ON THE VARIATION OF *S ARAE*

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1. The light-curve of *S Arae*, and of stars of this definite type of variation, of which the salient characteristics are a distinct stationary period, a very rapid rise to maximum, and a slow fall to minimum phase, exhibits features that apparently arise from a combination of two other definite types, an eclipse-curve superimposed upon an ordinary short-period curve. The variation of *S Arae* is, therefore, on this supposition, of a compound character, a part being due to intrinsic light-change in one of the component stars, a part due to the position of the stars with respect to the sun.

This exposition of the variation of *S Arae* was impressed upon me two years ago, after I had made a special series of observations of the star at and near the stationary phase. The similarity between the light-curves of *RR Puppis*, *S Velorum*, and *S Arae* at this critical stage of their light-variation seemed to urge this contention, that the same cause or causes which produce a constant phase as *RR Puppis* and *S Velorum* pass through minimum, also operate in producing an almost similar constant phase in the case of *S Arae*.

In Figs. 1, 2, and 3 are given the portion of the light-curves of *RR Puppis*, *S Velorum*, and *S Arae* which includes the termination of the stationary phase and the beginning of the ascending phase. The curves are determined from observations made at Lovedale during the past ten years.

Now the only efficient and sufficient explanation of the stationary period at minimum phase of *RR Puppis* and *S Velorum* is that of eclipse. No other reasonable theory has, as yet, been suggested. In the case of these two stars, and of stars of a similar type, a small but bright companion passes behind its primary once every revolution, and is then for a space eclipsed. It may therefore reasonably be contended that at the stationary phase of *S Arae*, a small but bright satellite has passed behind its central and darker sun.

It is evident, also, that if the two components are not exceedingly disproportionate in brightness then there will be a slight

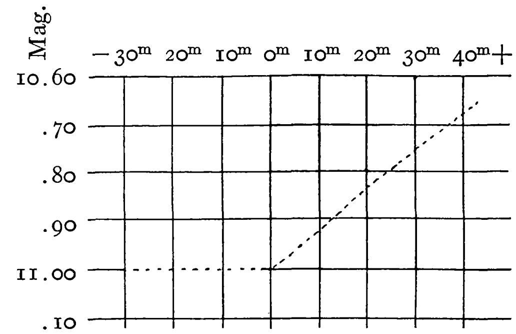

FIG. 1.—*RR Puppis* at end of stationary period.

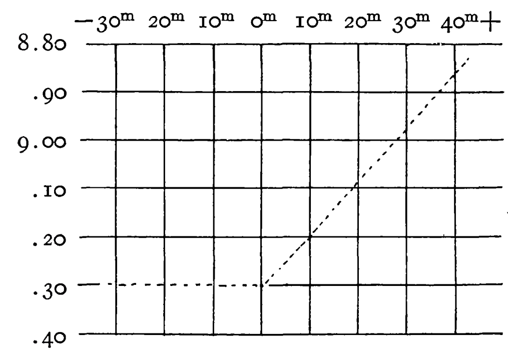

FIG. 2.—*S Velorum* at end of stationary period.

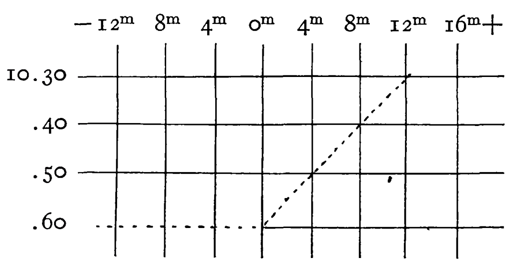

FIG. 3.—*S Arae* at end of stationary period.

diminution in brightness when S_2 passes in front of S_1: the middle dates of these two phases would be at the instant when S_2 crosses the line of sight. But while the stationary period of *S Arae* at minimum associates it intimately with stars of the *S Velorum* type, during the rest of its light-curve, and especially during its decreasing phase, the character of its light-changes allies it to stars of a different type. The variation of *S Arae* is then of the well-known short-period type. So that we have in the variation of *S Arae* the revelation of the following circumstances.

The star is evidently a binary system, the smaller but brighter component of which varies continuously as a Cepheid or Geminid variable would: while the nearness of the component stars and the inclination of their orbit are such that with every revolution we have the phenomena of a primary and secondary eclipse.

Albrecht in the *Lick Observatory Bulletin*, **4**, 138, has pointed out that the maximum light of all short-period stars, in which the relation of orbital movement to light variation can be established, synchronizes with the maximum velocity of approach, occurring a little before minimum velocity, and the minimum brightness with the maximum recession, being usually a little after maximum velocity. If *S Arae* varies conformably to short-period type, then its maximum brightness should occur a little before it reaches approaching quadrature, and minimum brightness after it has passed receding quadrature. The conditions of eclipse give the instant when the component stars are in line with the sun, and consequently the position in time of quadrature passage.

The present paper is to consider how far this theory is borne out by the facts of observation. The investigation is urged with some diffidence. Campbell has pertinently and timely said that "facts brought out concerning the eccentricities of orbits, relative size and brightness of the component stars, the average density, the distance between components . . . . based exclusively upon photometric data, without the illuminating assistance of radial velocity measurements for orbital proportions, and scale values, must be considered as roughly approximate." But while there is reluctance to enter into avenues of argument that are at all times ill-defined, it is also true that there is no other direction open for progress, with respect to such stars as *S Arae*, until a complete revolution has been effected in spectroscopic research. And thus, in the meantime, it is more reasonable to go forward, even uncertainly, than to wait indefinitely for the illumination that spectroscopic data afford.

The special series of observations discussed in this paper was made in 1910. *S Arae* has, however, been under regular observation at Lovedale for ten years. The star was discovered by Innes in 1898. A most valuable discussion of the star's variation by this observer may be found in the *Annals of the Cape Observatory*, **9**, 126B ff. Innes there derives a period of

$$10^{h}\ 50^{m}\ 43^{s}.5$$

for the star's variation.

The Lovedale observations yield a period of

$$10^{h}\ 50^{m}\ 43^{s}.45,$$

a value which Innes confirms in a private letter. The Lovedale observations also indicate that this period is at present decreasing at the rate of

$$0^{s}.000049$$

per revolution.

A word may be allowed as to the method of determining the period. With very rapid variation the method that has been found most accurate is to determine instants of time when the variable passes through a certain definite magnitude in its increasing phase. In the case of *S Arae* the magnitude adopted was $10^{m}.0$.

Table I sets forth the observed instants, as determined during 1910.

The computed dates are obtained from the elements:

$$\text{J.D. } 2418854-5^{h}\ 17^{m}.0\ (\text{G.M.T.})+(10^{h}\ 50^{m}\ 43^{s}.45)E.$$

The mean departure of a single observation is $2^{m}.5$. In this space of time *S Arae*, in its ascending phase, moves through 0.075 magnitude.

3. The observations made during 1910, and indeed all observations of *S Arae*, were secured in the usual manner which obtains at Lovedale with stars fainter than 9.0 magnitudes; each observation is the mean of two determinations of magnitude, one with the field direct, the other with the field reversed.

The star is related to a group of comparison stars—as far as possible stars in the same field—and by a series of sequences the magnitude of the variable and of its comparison stars is determined. Each observation is then reduced for scale value and standard values. Standard values are determined as far as pos-

TABLE I

Date of Passage through 10^m0	Julian Day of Passage	Computed Date	O.−C.
1910	241		
April 1 9^h24^m7	8763 9^h24^m7	9^h21^m5	$+3^m2$
10 10 20.0	8772 10 20.0	10 16.0	+4.0
11 7 59.6	8773 7 59.6	7 57.4	+2.2
15 9 31.0	8777 9 31.0	9 33.9	−2.9
30 7 26.0	8792 7 26.0	7 27.8	−1.8
May 3 11 25.5	8795 11 25.5	11 22.9	+2.6
4 8 59.5	8796 8 59.5	9 4.3	−4.8
7 12 59.5	8799 12 59.5	12 59.4	+0.1
8 10 38.0	8800 10 38.0	10 40.8	−2.8
9 8 18.5	8801 8 18.5	8 22.3	−3.8
10 6 1.0	8802 6 1.0	6 3.7	−2.7
14 7 36.5	8806 7 36.5	7 40.3	−3.8
June 1 9 31.5	8824 9 31.5	9 29.2	+2.3
2 7 7.5	8825 7 7.5	7 10.6	−3.1
3 4 49.6	8826 4 49.6	4 52.0	−2.4
3 15 46.2	15 46.2	15 42.8	+3.4
6 8 49.5	8829 8 49.5	8 47.2	+2.3
11 8 4.5	8834 8 4.5	8 5.1	−0.6
15 9 42.2	8838 9 42.2	9 41.7	+0.5
Aug. 3 5 5.2	8887 5 5.2	4 59.9	+5.3
5 11 14.6	8889 11 14.6	11 13.5	+1.1
6 8 54.2	8890 8 54.2	8 54.9	−0.7
10 10 29.0	8894 10 29.0	10 31.4	−2.4
11 8 12.0	8895 8 12.0	8 12.9	−0.9
Sept. 13 7 57.0	8928 7 57.0	7 55.8	+1.2
22 8 54.0	8937 8 54.0	8 50.2	+3.8

sible by limiting apertures, but too much confidence should not be placed in this method of securing absolute magnitudes.

Table II shows the observations secured.

In column 1 is given the heliocentric Greenwich mean time of observation; in column 2, this date reduced to the mean curve of July 1, 1910, by the period $10^h\ 50^m\ 43^s.45$; in column 3 is found the magnitude of the variable at the time of observation; and in column 4 is given the mean magnitude, for the same date, as indicated by the mean light-curve for July 1, 1910 (Fig. 4, and paragraph 4).

The residuals are given in the last column. From these it appears that the mean error of a single observation is $0^m.070$. This is a somewhat higher value than obtains in purely eclipse stars, and leads to the conclusion that the variation of *S Arae* fluctuates to the extent of about $0^m.04$. An examination of the article by Innes already referred to points to errancy of this char-

TABLE II

Date of Observation	Reduced Date	Observed Magnitude	Computed Magnitude	O.−C.
April 1 $8^h 32^m$	July 1 $4^h 28^m$	10.60	10.61	−0.01
8 37	4 33	10.65	10.61	+0.04
8 42	4 38	10.61	10.61	0.00
8 52	4 48	10.60	10.61	−0.01
8 57	4 53	10.61	10.60	+0.01
9 2	4 58	10.55	10.52	+0.03
9 9	5 5	10.30	10.35	−0.05
9 15	5 11	10.15	10.19	−0.04
9 21	5 17	10.08	10.01	+0.07
9 26	5 22	9.98	9.85	+0.13
9 32	5 28	9.87	9.67	+0.20
9 38	5 34	9.59	9.51	+0.08
9 47	5 43	9.39	9.36	+0.03
9 54	5 50	9.37	9.35	+0.02
10 9 4	4 5	10.65	10.61	+0.04
9 26	4 27	10.65	10.61	+0.04
9 40	4 41	10.65	10.61	+0.04
9 54	4 55	10.59	10.58	+0.01
10 6	5 7	10.43	10.31	+0.12
10 16	5 17	9.99	10.01	−0.02
10 22	5 23	9.88	9.82	+0.06
10 29	5 30	9.57	9.61	−0.04
10 37	5 38	9.36	9.42	−0.06
11 7 54	5 14	10.23	10.10	+0.13
7 59	5 19	10.05	9.94	+0.11
8 3	5 23	9.85	9.82	+0.03
8 8	5 28	9.62	9.67	−0.05
8 13	5 33	9.48	9.53	−0.05
8 19	5 39	9.40	9.40	0.00
15 8 46	4 29	10.64	10.61	+0.03
9 4	4 47	10.64	10.61	+0.03
9 40	5 23	9.69	9.82	−0.13
9 46	5 29	9.54	9.64	−0.10
9 59	5 42	9.39	9.37	+0.02
30 6 37	4 26	10.61	10.61	+0.00
6 51	4 40	10.59	10.61	−0.02
7 12	5 1	10.57	10.46	+0.11
7 18	5 7	10.24	10.31	−0.07
7 23	5 12	10.11	10.16	−0.05
7 27	5 16	9.95	10.04	−0.09
7 33	5 22	9.91	9.85	+0.06
7 39	5 28	9.61	9.67	−0.06
7 46	5 35	9.35	9.49	−0.14
May 3 10 11	4 5	10.60	10.61	−0.01
10 33	4 27	10.60	10.61	−0.01
10 45	4 39	10.60	10.61	−0.01
10 57	4 51	10.55	10.61	−0.06
11 7	5 1	10.44	10.46	−0.02
11 16	5 10	10.20	10.22	−0.02
11 20	5 14	10.10	10.10	−0.00
11 26	5 20	10.02	9.91	+0.11
11 33	5 27	9.80	9.70	+0.10
11 42	5 36	9.43	9.46	−0.03

TABLE II—*Continued*

Date of Observation	Reduced Date	Observed Magnitude	Computed Magnitude	O.−C.
May 4 7^h40^m	July 1 3^h53^m	10.64	10.61	+0.03
7 47	4 0	10.65	10.61	+0.04
8 2	4 15	10.65	10.61	+0.04
8 12	4 25	10.64	10.61	+0.03
8 22	4 35	10.60	10.61	−0.01
8 25	4 38	10.61	10.61	−0.00
8 35	4 48	10.61	10.61	−0.00
8 43	4 56	10.45	10.55	−0.10
8 51	5 4	10.11	10.38	−0.27
8 55	5 8	10.08	10.28	−0.20
9 2	5 15	9.97	10.07	−0.10
9 11	5 24	9.61	9.79	−0.18
9 20	5 33	9.44	9.54	−0.10
10 5	6 18	9.44	9.43	+0.01
7 12 36	4 54	10.60	10.58	+0.02
12 44	5 2	10.49	10.43	+0.06
12 53	5 11	10.24	10.19	+0.05
12 57	5 15	10.04	10.07	−0.03
13 0	5 18	10.00	9.97	+0.03
13 5	5 23	9.69	9.82	−0.13
13 9	5 27	9.51	9.70	−0.19
13 16	5 34	9.34	9.51	−0.17
8 9 51	4 27	10.59	10.61	−0.02
10 2	4 38	10.59	10.61	−0.02
10 13	4 49	10.59	10.61	−0.02
10 26	5 2	10.54	10.43	+0.11
10 31	5 7	10.25	10.31	−0.06
10 34	5 10	10.17	10.22	−0.05
10 37	5 13	10.08	10.13	−0.05
10 44	5 20	9.69	9.91	−0.22
10 50	5 26	9.51	9.73	−0.22
11 1	5 37	9.26	9.44	−0.18
9 7 29	4 23	10.65	10.61	+0.04
7 48	4 42	10.65	10.61	+0.04
7 57	4 51	10.65	10.61	+0.04
8 3	4 57	10.50	10.53	−0.03
8 8	5 2	10.40	10.43	−0.03
8 10	5 4	10.35	10.38	−0.03
8 14	5 8	10.25	10.28	−0.03
8 20	5 14	9.90	10.10	−0.20
8 24	5 18	9.76	9.97	−0.21
8 29	5 23	(9.47)	9.82	......
8 40	5 34	9.35	9.51	−0.16
10 5 28	4 41	10.64	10.61	+0.03
5 33	4 46	10.64	10.61	+0.03
5 43	4 56	10.54	10.55	−0.01
5 49	5 2	10.29	10.43	−0.14
5 54	5 7	10.13	10.31	−0.18
5 58	5 11	10.10	10.19	−0.09
6 3	5 16	9.99	10.04	−0.05
6 8	5 21	9.81	9.88	−0.07
6 15	5 28	9.41	9.67	−0.26
6 26	5 39	9.32	9.41	−0.09

TABLE II—*Continued*

Date of Observation	Reduced Date	Observed Magnitude	Computed Magnitude	O.−C.
May 14 6h 44m	July 1 4h 21m	10.60	10.61	−0.01
7 9	4 46	10.60	10.61	−0.01
7 19	4 56	10.59	10.55	+0.04
7 29	5 6	10.30	10.33	−0.03
7 34	5 11	10.20	10.19	+0.01
7 39	5 16	(9.59)	.....	......
7 41	5 18	(9.56)	.....	......
7 44	5 21	(9.56)	.....	......
7 50	5 27	9.45	9.70	−0.25
June 1 8 33	4 21	10.65	10.61	+0.04
9 0	4 48	10.59	10.61	−0.02
9 10	4 58	10.60	10.52	+0.08
9 16	5 4	10.53	10.38	+0.15
9 24	5 12	10.30	10.16	+0.14
9 29	5 17	9.95	10.01	−0.06
9 36	5 24	9.92	9.79	+0.13
9 44	5 32	9.64	9.56	+0.08
9 52	5 40	9.54	9.39	+0.15
2 6 32	4 38	10.64	10.61	+0.03
6 45	4 51	10.60	10.61	−0.01
6 53	4 59	10.50	10.50	+0.00
6 58	5 4	10.30	10.38	−0.08
7 1	5 7	10.20	10.31	−0.11
7 6	5 12	10.12	10.16	−0.04
7 11	5 17	10.05	10.01	+0.04
7 13	5 19	9.80	9.94	−0.14
7 19	5 25	9.60	9.76	−0.16
7 34	5 40	9.30	9.39	−0.09
3 4 34	4 59	10.55	10.50	+0.05
4 39	5 4	10.35	10.38	−0.03
4 48	5 13	10.07	10.13	−0.06
4 54	5 19	9.82	9.94	−0.12
5 2	5 27	9.50	9.70	−0.20
5 7	5 32	9.30	9.56	−0.26
15 15	4 49	10.64	10.61	+0.03
15 31	5 5	10.64	10.36	+0.28
15 37	5 11	10.36	10.19	+0.17
15 42	5 16	10.15	10.04	+0.11
15 45	5 19	10.02	9.94	+0.08
15 47	5 21	10.03	9.88	+0.15
15 49	5 23	9.95	9.82	+0.13
15 53	5 27	9.75	9.70	+0.05
15 56	5 30	9.53	9.61	−0.08
16 2	5 36	9.46	9.46	+0.00
16 5	5 39	9.26	9.41	−0.15
5 4 42	9 43	10.40	10.34	+0.06
4 56	9 57	10.37	10.37	+0.00
5 36	10 37	10.40	10.44	−0.04
6 1	0 12	10.43	10.47	−0.04
6 41	0 52	10.54	10.54	+0.00
7 26	1 37	10.55	10.57	−0.02
8 2	2 13	10.57	10.57	+0.00
8 49	3 0	10.63	10.61	+0.02

TABLE II—*Continued*

Date of Observation		Reduced Date		Observed Magnitude	Computed Magnitude	O.−C.
June 5	$9^h 31^m$	July 1	$3^h 42^m$	10.63	10.61	+0.02
6	4 36		1 6	10.54	10.56	−0.02
	5 21		1 51	10.62	10.57	+0.05
	5 41		2 11	10.60	10.57	+0.03
	5 57		2 27	10.60	10.59	+0.01
	6 40		3 10	10.62	10.61	+0.01
	7 5		3 35	10.60	10.61	−0.01
	7 30		4 0	10.57	10.61	−0.04
	7 51		4 21	10.64	10.61	+0.03
	8 9		4 39	10.61	10.61	+0.00
	8 25		4 55	10.60	10.57	+0.03
	8 35		5 5	10.54	10.36	+0.18
	8 45		5 15	10.06	10.07	−0.01
	8 48		5 18	10.05	9.97	+0.08
	8 51		5 21	9.95	9.88	+0.07
	8 54		5 24	9.90	9.79	+0.11
	8 57		5 27	9.85	9.70	+0.15
	9 1		5 31	9.76	9.59	+0.17
	9 7		5 37	9.45	9.44	+0.01
	9 24		5 54	9.30	9.34	−0.04
9	8 7		0 42	10.44	10.52	−0.08
	9 12		1 47	10.54	10.57	−0.03
	9 52		2 27	10.60	10.58	+0.02
10	6 37		1 30	10.60	10.57	+0.03
11	4 47		1 59	10.64	10.58	+0.06
	6 7		3 19	10.65	10.61	+0.04
	7 2		4 14	10.65	10.61	+0.04
	7 42		4 54	10.43	10.58	−0.15
	7 49		5 1	10.33	10.46	−0.13
	7 54		5 6	10.28	10.33	−0.05
	7 59		5 11	10.13	10.19	−0.06
	8 17		5 29	9.70	9.64	+0.06
	8 22		5 34	9.49	9.51	−0.02
	8 31		5 43	9.35	9.36	−0.01
	8 42		5 54	9.25	9.34	−0.09
13	6 27		8 16	10.10	10.08	+0.02
14				10.21		
15	5 42		1 17	10.59	10.56	+0.03
	8 24		3 59	10.54	10.61	−0.07
	8 32		4 7	10.60	10.61	−0.01
	8 41		4 16	10.59	10.61	−0.02
	8 49		4 24	10.57	10.61	−0.04
	8 57		4 32	10.59	10.61	−0.02
	9 7		4 42	10.57	10.61	−0.04
	9 13		4 48	10.57	10.61	−0.04
	9 21		4 56	10.52	10.55	−0.03
	9 28		5 3	10.33	10.41	−0.08
	9 32		5 7	10.28	10.31	−0.03
	9 37		5 12	10.10	10.16	−0.06
	9 42		5 17	10.02	10.01	+0.01
	9 48		5 23	9.89	9.82	+0.07
	9 52		5 27	9.45	9.70	−0.25
	10 7		5 42	9.25	9.37	−0.12

TABLE II—*Continued*

Date of Observation	Reduced Date	Observed Magnitude	Computed Magnitude	O.−C.
June 19 15ʰ 35ᵐ	July 1 9ʰ 34ᵐ	10.35	10.31	+0.04
16 7	10 6	10.49	10.38	+0.11
July 30 10 31	1 34	10.60	10.57	+0.03
Aug. 2 5 11	3 10	10.64	10.61	+0.03
5 50	3 49	10.59	10.61	−0.02
3 4 48	5 5	10.42	10.36	+0.06
4 53	5 10	10.31	10.22	+0.09
4 57	5 14	10.21	10.10	+0.11
5 3	5 20	10.07	9.91	+0.16
5 7	5 24	10.05	9.79	+0.26
5 11	5 28	9.82	9.67	+0.15
5 17	5 34	9.41	9.51	−0.10
5 25	5 42	9.34	9.37	−0.03
5 40	5 57	9.29	9.33	−0.04
6 7	6 24	9.29	9.47	−0.18
6 48	7 5	9.55	9.71	−0.16
8 25	8 42	10.05	10.17	−0.12
9 23	9 40	10.15	10.33	−0.18
10 1	10 18	(10.09)	10.40	(−0.31)
10 17	10 34	10.30	10.43	−0.13
10 35	0 2	10.42	10.45	−0.03
4 4 55	7 31	9.90	9.85	+0.05
5 10	7 46	9.95	9.94	+0.01
5 42	8 18	10.14	10.09	+0.05
5 4 56	9 50	10.42	10.35	+0.07
5 45	10 39	10.44	10.44	+0.00
8 46	2 50	10.55	10.60	−0.05
9 46	3 50	10.57	10.61	−0.04
10 1	4 5	10.59	10.61	−0.02
10 25	4 29	10.60	10.61	−0.01
10 44	4 48	10.60	10.61	−0.01
10 58	5 2	10.54	10.43	+0.11
11 5	5 9	10.24	10.25	−0.01
11 8	5 12	10.15	10.16	−0.01
11 11	5 15	10.11	10.07	+0.04
11 19	5 23	9.90	9.82	+0.08
11 23	5 27	9.76	9.70	+0.06
11 28	5 32	9.66	9.56	+0.10
11 35	5 39	9.56	9.41	+0.15
11 45	5 49	9.41	9.34	+0.07
11 58	6 2	9.56	9.36	+0.20
12 31	6 35	9.59	9.53	+0.06
6 8 20	4 42	10.55	10.61	−0.06
8 41	5 3	10.42	10.41	+0.01
8 45	5 7	10.42	10.31	+0.11
8 52	5 14	10.05	10.10	−0.05
8 58	5 20	9.86	9.91	−0.05
9 4	5 26	9.50	9.73	−0.23
9 10	5 32	9.45	9.56	−0.11
9 25	5 47	9.24	9.34	−0.10
9 43	6 5	9.34	9.37	−0.03
10 13	6 35	9.50	9.53	−0.03
7 4 45	3 26	10.65	10.61	+0.04

TABLE II—*Continued*

Date of Observation	Reduced Date	Observed Magnitude	Computed Magnitude	O.−C.
Aug. 10 $5^h 20^m$	July 1 $0^h 6^m$	10.54	10.46	+0.08
6 10	0 56	10.60	10.55	+0.05
9 45	4 31	10.54	10.61	−0.07
10 5	4 51	10.55	10.61	−0.06
10 12	4 58	10.59	10.52	+0.07
10 19	5 5	10.55	10.36	+0.19
10 25	5 11	10.18	10.19	−0.01
10 28	5 14	10.10	10.10	+0.00
10 30	5 16	9.92	10.04	−0.12
10 34	5 20	9.81	9.91	−0.10
10 40	5 26	9.56	9.73	−0.17
11 5 25	2 29	10.57	10.58	−0.01
7 27	4 31	10.60	10.61	−0.01
7 48	4 52	10.65	10.61	+0.04
7 59	5 3	10.42	10.41	+0.01
8 10	5 14	10.09	10.10	−0.01
8 14	5 18	9.92	9.97	−0.05
8 19	5 23	9.66	9.82	−0.16
8 30	5 34	9.44	9.51	−0.07
8 43	5 47	9.34	9.34	+0.00
8 55	5 59	9.41	9.35	+0.06
9 30	6 34	9.46	9.53	−0.07
10 1	7 5	9.73	9.71	+0.02
10 25	7 29	9.98	9.85	+0.13
11 15	8 19	10.15	10.10	+0.05
Sept. 13 7 14	4 35	10.59	10.61	−0.02
7 36	4 57	10.57	10.54	+0.03
7 47	5 8	10.17	10.28	−0.11
7 52	5 13	10.10	10.13	−0.03
7 58	5 19	10.00	9.94	+0.06
8 1	5 22	9.85	9.85	+0.00
8 5	5 26	9.89	9.73	+0.16
8 18	5 39	9.50	9.41	+0.09
22 7 5	3 32	10.62	10.61	+0.01
7 30	3 57	10.64	10.61	+0.03
7 55	4 22	10.62	10.61	+0.01
8 10	4 37	10.60	10.61	−0.01
8 24	4 51	10.59	10.61	−0.02
8 30	4 57	10.49	10.54	−0.05
8 40	5 7	10.42	10.31	+0.11
8 45	5 12	10.25	10.16	+0.09
8 50	5 17	10.08	10.01	+0.07
8 55	5 22	10.05	9.85	+0.20
9 0	5 27	9.90	9.70	+0.20
9 5	5 32	9.79	9.56	+0.23

acter. The light-curve determined by this refined and accurate observer (*Annals Cape Observatory*, **4**, 129B) shows residuals greater than his accustomed errors of observations.

4. Combining the preceding observations in sets, we obtain the following data (Table III) for the mean curve of *S Arae*. This

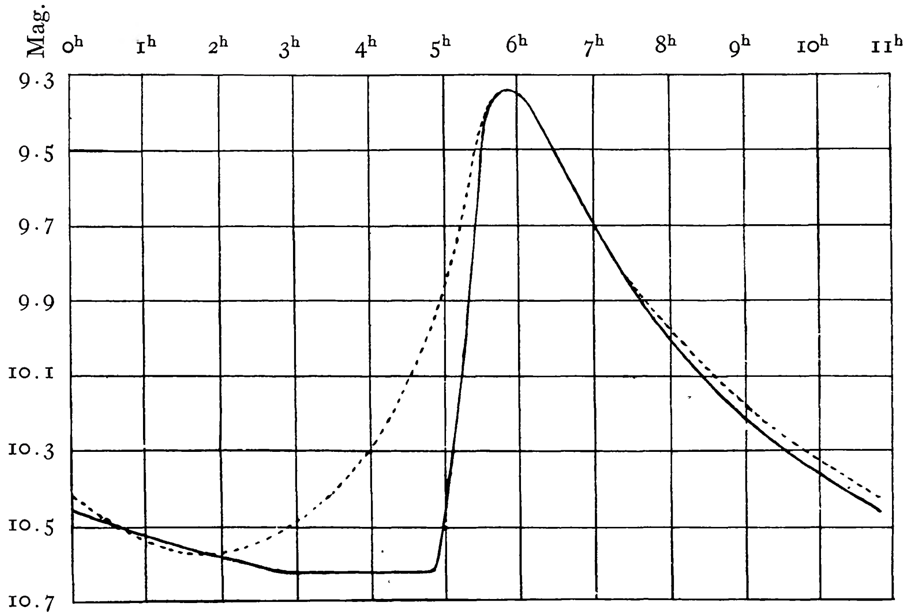

FIG. 4.—Light-curve of *S Arae*, reduced to mean curve of July 1, 1910. Unbroken line, observed line. Broken line, theoretical curve.

curve is set forth in Fig. 4, unbroken line. Its peculiar character —a stationary period at minimum, a rapid rise to maximum, and a slow decline to constant phase—will at once be manifest.

TABLE III

MEAN MAGNITUDES OF *S Arae*, JULY 1, 1910

Date	Mean Magnitude	Observations Used	Date	Mean Magnitude	Observations Used
1910			1910		
July 1 $0^h 33^m.6$	$10^m.51$	5	July 1 $5^h 13^m.7$	$10^m.09$	10
1 21.8	10.58	4	15.7	10.03	9
48.5	10.59	4	17.5	9.98	9
2 26.2	10.58	6	19.5	9.93	10
3 19.0	10.63	7	21.8	9.90	9
52.0	10.60	6	23.3	9.82	10
4 5.1	10.61	7	26.4	9.72	12
20.4	10.62	8	28.0	9.67	10
27.3	10.62	8	31.7	9.56	10
34.4	10.60	9	34.1	9.44	8
40.2	10.61	10	37.9	9.40	10
47.7	10.61	10	42.9	9.36	9
52.6	10.59	11	53.8	9.34	6
57.3	10.54	12	6 21.9	9.45	7
5 1.9	10.44	10	7 23.2	9.82	5
4.3	10.39	10	8 23.8	10.11	4
6.8	10.30	10	9 45.2	10.34	5
9.6	10.22	9	10 27.8	10.41	6
11.6	10.16	10			

5. As already stated (paragraph 1) the probable explanation of this curve, and of all curves of this type, is that we have *Algol-* or eclipse-variation superimposed upon ordinary short-period variation.

The stationary phase of *S Arae* lasts from $2^h\ 52^m$ to $4^h\ 52^m$, that is for 2^h out of a period of $10^h\ 50^m\ 43^s.45$.

It is suggested that during this period one of the components, the smaller and brighter, is eclipsed totally by the primary component of the binary system, *S Arae.* It is not possible to determine definitely from the light-curve when the eclipse begins or ends, but in order to arrive, in the first instance approximately, at these dates, an arbitrary short-period light-curve was drawn, such a light-curve as is shown by a dotted line in Fig. 4. If *S Arae* were simply a short-period variable this would probably be the form of its light-curve.

The arbitrary uneclipsed light-curve, first drawn from experience of other short-period curves, was modified to meet the argument adopted and thus finally the harmonic curve indicated by a dotted line in Fig. 4 was arrived at.

The harmonic elements of this regular curve are:

Magnitude at any time T

$$
\begin{aligned}
&= 10^m.151 \\
&+ 0.491\ (\cos\ \theta - 38^\circ 58') \\
&- 0.170\ (\cos 2\theta - 37^\circ 36') \\
&+ 0.081\ (\cos 3\theta - 58^\circ 40') \\
&- 0.041\ (\cos 4\theta - 53^\circ 58') \\
&+ 0.025\ (\cos 5\theta - 69^\circ 33') \\
&- 0.014\ (\cos 6\theta - 68^\circ 58')
\end{aligned}
$$

where

$$\theta = (0^\circ.5532)T$$

T being time from July 1, $0^h\ 0^m$, expressed in minutes.

This fundamental or primary light-curve of *S Arae* would indicate that eclipse is ended by $5^h\ 48^m$.

6. Grouping together and amplifying these statements we have:

Duration of stationary period = 2 hours

Magnitude of system at stationary period, that is of S_1 on the theory of eclipse $= 10^m.61$

Middle of total eclipse of S_2	=	3^h52^m
End of total eclipse of S_2	=	4 52
End of eclipse of S_2	=	5 48
S_2 in approaching quadrature	=	6 35

Taking

R = radius of S_1
r = radius of S_2
1 = radius of orbit, considered as circular,

Then, on the supposition that the eclipse is central,

$$R+r=\cos\left\{\left(\frac{47^m}{10^h 50^m 43^s}\right)360°\right\}$$
$$=0.899$$
$$R-r=\cos\left\{\left(\frac{1^h 43^m}{10^h 50^m 43^s}\right)360°\right\}$$
$$=0.545$$

Therefore

$$R=0.722$$
$$r=0.177,$$

and distance between circumference of components

$$=0.101$$

7. Fig. 5 is a diagrammatic view of the binary system *S Arae*, a system comprising a central star, S_1, of radius 0.722, of constant brightness $10^m.61$, and a satellite star, S_2, of radius 0.177, revolving round the central star in $10^h\ 50^m\ 43^s.45$, and constantly varying as it revolves.

Where the constantly varying *comes*, S_2, is eclipsed by S_1, we have a stationary period when only S_1 is visible. This phase lasts two hours. We shall also have a similar eclipse, but less pronounced, when S_2 passes before S_1.

It remains now to discover how far this theory meets the facts of variation as determined by observation. In Table IV is given the computed magnitudes of *S Arae* at intervals of ten minutes.

In column 1 we find the date, the day being, as before, July 1, 1910. Column 2 gives the uneclipsed magnitude of the system as computed from the harmonic elements stated in paragraph 5, and charted down (dotted line) in Fig. 4. Column 3 gives the eclipsed light of S_1 at any instant, its uneclipsed light is taken as

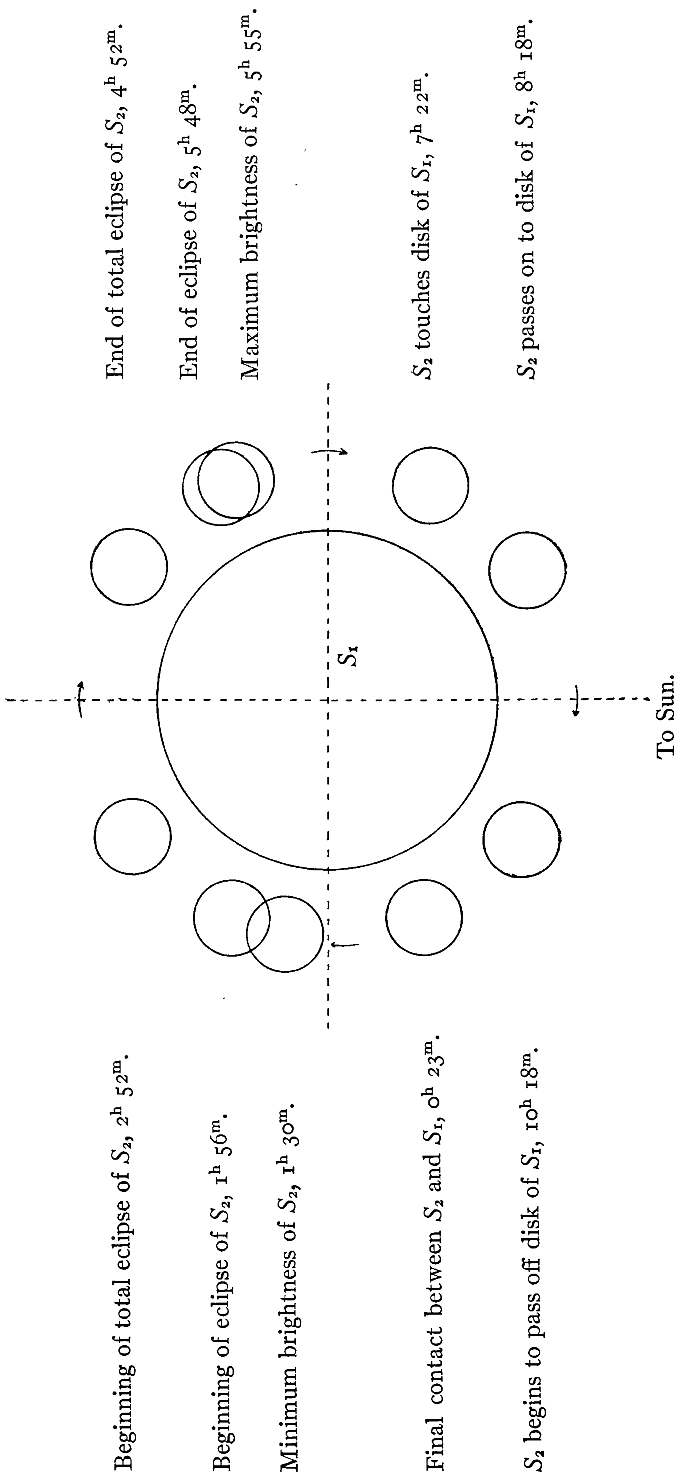

FIG. 5.—System of *S Arae:* Dates from mean curve of July 1, 1910

TABLE IV

Date	Theoretical Magnitude of System (Unclipsed)	Light of S_1 (Eclipsed)	Light of S_2 (Unclipsed)	Light of S_2 (Eclipsed)	Light of System (Eclipsed)	Theoretical Magnitude of System (Eclipsed)
0^h 0^m	$10^{m}42$	0.97	0.19	0.19	1.16	10.45
10	10.45	0.98	0.16	0.16	1.14	10.47
20	10.47	0.99	0.14	0.14	1.13	10.49
30	10.50	1.00	0.11	0.11	1.11	10.50
40	10.52	1.00	0.09	0.09	1.09	10.52
50	10.54	1.00	0.07	0.07	1.07	10.54
1 0	10.55	1.00	0.06	0.06	1.06	10.55
10	10.56	1.00	0.05	0.05	1.05	10.56
20	10.56	1.00	0.05	0.05	1.05	10.56
30	10.57	1.00	0.04	0.04	1.04	10.57
40	10.57	1.00	0.04	0.04	1.04	10.57
50	10.57	1.00	0.04	0.04	1.04	10.57
2 0	10.56	1.00	0.05	0.04	1.04	10.57
10	10.56	1.00	0.05	0.04	1.04	10.58
20	10.55	1.00	0.06	0.04	1.04	10.58
30	10.54	1.00	0.07	0.03	1.03	10.58
40	10.53	1.00	0.08	0.02	1.02	10.59
50	10.51	1.00	0.10	0.01	1.01	10.60
3 0	10.49	1.00	0.12	0.00	1.00	10.61
10	10.47	1.00	0.14	0.00	1.00	10.61
20	10.44	1.00	0.17	0.00	1.00	10.61
30	10.41	1.00	0.20	0.00	1.00	10.61
40	10.38	1.00	0.24	0.00	1.00	10.61
50	10.34	1.00	0.28	0.00	1.00	10.61
4 0	10.30	1.00	0.33	0.00	1.00	10.61
10	10.25	1.00	0.39	0.00	1.00	10.61
20	10.19	1.00	0.47	0.00	1.00	10.61
30	10.12	1.00	0.57	0.00	1.00	10.61
40	10.05	1.00	0.68	0.00	1.00	10.61
50	9.98	1.00	0.79	0.00	1.00	10.61
5 0	9.89	1.00	0.94	0.13	1.13	10.48
10	9.79	1.00	0.14	0.43	1.43	10.22
20	9.64	1.00	1.44	0.90	1.90	9.91
30	9.48	1.00	1.83	1.49	2.49	9.61
40	9.36	1.00	2.16	2.06	3.06	9.39
50	9.34	1.00	2.22	2.22	3.22	9.34
6 0	9.35	1.00	2.19	2.19	3.19	9.35
10	9.39	1.00	2.08	2.08	3.08	9.39
20	9.44	1.00	1.94	1.94	2.94	9.44
30	9.50	1.00	1.78	1.78	2.78	9.50
40	9.56	1.00	1.63	1.63	2.63	9.56
50	9.62	1.00	1.49	1.49	2.49	9.62
7 0	9.68	1.00	1.36	1.36	2.36	9.68
10	9.74	1.00	1.23	1.23	2.23	9.74
20	9.80	1.00	1.11	1.11	2.11	9.80
30	9.85	0.99	1.01	1.01	2.00	9.85
40	9.90	0.98	0.92	0.92	1.90	9.91
50	9.94	0.96	0.85	0.85	1.82	9.96
8 0	9.98	0.95	0.79	0.79	1.74	10.01
10	10.02	0.94	0.72	0.72	1.67	10.06
20	10.06	0.94	0.66	0.66	1.60	10.10
30	10.09	0.94	0.61	0.61	1.55	10.13

TABLE IV—*Continued*

Date	Theoretical Magnitude of System (Uneclipsed)	Light of S_1 (Eclipsed)	Light of S_2 (Uneclipsed)	Light of S_2 (Eclipsed)	Light of System (Eclipsed)	Theoretical Magnitude of System (Eclipsed)
$8^h\ 40^m$	10^m13	0.94	0.56	0.56	1.50	10.17
50	10.16	0.94	0.51	0.51	1.45	10.20
9 0	10.19	0.94	0.47	0.47	1.41	10.23
10	10.21	0.94	0.45	0.45	1.39	10.26
20	10.23	0.94	0.42	0.42	1.36	10.28
30	10.25	0.94	0.39	0.39	1.33	10.30
40	10.28	0.94	0.36	0.36	1.30	10.33
50	10.30	0.94	0.33	0.33	1.27	10.35
10 0	10.32	0.94	0.31	0.31	1.25	10.37
10	10.34	0.94	0.28	0.28	1.22	10.39
20	10.36	0.94	0.26	0.26	1.20	10.41
30	10.38	0.95	0.24	0.24	1.18	10.43
40	10.40	0.96	0.21	0.21	1.17	10.44

unity. In column 4 we find the uneclipsed light of S_2, and in column 5 the eclipsed light. In column 6 is given the total light of the system, which in column 7 is reduced to magnitudes.

8. From Table IV we are able to place computed values against the observed magnitudes given in paragraph 4, from which the mean curve of *S Arae* has been drawn.

Table V sets forth the agreement between observation and theory. The discordance amounts to 0^m010.

9. If we inquire what measure of confidence we may place in the theory of variation of stars of the *S Arae* and *Y Lyrae* type, thus preferred, it may be urged,

a) There is a remarkable accordance between the computed and observed light-curves.

b) A constant phase at minimum can only reasonably be explained by the theory of eclipse.

c) Albrecht and others have drawn attention to the fact that maximum brightness takes place a little before maximum approach, and minimum brightness a little after maximum recession, in the case of such short-period stars as are bright enough to yield these facts.

In the case of *S Arae* the theory urged places maximum 40 minutes before maximum approach and minimum 20 minutes after maximum recession.

d) In the *Lick Observatory Bulletin*, No. 151, Duncan suggests a theory of Cepheid variables that has much to commend it. It certainly explains the variation of *S Arae*. The distance of S_2 from S_1 is only one-tenth of the radius of their orbit. It is evident

TABLE V

Date	Observed Magnitude	Computed Magnitude	O.−C.
July 1 0^h33^m6	10.51	10.51	−0.00
1 21.8	10.58	10.56	+0.02
48.5	10.59	10.57	+0.02
2 26.2	10.58	10.58	+0.00
3 19.0	10.63	10.61	+0.02
52.0	10.60	10.61	−0.01
4 5.1	10.61	10.61	+0.00
20.4	10.62	10.61	+0.01
27.3	10.62	10.61	+0.01
34.4	10.60	10.61	−0.01
40.2	10.61	10.61	+0.00
47.7	10.61	10.61	+0.00
52.6	10.59	10.60	−0.01
57.3	10.54	10.54	+0.00
5 1.9	10.44	10.44	+0.00
4.3	10.39	10.37	+0.02
6.8	10.30	10.31	−0.01
9.6	10.22	10.23	−0.01
11.6	10.16	10.17	−0.01
13.7	10.09	10.11	−0.02
15.7	10.03	10.05	−0.02
17.5	9.98	9.98	+0.00
19.5	9.93	9.93	+0.00
21.8	9.90	9.86	+0.04
23.3	9.82	9.81	+0.01
26.4	9.72	9.72	+0.00
28.0	9.67	9.67	+0.00
31.7	9.56	9.57	−0.01
34.1	9.44	9.51	−0.07
37.9	9.40	9.43	−0.03
42.9	9.36	9.37	−0.01
53.8	9.34	9.34	+0.00
6 21.9	9.45	9.45	+0.00
7 23.2	9.82	9.82	+0.00
8 23.8	10.11	10.11	+0.00
9 45.2	10.34	10.34	+0.00
10 27.8	10.41	10.42	−0.01

that at this distance from S_1, S_2 must revolve through the very rarefied outer envelope of the primary. Thus the advancing hemisphere of S_2 will be greatly more luminous than the following surface, the difference in brightness depending on the amount of atmosphere which has been driven off from the advancing hemisphere. And as the tenuous atmosphere surrounding S_1 is denser, the deeper it is, maximum brightness of S_2 will occur before the star reaches quadrature. This is an essential condition of the theory suggested by Duncan.

e) At its minimum the light of S_2, surface for surface, is only a little fainter than that of S_1.

f) The period of the system is decreasing.

10. I have not been unmindful, while preparing this paper, of the many and weighty arguments which tell against the validity of the theory proposed. Indeed I was so conscious of the difficulties that arose, hydra-headed, that for some time I set the theory aside. Campbell's pregnant remark that "the future will probably establish that the cluster variables are binaries" gave an appearance of reasonableness to the hypothesis I have tried to prove.

Against the hypothesis of combined eclipse and Cepheid variation as an explanation of cluster variables, of which *S Arae* may be taken as the type, there are:

a) The extraordinary range of magnitude that must be admitted for S_1. At maximum this companion is *fifty* times brighter than it is at minimum. It is difficult to premise an atmosphere dense enough to absorb forty-nine fiftieths of the light of the nucleus. Of course it is possible that friction adds to the luminosity of the advancing hemisphere, but this would mean that the revolution and rotation of S_2 were synchronous.

b) S_2 must revolve faster than S_1 rotates, a difficult assumption, yet not one out of accord with recent views on cosmic evolution.

c) Roche's criterion demands a high density for S_2. Here again the density is in agreement with the luminosity, at least with the luminosity of the nucleus.

There are other difficulties that will arise in the minds of those who deal with such investigations as I have endeavored to bring to some issue in this paper.

11. In conclusion it remains to be said that not the least value of the theory suggested is that it co-ordinates variation of several

types, bringing them all under the fundamental conception of binary movement.

That stars of the *S Arae* type should be found mainly in clusters need not surprise us. It is in such aggregations that we might expect to find stars that are apparently at the starting-point of their history.

LOVEDALE, SOUTH AFRICA
November 25, 1910