The Light Curve of SU Carinae

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Abstract Pitfalls for observers are highlighted through examination of the light curve of SU Car. For many years this Mira variable has been misidentified during certain parts of its light curve. The reasons are explored and valid observations discerned. A reviewed light curve is presented, to which is added data (containing no misidentifications) from 1962 to 1972. This last is presented as part of a longer-term, if fragmentary, light curve, probably for the first time. Finally, a new "g" scale chart is offered to aid better quality observations in the future.

1. Introduction

Observers experienced and otherwise, including the *All Sky Automatic Survey* (ASAS, Pojmański 2002), have had trouble identifying the Mira variable SU Car when faint (<12th magnitude). Figure 1 shows the last twelve years of observations of SU Car from the combined data bases of the AAVSO, the ASAS, and the Variable Star Section of the Royal Astronomical Society of New Zealand (VSS RASNZ). The confusion in the light curve appears in all these data sets, and is shown by the plateau of "noise" between 12th and 13th magnitude interrupting the rise and fall a Mira variable is expected to show.

In passing it is worth noting that the SIMBAD online database states correctly the range of SU Car as 10–17.5p but incorrectly states the period as 230.9 days (citing Kukarkin *et al.* 1971). The online version of the *General Catalogue of Variable Stars* (GCVS, Samus 2004), however, correctly lists the period as 575.6 days, citing Bateson and Menzies (1975).

2. The observations

2.1. Background

SU Car (= HD 88918 R.A. (2000) $10^h\ 13^m\ 30.42^s$, Dec. –60° 53' 09.5") was discovered by A. Cannon (Cannon *et al.* 1909); her examination of fifty photographs showing a long period variable with a period thought to be 231 days. Regular observation of the star did not commence until 1961, when the VSS RASNZ began a study lasting until 1972, and published in Bateson and

Menzies (1975). They found the period to be 575.6 days with a visual maximum of between 8.5 to 10.9v. There was no attempt to observe the object past 12th magnitude or so.

2.2. 1962–1972

A chart was made for the RASNZ study by plotting stars from the *Cape Photographic Durchmusterung* (CPD, Astron. Data Center 1993) catalogue down to about 11.5B, and then sketching stars at the telescope down to about 13.0v. The sketch was confined to sequence stars, only. Field stars not relevant were ignored. The completed chart was eventually published as chart 284 (Bateson *et al.* 1971). The sequence stars used were labeled with letters, as reliable *V* magnitudes were not yet known. Menzies later determined the *V* and *B–V* values for the lettered stars on chart 284 in order to write the Bateson and Menzies (1975) paper.

The observations of SU Car from 1962 to 1972 were not in the RASNZ (or AAVSO) database at the time of writing. They were originally published in the form of seven short handwritten graphic fragments. The original observers' notes being unavailable, these graphs were enlarged and overlaid with a grid, and the estimates then entered into PERANSO light curve software (Vanmunster 2005) for use here. The obvious uncertainty with this method does not matter much with a star of this nature. These data constitute the first section of the light curve in Figure 2.

2.3. 1977–2008

The next data that appear are from 1977 onwards, and are contained in the databases of the RASNZ, the AAVSO (which is almost identical), and later, the ASAS (Pojmański 2002). All of these data are problematic. Concerning the visual observations, it appears that the causes of the errors seen in Figure 1 have been attempts to make estimates fainter than chart 284 and its 1995 replacement chart 1105 (Bateson and Morel 1995), which was designed to be used down to, for example, 12.9v. The chart was designed to do what it did: correctly determine the period of the Mira variable. The chart was never designed to be used as deeply as has been attempted, and it causes misidentifications when used near the limit of the chart and beyond. The complete sequence of RASNZ charts 284 and 1105 is shown in Table 1. The cause of the ASAS misidentifications is not known. However, with a pixel size of 15" in such a crowded field, proximate objects could well be responsible.

2.4. Two skilled observers

Examination of the post-1977 data separated into individual observers shows only two people who appear to have avoided problems: Peter Williams and Rod Stubbings. First, both have been careful to identify the variable when faint. Stubbings then used comparison stars in nearby fields, of which there

are plenty in this part of the sky, to extend the sequence (Stubbings 2008). Williams used another way. He "eyeballed" an appropriate star, in this case one of ~13.5v, and also used the limiting magnitude on a given night of his 30-cm Newtonian as a fainter-still "comparison star" (Williams 2008).

Both are thoroughly experienced and skilled observers who correctly identified the variable over a period of years and their estimates are to be taken seriously. The worst one should do is simply to assign them greater error bars than usual.

2.5. Reviewing the observations

It is worth subjecting all available data to an editing process to see what remains. First, all of the Bateson and Menzies (1975) data can remain untouched, as can those of Williams and Stubbings. Of the rest, including the ASAS data, all estimates less than 12.0v are removed, including those of one of us (A.P.). This cutoff is chosen to be well out of the way of the above mentioned problems yet retain information about the period and maxima.

3. The reviewed light curve

The observations remaining after the above process comprise Figure 2. Note that virtually no observations from the period 1977–1992 remain after this treatment. For comparison, both the edited Figure 2 data and the entire unedited observation set (not shown here) are subjected to period analysis and the resulting phase plots shown. The periodograms of the two sets are identical, one of which appears as Figure 3, and show a period 575.3740 days. This is in fine agreement with the 575.6 days found by Bateson and Menzies (1975) and in the online GCVS, if not the SIMBAD database. The phase diagram of the unedited data set is shown in Figure 4(a) and that of the edited set in Figure 4(b).

4. Conclusion: a "g" scale chart

By way of conclusion, a new "g" scale chart is presented as Figure 5 to help with the future observation of SU Car, and an extended provisional sequence is given in Table 2. It is hoped that when problems like this are found and discussed there is less chance of them happening in the future—with any variable star.

5. Acknowledgements

Thanks go to Bob Evans and Ranald McIntosh of the RASNZ, Peter Williams, Rod Stubbings, and all of the observers from the AAVSO and the RASNZ who have observed this star. This research has made use of the

SIMBAD database, operated at Centre de Données astronomiques de Strasbourg, Strasbourg, France.

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Table 1.V Sequence of lettered comparison stars for SU Carinae (1010–60 SU Car = HD 88918 (2000) R.A. $10^h\ 13^m\ 30.42^s$, Dec. –60° 53' 09.5").

Chart Nr. 284/1105	*mag.*	*R.A. (2000)* *h m s*	*Dec.* ° ′ ″	V	B–V	*S*	*HD/DM*
a	82	10 11 32.54	–61 14 23.3	8.12	+0.56	HIP	88663
c	87	10 13 2.53	–61 10 44.9	8.49	–0.11	T2	88844
b	85	10 15 30.43	–60 44 16.5	8.51	+0.55	HIP	89187
d	90	10 10 47.66	–60 56 34.8	8.96	–0.05	T2	88543
e	91	10 14 53.02	–60 44 30.8	9.14	+0.08	T2	89096
f	93	10 11 42.64	–60 50 5.0	9.18	–0.06	T2	88674
g	96	10 16 1.67	–60 42 47.7	9.41	+0.25	T2	89218
l	95	10 13 48.41	–60 52 46.1	9.52	+1.10	23	305018
h	99	10 14 21.24	–61 2 26.2	9.79	+0.01	T2	89017
m	99	10 13 41.33	–60 51 31.3	9.85	+1.02	23	305017
q	109	10 13 51.88	–60 52 1.7	10.87	+1.25	23	
o	109	10 12 59.28	–60 54 6.4	10.93	+0.69	26	
k	111	10 13 3.17	–60 58 5.4	11.06	+0.10	26	CPD–60 1764
p	112	10 13 44.33	–60 52 13.8	11.19	+1.67	23	
n	113	10 12 58.06	–60 55 21.8	11.32	+0.01	26	CPD–60 1762
s	119	10 13 19.71	–60 49 41.0	11.87	+0.81	26	
t	120	10 13 20.90	–60 48 35.6	12.01	+1.71	23	
r	129	10 13 26.40	–60 51 1.6	12.89	+0.24	23	
ASAS-3 Photometry				V	*Err*		
u		10 13 13.93	–60 52 38.4	12.68	0.08		

Source codes: HIP = Hipparcos (Perryman et al. *1997); T2 = Tycho-2 Catalogue (*Høg et al. *2000); 23 = Bateson, F. M., and Menzies, B. 1975, Publ. Var. Star Sec. RASNZ 3, 47; 26 = Menzies, B. 1977, Publ. Var. Star Sec. RASNZ, 5, 6.*

Table 2. Provisional values for the "g" scale chart for SU Car.

Label	*R.A. (2000)* *h* *m* *s*	*Dec. (2000)* ° ′ ″	V	*Err*	*Source*
u127	10 13 13.93	–60 52 38.4	12.68	0.04	ASAS-3
v135	10 13 21.08	–60 53 33.3	13.54	0.16	ASAS-3
w138	10 13 19.71	–60 54 52.9	13.8		Provisional v
x140	10 13 38.51	–60 52 36.8	14.0		Provisional v
y142	10 13 13.92	–60 52 22.5	14.2		Provisional v
z150	10 13 22.80	–60 53 03.6	15.0		Provisional v red?

Stars "v" to "z" are new, and provisional visual, pending determination of precise values. Star "u" is in the ASAS-3 *database and is reliable for visual work.*

Note. No ASAS-3 *data are available for stars w to z, so the* GSC2.2 *catalogue (STScI 2001) was examined. However, their* V *magnitudes (at least those below 13.0) appear to be too bright by about 0.4, so an appropriate adjustment has been made. In view of the uncertainties, the extended provisional sequence is terminated at 15.0v (M.M.).*

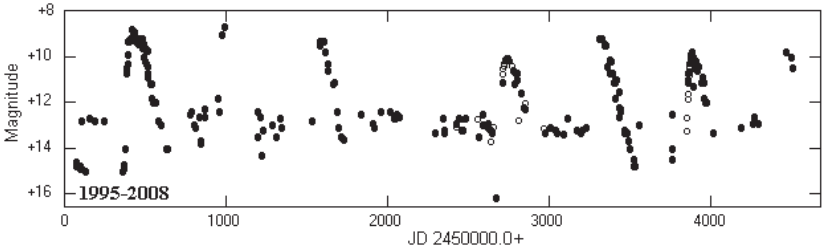

Figure 1. An excerpt of the AAVSO and RASNZ data (dots) and ASAS data (circles) on SU Car.

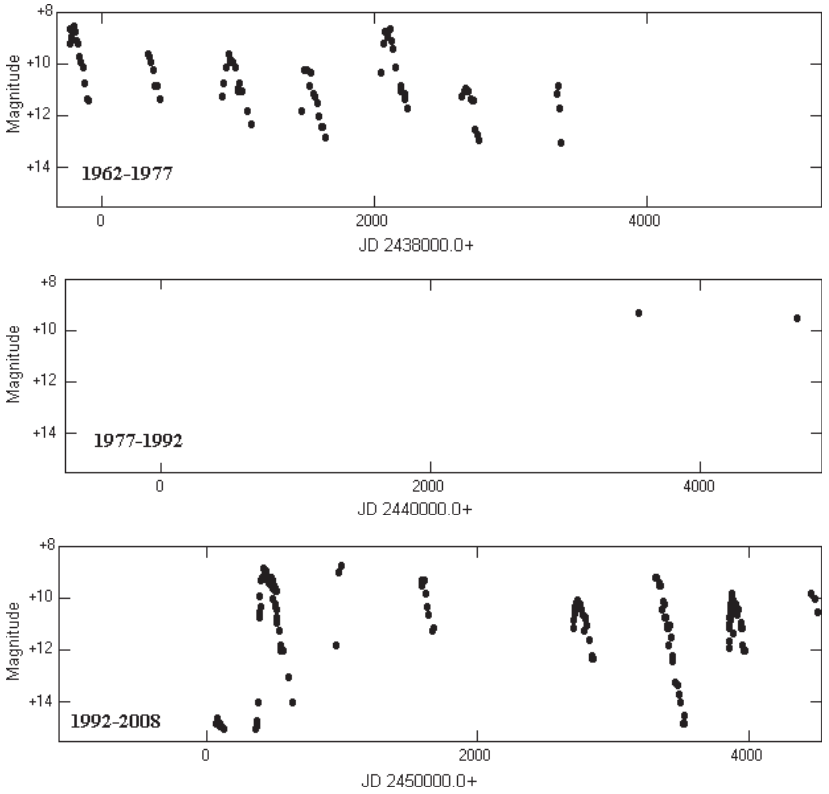

Figure 2. The reviewed light curve of SU Car.

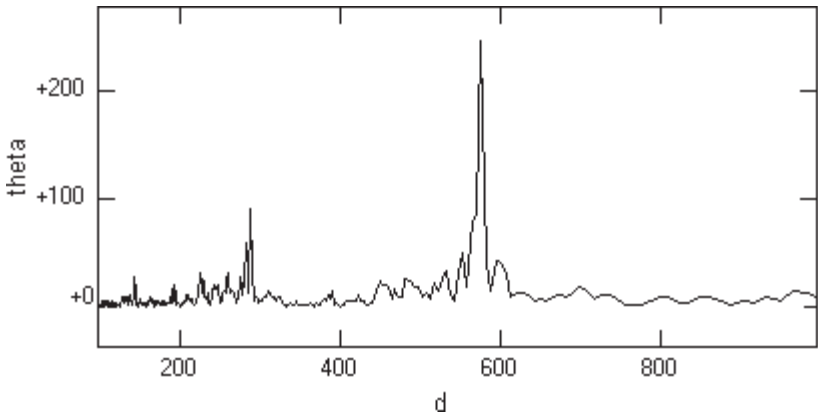

Figure 3. The periodogram of SU Car, showing 575.3740 days.

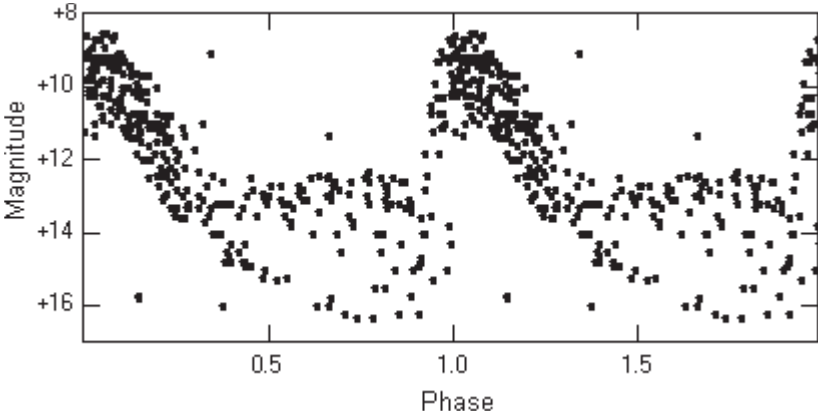

Figure 4(a) The phase diagram of SU Car from the full data set.

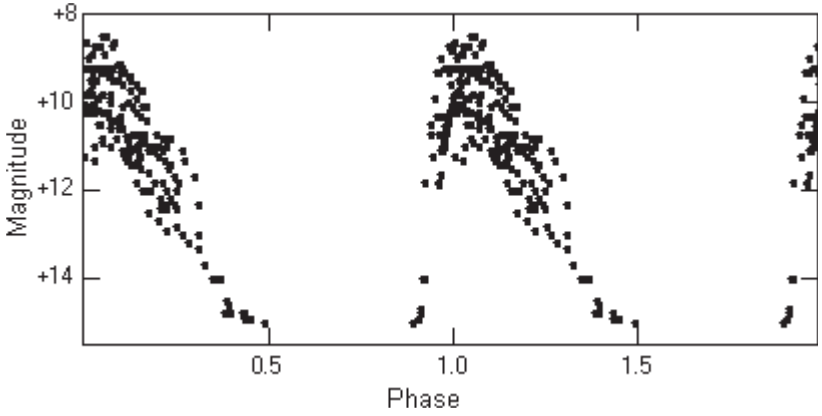

Figure 4(b) The phase diagram of SU Car from the edited data set of Figure 2. The scatter in the brighter part of the curve is from a combination of sources. Many more observers have contributed to this part of the curve, each with their inherent scatter, and every maximum is a different peak brightness.

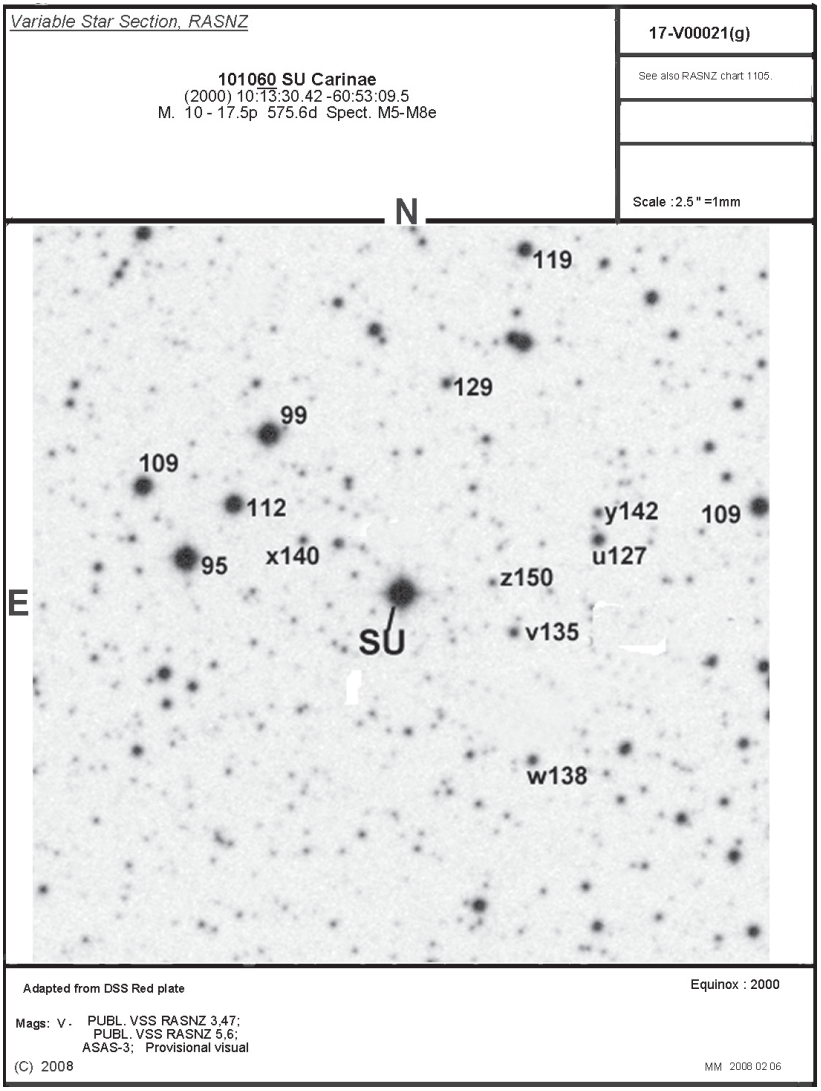

Figure 5. The "g" scale chart for SU Car (previously unpublished). Height of field = 7.5'. Comparison star data are in Table 1.