stars are generally around 14.0p, the default catalogues provide neither color information nor sufficient detail to be certain of identification. MM then referred to other materials, listed in the previous section, for a closer examination. This enabled the compilation of a list of likely candidates. For each candidate, magnitudes were compiled: *V*—generally from ASAS-3 (Pojmański 2002) or GSC2.2 (Space Telescope Science Institute 2001); *B*—eyeball estimates from available *B* plates, calibration mainly from following sequences:

- GSPC S128 (*Guide Star Photometric Catalogue*, Lasker *et al.* 1988);
- "OB Stars in the Field of the Carina Nebula," (Forte and Orsatti 1981).

While MM's eyeball *B* magnitudes were good to only ±0.3 magnitude (approximately), the indicative *B–V* index derived was a handy indicator of color for this purpose. The list of identifications is presented in Table1.

Finder charts were prepared for the eight red stars, not hitherto observed, and multi-color observations were made in *BVRI* by GDS. Details of his setup are given in Section 6.

Finder charts for all stars discussed in this paper are given in Figure 1.

## 6. Multi-color observations

In February and March 2007, observations were obtained in *BVRI* by GDS at the Carnes Hill Observatory. Instrumental and observing parameters were :

- telescope: 12-inch LX200 GPS;
- imaging: SBIG ST9XE;
- standard: E532 (= HD104720 = CoD–45 7495) for *BVRI*; Spec. K4/5 III;
- adopted values: $V = 9.237$; $B–V = 1.510$; $U–B = 1.890$; $V–R_c = 0.811$; $V–I_c = 1.557$.

Each star was observed at least four times, and the results are tabulated in Table 2, grouped by variable name. Errors are quoted for each color, and the final column ("Transform") indicates whether the results have been transformed, "Y".

## 7. Discussion

From work done by the first author in matching Worssell's rough coordinates with blue and yellow plates, an apparently red star can be found rather close to each position for BE, BG, BH, BM, BN, and BW Carinae. For BF and BY Car the nearest red stars are a little further away, but after allowing for the crudeness of Worssell's positions, the match- ups are plausible.

Precise *BVRI* data by GDS confirms the redness of each star, but not the reported variability.

This subset of eight red stars appear to have much in common. They are mostly between 14.0 and 14.5*B*, in agreement with Worssell's rough estimates. *V* is much brighter, with mean $V = 12.22$. Worssell's ranges are all rather similar, most lying between 1.0 and 1.5 magnitude, with two outliers BE and BN Car, ranges 0.8 and 2.0 magnitudes, respectively. This degree of uniformity seems a little suspicious, being based on only two plates.

The η Car/Cr228 nebular region is rich in luminous, early-type stars. Late-type stars are fairly uncommon, but Worssell seems to have succeeded in picking up a number of such stars at about $B = 14$. The stated ranges, about 1.5 magnitude, would have been obvious on photographs, and should have been easy to detect on subsequent surveys. In 1923 the Leiden Observatory (Netherlands) and Union Observatory signed an agreement to share each other's resources. In practice,

Union Observatory became the southern station for Leiden, whose adjunct director was Ejnar Hertzsprung. A meticulous observer with a keen eye, Hertzsprung had a special interest in the η Car region. Between 1923 and 1957 about 12,000 plates of the southern sky had been exposed. The results from Leiden appeared in many issues of the B.A.N. (*Bulletin of the Astronomical Institute of the Netherlands*). Short period variables were of particular interest and the η Car region was worked over fairly thoroughly at Leiden. If any of Worssell's Cape variables were, for argument's sake, an eclipsing star, the chances are good that Hertzsprung would have recovered it. In fact, only one star, BP Car, turned out to be an eclipsing variable (Hertzsprung 1925). No short period variables, or stars of large amplitude, were found close to the others. We have downloaded ASAS-3 light curves for most of the variables discussed here.

Because of crowding and the bright background of the η Car nebula good data can be hard to obtain, even at the $V = 12$ level. Most of the red stars (except for BF and BH Car, insufficient data points) have light curves which show :

- a fair bit of noise;
- no evidence for variations of 1.0–1.5 magnitude; any intrinsic variations hardly exceed 0.2 to 0.3 magnitude.

In contrast, the data obtained by GDS has, in general, errors of ± 0.02 or 0.03, with little variation in *V* over a forty-day period. The mean values of *B* in Table 2 are all fairly consistent with the "maximum" photoblue values reported by Worssell; none are near his "minimum" values. The magnitude ranges reported by Worssell appear to be spurious, due to variations in the quality of the single pair of plates which he had compared. To get the best results in photographic work, one should use plates of the most consistent quality, a point appreciated well by Hertzsprung (1930), who explicitly makes this point: "Care is taken to compare plates of good gradation and as similar to each other in all respects as can be found."

It may be that in Worssell's situation such rigorous standards were not realistic or achievable.

## 8. NSV 4957 = BK Car?

NSV 4957 is an S-type star previously observed by Andrews (1976), who found variations in *V* from 12.53 to 13.69, and *B–V* from 2.42 to 2.78. GDS has examined some old CCD images, with these results.

| | | | | | |
|---|---|---|---|---|---|
| JD | 2453889.9160 | 13.21*V* | 2453898.9083 | 13.38*V* | 2453903.9243 13.35*V* |
| | 2453897.8868 | 13.25*V* | 2453898.9375 | 13.28*V* | Mean $V = 13.30$. |
| | 2453897.9625 | 13.26*V* | 2453899.0042 | 13.39*V* | Standard error : +/–0.05 |

Standard star: CPD-58 2625, $V = 10.71$, $B–V = 0.43$.

A more recent observation: JD 2454163.0243, $V = 13.38 \pm 0.02$, $B = 15.87 \pm 0.05$, Transform: Y.

There is no known variable at the position of BK Car given by Worssell (1919), which happens to be just 10' due north of NSV 4957. As NSV 4957 has the parameters (apparent *B* magnitude, color, and range) which are not inconsistent with the range given by Worssell, this leads us to strongly suspect a typographical error in the declination of BK Car. The precise position of NSV 4957 appears in Table 1.

It is not unreasonable to propose that BK Car = NSV 4957.

## 9. Summary

Based on the limited photometric data presented in this paper, we can summarize each observed candidate star as follows:

| Star | *V* (mean) | *B*–*V* (mean) | Variability |
|---|---|---|---|
| BE Car | 12.55 | 1.64 | Constant |
| BF Car | 12.86 | 1.78 | Constant |
| BG Car | 12.16 | 1.74 | Constant? Or very slight var. |
| BH Car | 12.50 | 1.32 | Constant? Close comp. to east. |
| BK Car | 13.35 | 2.56 | Var. Assumed identification with NSV 4957. |
| BM Car | 12.26 | 1.96 | Constant? Or very slight var. |
| BN Car | 11.90 | 2.50 | Var? Slight rise, 11.98 to 11.87*V*. |
| BW Car | 12.13 | 1.73 | Constant? Or very slight var. |
| BY Car | 12.05 | 1.84 | Constant. |

Of the few stars which appear in ASAS-3, there is no indication of large amplitude variations. We find no support for the ranges reported by Worssell in the data we have collected.

## 10. Acknowledgements

This research has made use of several astrometric catalogues, via the VIZIER facility operated at CDS, Strasbourg, France. We acknowledge the use of *Digitized Sky Survey* (DSS) images, obtained from the Space Telescope Science Institute site, http://archive.stsci.edu/dss; also the use of the Astrophysics Data Service for providing online access to historical papers.

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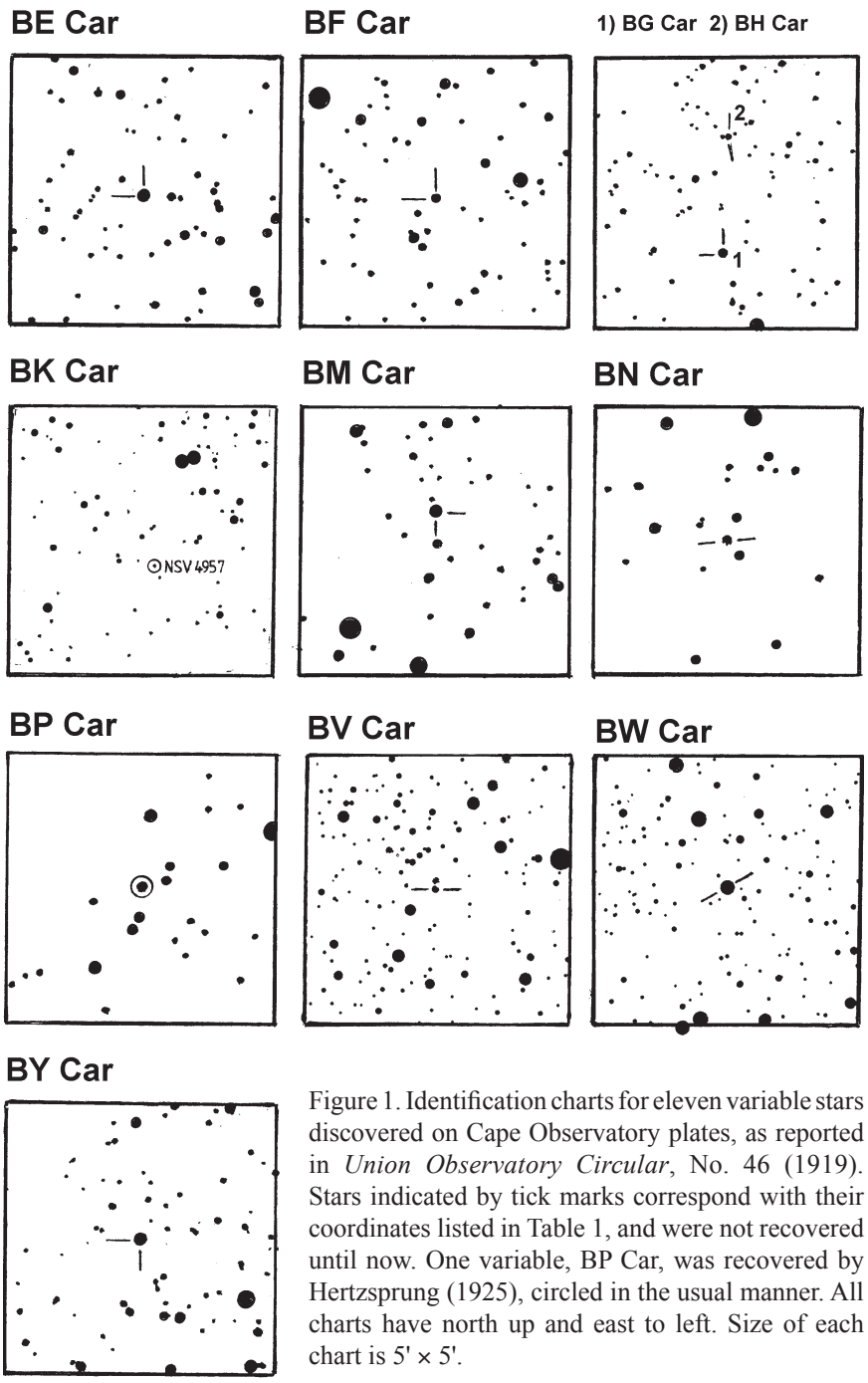


Figure 1. Identification charts for eleven variable stars discovered on Cape Observatory plates, as reported in *Union Observatory Circular*, No. 46 (1919). Stars indicated by tick marks correspond with their coordinates listed in Table 1, and were not recovered until now. One variable, BP Car, was recovered by Hertzsprung (1925), circled in the usual manner. All charts have north up and east to left. Size of each chart is 5' × 5'.

Table 1. Identifications for thirteen Cape variables.

| *GCVS* | *Position from Worssell (1919)* | | *Astrometric Position* | | | *B* | | | *Published* | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Name* | *R.A. 2000* | *Dec. 2000* | *R.A. 2000* | *Dec. 2000* | *Source* | *mag.* | *Plate* | *Color* | *Range* | *Remarks* |
| BC Car | 10 37 33 | –59 00 38 | 10 37 32.23 | –59 00 38.0 | U | | | Red | 3.0 p | HV 1222 SR |
| TV Car | 10 38 45 | –60 49 37 | 10 38 43.55 | –60 49 25.0 | T2 | | | Red | 2.32B | HV 1223 LB Sp.C |
| BE Car | 10 41 38 | –60 19 48 | 10 41 36.35 | –60 19 45.8 | G | 14.0 | St | Red | 0.8 p | AN 1919.0095 |
| BF Car | 10 42 40 | –60 15 04 | 10 42 22.81 | –60 15 02.5 | U | 14.5 | St | Red | 1.2 p | AN 1919.0096 |
| BG Car | 10 42 53 | –60 09 05 | 10 42 52.75 | –60 09 02.5 | G 2 | 14.0 | St,Sy | Red | 1.2 p | AN 1919.0097 |
| BH Car | 10 42 53 | –60 06 35 | 10 42 52.09 | –60 06 52.9 | G2 | 13.7 | Sy | Red | 1.5 p | AN 1919.0098 |
| HV 4957 | | | 10 44 13.48 | –59 36 39.6 | U | 15.0 | Sy | Red | 2.0 p | BK CAR?1919.0100? |
| BM Car | 10 45 18 | –60 23 20 | 10 45 16.31 | –60 23 25.4 | U | 14.0 | St | Red | 1.5 p | AN 1919.0102 |
| BN Car | 10 45 38 | –60 08 33 | 10 45 35.10 | –60 08 36.6 | U | 14.3 | St,Sy | Red | 2.0 p | AN 1919.0103; |
| BP Car | 10 46 45 | –60 09 55 | 10 46 45.42 | –60 09 51.6 | U | 14.0 | Sy | | 1.0 p | AN 1919.0105;EA/SD |
| BV Car | 10 51 42 | –60 13 47 | 10 51 39.22 | –60 14 26.1 | A2 | 13.9 | A2 | | >2.0 p | AN 1919.0114 |
| BW Car | 10 51 59 | –58 47 42 | 10 51 56.47 | –58 47 44.0 | G | 14.0 | St | Red | 1.0 p | AN 1919.0115 |
| BY Car | 10 52 58 | –60 16 10 | 10 52 50.79 | –60 16 44.6 | U | 14.5 | St | Red | 1.5 p | AN 1919.0117 |

*Plate Codes:St = Stockholm Survey plate; Sy = Sydney astrograph plate.*
*Catalogue Codes: A2 = USNO-A2.0; G = GSC-ACT; G2 = GSC2.2; T2 = Tycho-2; U = UCAC2.*

*Notes: 1. BK Car?: HV 4957 = BM VII 9 (Blanco and Munch,* Bol. de Ton. y. Tac., *No.12, 17, 1955). Mean V = 13.04, B-V = 2.64 (Andrews, P. J.,* Observatory, *96, 11, 1976). Strong possibility that BK Car = HV 4957. Decl. in UOC46 too small by 10'? 2. BN Car = AFGL4793S.*

Table 2. *BVRI* Photometry of eight Carina variables.

| *Star* | *JD 2454000+* | *B* | *Berr* | *V* | *Verr* | *R* | *Rerr* | *I* | *Ierr* | *Trans-form* |
|---|---|---|---|---|---|---|---|---|---|---|
| BE Car | 145.9736 | 14.20 | 0.035 | 12.54 | 0.035 | 11.53 | 0.02 | 10.50 | 0.02 | Y |
| | 155.0986 | 14.09 | 0.05 | 12.56 | 0.02 | 11.59 | 0.03 | 10.51 | 0.02 | Y |
| | 163.0972 | 14.28 | 0.03 | 12.54 | 0.03 | 11.48 | 0.03 | 10.49 | 0.02 | Y |
| | 170.1167 | 14.19 | 0.02 | 12.55 | 0.02 | 11.54 | 0.02 | 10.56 | 0.02 | Y |
| | 186.0410 | 14.19 | 0.02 | 12.55 | 0.02 | 11.55 | 0.02 | 10.56 | 0.02 | Y |
| BF Car | 145.9674 | 14.68 | 0.035 | 12.83 | 0.035 | 11.90 | 0.02 | 10.86 | 0.02 | Y |
| | 155.0951 | 14.57 | 0.05 | 12.85 | 0.02 | 11.87 | 0.03 | 10.84 | 0.02 | Y |
| | 163.0924 | 14.59 | 0.04 | 12.87 | 0.03 | 11.83 | 0.04 | 10.87 | 0.02 | Y |
| | 170.1139 | 14.71 | 0.02 | 12.88 | 0.02 | 11.90 | 0.02 | 10.91 | 0.02 | Y |
| | 186.0326 | 14.64 | 0.02 | 12.88 | 0.02 | 11.86 | 0.02 | 10.85 | 0.02 | |
| BG Car | 145.9674 | 13.92 | 0.035 | 12.13 | 0.035 | 11.05 | 0.02 | 9.88 | 0.02 | Y |
| | 155.0951 | 13.87 | 0.05 | 12.12 | 0.02 | 11.07 | 0.03 | 9.85 | 0.02 | Y |
| | 163.0924 | 13.95 | 0.03 | 12.16 | 0.03 | 11.11 | 0.03 | 9.90 | 0.02 | Y |
| | 170.1139 | 13.87 | 0.02 | 12.18 | 0.02 | 11.05 | 0.02 | 9.92 | 0.02 | Y |
| | 186.0326 | 13.87 | 0.02 | 12.19 | 0.02 | 11.08 | 0.02 | 9.90 | 0.02 | Y |
| BH Car | 145.9674 | 13.86 | 0.10 | 12.37 | 0.10 | *** | | *** | | |
| | 155.0951 | 13.85 | 0.10 | 12.47 | 0.10 | *** | | *** | | |
| | 163.0924 | 13.77 | 0.10 | 12.57 | 0.10 | 11.83 | 0.05 | 11.47 | 0.05 | |
| | 170.1139 | 13.86 | 0.10 | 12.57 | 0.10 | 11.94 | 0.10 | 11.48 | 0.05 | |
| | 186.0326 | 13.80 | 0.01 | 12.54 | 0.05 | 11.82 | 0.05 | 11.47 | 0.05 | |
| BM Car | 146.0646 | 14.26 | 0.035 | 12.26 | 0.05 | 11.07 | 0.05 | 9.77 | 0.04 | Y |
| | 155.1007 | 14.23 | 0.05 | 12.27 | 0.02 | 10.96 | 0.03 | 9.78 | 0.02 | Y |
| | 163.0951 | 14.13 | 0.03 | 12.27 | 0.03 | 10.50 | 0.03 | 9.75 | 0.02 | Y |
| | 170.1222 | 14.21 | 0.02 | 12.28 | 0.02 | 11.01 | 0.02 | 9.81 | 0.02 | Y |
| | 186.9521 | 14.26 | 0.03 | 12.21 | 0.03 | 10.98 | 0.02 | 9.79 | 0.02 | Y |
| BN Car | 146.0667 | 14.45 | 0.02 | 11.98 | 0.06 | 10.38 | 0.03 | 8.87 | 0.03 | Y |
| | 155.1035 | 14.42 | 0.05 | 11.94 | 0.02 | 10.35 | 0.03 | 8.87 | 0.02 | Y |
| | 163.1007 | 14.43 | 0.03 | 11.88 | 0.03 | 10.30 | 0.03 | 8.88 | 0.02 | Y |
| | 170.1194 | 14.41 | 0.02 | 11.87 | 0.02 | 10.26 | 0.02 | 8.89 | 0.02 | Y |
| | 172.9646 | 14.39 | 0.02 | 11.89 | 0.02 | 10.27 | 0.02 | 8.87 | 0.02 | Y |
| | 182.9736 | 14.31 | 0.02 | 11.86 | 0.03 | 10.29 | 0.02 | 8.87 | 0.02 | Y |
| | 186.0313 | 14.37 | 0.02 | 11.87 | 0.02 | 10.26 | 0.02 | 8.88 | 0.02 | Y |

*(Table 2 continued on following page)*

Table 2. *BVRI* Photometry of eight Carina variables, continued.

| *Star* | *JD 2454000+* | *B* | *Berr* | *V* | *Verr* | *R* | *Rerr* | *I* | *Ierr* | *Trans-form* |
|---|---|---|---|---|---|---|---|---|---|---|
| BW Car | 146.0618 | 13.86 | 0.05 | 12.17 | 0.03 | 11.12 | 0 .045 | 10.26 | 0.04 | Y |
| | 155.1063 | 13.91 | 0.05 | 12.11 | 0.02 | 11.14 | 0.03 | 10.20 | 0.02 | Y |
| | 163.0896 | 13.85 | 0.04 | 12.10 | 0.03 | 11.13 | 0.04 | 10.25 | 0.02 | Y |
| | 170.1250 | 13.85 | 0.02 | 12.15 | 0.02 | 11.13 | 0.02 | 10.25 | 0.02 | Y |
| | 186.0646 | 13.82 | 0.02 | 12.13 | 0.02 | 11.15 | 0.02 | 10.25 | 0.02 | Y |
| BY Car | 155.1111 | 13.93 | 0.05 | 12.04 | 0.02 | 10.93 | 0.03 | 9.92 | 0.02 | Y |
| | 163.0868 | 13.85 | 0.03 | 12.06 | 0.03 | 10.95 | 0.03 | 9.92 | 0.02 | Y |
| | 170.1271 | 13.88 | 0.02 | 12.04 | 0.02 | 10.91 | 0.02 | 9.95 | 0.02 | Y |
| | 186.0354 | 13.89 | 0.02 | 12.06 | 0.02 | 10.93 | 0.02 | 9.95 | 0.02 | Y |

*Notes:*

*BE Car* V = *12.57 ± 0.11 ASAS-3.*

*BG Car* V = *12.32 ± 0.09 ASAS-3.*

*BH Car* *Close companion to east, d = 10". Difficult to measure. Some measures in* R *and* I *rejected, as clearly erroneous.*

*BM Car* V = *12.08 ± 0.08 ASAS-3.*

*BN Car* V = *11.63 ± 0.08 ASAS-3. Contaminated by background nebula?*

*BW Car* V = *12.16 ± 0.07 ASAS-3.*

*BY Car* V = *12.05 ± 0.06 ASAS-3.*