The Contribution of A. W. Roberts' Observations to the AAVSO International Database

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Abstract Alexander William Roberts observed around one hundred variable stars mainly during the period 1891–1912. In 2004 we succeeded in digitizing around 70,000 of his visual observations which were added to the AAVSO International Database (AID), ensuring these are available for further study. These observations, many of which pre-date the existence of the AAVSO, extend the period of observation of many variable stars by one or two decades earlier. This paper summarizes the observations made by Roberts and added to the AID, and gives examples of some apparent discrepancies which warrant further investigation.

1. Introduction

Alexander William Roberts (AAVSO observer code RAE) was born in Farr, Scotland, on December 4, 1857. He emigrated to South Africa in 1883 aged twenty-five to take up a teaching post at Lovedale Missionary Institution, and later became Principal of Lovedale College. It was in the field of native affairs that he achieved his greatest endeavors, and in 1920 he became a Senator responsible for the Native Affairs Commission (Snedegar 2015). Roberts had a passion for astronomy, and under the influence of his friend Sir David Gill, Astronomer Royal at the Cape, he took an increasing interest in visual observation of variable stars. He was familiar with the work of Gould in preparation of his "Uranometria Argentina" (1879) and in his own words:

> Gould's work opened up a very great field. My own thoughts, since early youth, had turned to astronomy, and so in 1888, after considerable correspondence with Gould and Pickering and in consultation with Gill, I determined to erect a small observatory at Lovedale for the single purpose of observing southern variable stars and other allied phenomena. I spent two years in getting my hand into the work, becoming skillful in determining differences of magnitude, acquainting myself with the labours of other observers. (McIntyre 1938)

Roberts duly set up his observatory at Lovedale and began observing in 1891, when only 35 variable stars were catalogued south of declination –30° (Roberts 1891). His first observation was of the delta Cepheid variable l Car on 1891 April 7 (JD 2411829). In the following years Roberts concentrated on variable stars generally south of declination –30°, the most northerly object being the long period variable RZ Sco at declination –23°. The star which he observed on the largest number of occasions is the eclipsing binary RR Cen, with 2,289 observations in the AID. Roberts himself discovered the variability of this star.

Roberts remained active as a variable star observer until 1922, when, apart from κ Pav, he ceased to observe due to work commitments. He wrote:

> During the year 1922 work has been interrupted at this observatory. The Director was called upon by the Union Government to take over the post of Senior Native Commissioner for South Africa.... The delicate conditions of many of the native questions and difficulties made it impossible for the Director to give any part of his time to astronomical work. (Roberts 1923)

After observing for three decades, Roberts' contribution to variable star observation had virtually ended, but the legacy he left behind was enormous. Apart from the large number of observations, Roberts was responsible for the formation of the Variable Star Section of the old Cape Astronomical Association, which amalgamated in 1922 with the Johannesburg Astronomical Association to form the Astronomical Society of South Africa (ASSA , today Astronomical Society of Southern Africa). In his Presidential Address he said:

> In our own southern land this Society, over which I have the honour to be president, has put variable star work in the forefront of its endeavours, and as an Association we may point with no mean gratification to the achievements of Watson, Long, Cousins, Houghton, Skjellerup, Smith, Ensor, and others, who in this wonderful, sundrenched, star-lit land of ours have found success and happiness in their scientific pursuits. (McIntyre 1938)

Members of ASSA are active still today in observing stars which were observed by Roberts, and we are fortunate to have had the opportunity to finally add the observations he made to the AID, and open these up for study more than a century later.

2. Roberts' observations, instrumentation, and methodology

Roberts died on January 27, 1938, at Alice, South Africa. His extensive records, including raw observations, lists of magnitude estimates, hand-drawn charts and sequences, and manuscripts on each star were stored, and were subsequently found, in four cupboards in the library of Boyden Observatory (van Zyl 2003). These records consisted of around 140 packets wrapped in brown paper, which when stacked on top of each other would have formed a stack four metres high! Following a suggestion by Dr. Janet Mattei in 2002, a team succeeded in digitizing the observations, with the result that more than 70,000 visual observations were added to the AID (Cooper *et al.* 2004). More recently a team from the Centre for Astronomical Heritage (CfAH), funded by the Endangered Archives Programme of the British Library, has embarked on a program to digitize the entire archive held at Boyden, including all of the Roberts documents.

Roberts' observations were made with rather modest equipment by today's standards. His early observations were made with a 1-inch theodolite by Troughton and Simms. From 1900 he used a 2-inch refractor made by Messrs. Thomas Cooke and Sons of York, and provided by Sir John Usher, Norton, Edinburgh (Roberts 1900). This instrument had a rotating prism at the front of the objective, which allowed Roberts to adjust the position angle of stars being compared in order to prevent errors due to "position error" (Roberts 1896a, 1896b). With its field of view of nearly 3°, Roberts was able to measure star magnitudes down to about magnitude 10. He also had access to a 3¼-inch Ross telescope, which was loaned to him by the RAS, but as Roberts commented (1902): "it is a matter of regret to me that I am unable to follow stars below magnitude 11.2, the limit of the Ross glass." Thus Roberts could not follow the many long period variables he studied when they were fainter than about magnitude 11, a fact which stands out when we plot his observations in the AID (see Figures 1–3 for examples). By 1904 he was using the 1-inch and 3¼-inch telescopes for short and long period variables, and the 2-inch Cooke prismatic telescope for eclipsing variables (Roberts 1905).

When he began observing in 1891, suitable variable star charts were not available for most of the stars he wished to observe and Roberts had to prepare his own. In order to do this he would plot the positions of all stars in the vicinity of a known variable star on a sheet of plain paper, using the positions given in the "Cape Photographic Durchmusterung" when that catalogue became available (Gill and Kapteyn 1896–1900). The next step was to "fix upon certain stars as starting points from which to give relative magnitudes to all the other stars in the zone." He generally used Gould's "Uranometria Argentina" (1879) for his early magnitudes, but later used Harvard College Observatory magnitudes where these became available, and in 1912 he acquired on loan "through the very great kindness of Professor Pickering" the 4-inch Harvard meridian photometer, which he used to determine accurate comparison star magnitudes, especially for observing Algol variables (Roberts 1913).

In this way Roberts continued to observe variable stars on a regular basis between 1891 and 1907, except for 1897, when he made no observations. There was a further lull in 1907, when Roberts spent much of the time away overseas, and used the opportunity to reduce the observations made so far. In 1909 he "stopped observing short period variables and Algol variables." mainly due to weather (Roberts 1910), and the following year paid special attention to the variability of S Ara and κ Pav (Roberts 1911a) as he stated: "these stars show evidence of possessing characteristics both of short period variation and Algol variation; that is, they exhibit variation due to eclipse, superimposed upon the ordinary Cepheid type of continuous light change."

After about 1912 his observations of many stars became infrequent, occupying his time rather with reducing the observations made over the preceding twenty years, and making observations in order to qualify some specific aspect of a specific star's period. The process of reducing his observations was largely completed by 1914, and appears to take the form of hand-written manuscripts on each star, which we found in the wrapped packs at Boyden Observatory. Results from these manuscripts were used to prepare numerous papers, but the actual manuscripts were never published. The digitization currently conducted by the CfAH will finally go a long way to enabling publication of his manuscripts.

3. Summary of observations and types of stars observed

Roberts' various reports mention having observed 105 different variable stars (Roberts 1906). In the process of digitizing his observations, we found observations of 98 separate stars, which were processed and added to the AID, listed in Appendix A by type, and summarized in Table 1. Appendix A also lists the Julian Date of the first observation by Roberts, the first date of observation not made by Roberts, and the number of days his observations predate the first AAVSO observation for each star. From this it can be seen that Roberts extended the observations for all stars he observed except for three (Beck 2019), being R Car (observed by Tebbutt), R Ret (by Pogson), and S Ara (by Innes). Note also that although Roberts is said to have observed RS Car (= Nova Car 1896), no observations were found. The total number of observations processed and added to the database was 70,034, whereas some, including no less than Sir David Gill, credit Roberts with over 280,000 observations. We ascribed this discrepancy to a difference in what constitutes "an observation" in the AID. A single observation is the result of estimating the brightness of a variable star and reporting that magnitude as a single-line entry for the time of observation. But this observation is never the result of a single estimation, and the proficient observer always makes several estimates in order to improve accuracy, before averaging the individual estimates to arrive at the final observation. Roberts himself commented on this procedure (Roberts 1896a), and so, for example, his total observations reported for 1895 was 2,893, but he noted:

Table 1. Types of stars for which observations were added to the AAVSO International Database (observer RAE).

Type of Variable	*Classification*	*No. of Stars*
Long period	M	55
Semi-regular	SR	10
Eclipsing	E	7
Cepheid	DCEP	20
Novae	N	1
R CrB	RCB	1
Irregular, poorly studied	I	3
Constant	CST	1
RR Lyr	RRAB/BL	1

> Each of the observations is the mean of two, one direct and the other reverse. This mode of observation has been adopted to eliminate "position error." As each observation also means, on the average, the determination of five comparison stars, the individual determinations of magnitude throughout the year are considerably over 30,000.

For this reason we believe Roberts' contribution is correctly around 70,000 observations, and all these have been captured and entered into the AID.

4. Details of some individual stars

Despite Roberts being best known for his observation of eclipsing binaries, the largest number of observations was of long period variables, which account for more than half of the number. In fact, eclipsing variables (types E and EW) make up less than ten percent of the stars observed. The author has prepared light curve plots for all 98 stars observed by Roberts and for which observations were submitted to the AID. Examination of these light curves is useful to understand where Roberts' data can add to the knowledge of certain stars by extending their light curves by around two decades earlier than previous, as well as highlighting some opportunities which require further investigation. The following light curves are presented as examples.

4.1. The long period variables: R Cen, S Hor, and U CrA

Observations of long period variable stars makes up the majority of stars observed, numbering 55 stars. The light curve for R Cen (Figure 1) is typical of Roberts' observations of long period variables. Observations by Roberts are shown in blue, while all other observers are in black.

The absence of observations fainter than magnitude 11 is already evident, which was the limit of the Ross 3¼-inch refractor used when stars were faint, although R Cen at minimum was only just below his grasp. His first observation was on August 29, 1892 (JD 2411972), and his last was on January 25, 1917 (JD 2421253), making 999 observations during this interval. Following this Roberts produced a manuscript for R Cen, describing the discovery as a variable star by Gould in 1871, followed by a rigorous description of the derivation of comparison star magnitudes he used, a list of his observations, and his analysis of dates of maxima and minima. He concluded: "The Lovedale observations are sufficient in number and in range to indicate with certainty that during the time R Centauri has been observed at Lovedale its period has been steadily decreasing, falling from 567 days in 1891 to 552 days in 1916." Using these data Ramoshebi (2006) was able to model the changing period of R Cen, which has decreased further to the current value around 501.8 days (Samus *et al.* 2017).

Another southern long period variable which demonstrates the limitations of his equipment more clearly is S Hor (Figure 2). The star was confirmed as being variable by Roberts, following which it was entered in his catalogue "Southern Variable Stars" (see Roberts 1901a). From 420 observations made between JD 2414612 and 2421608 (November 1898 to January 1918) he

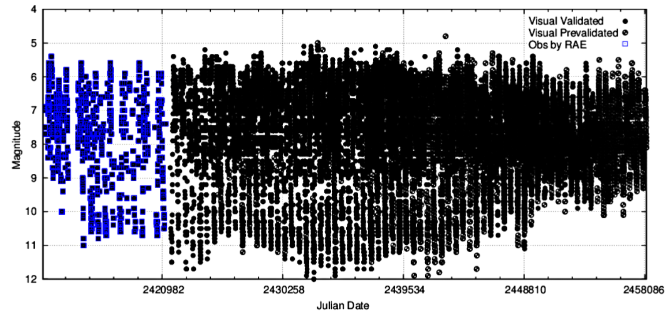

Figure 1. Light curve for R Cen from AAVSO data.

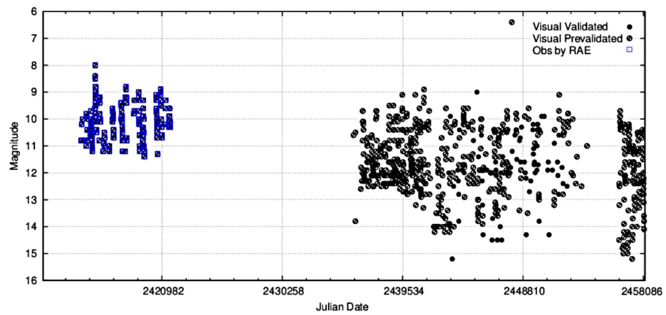

Figure 2. Light curve for S Hor from AAVSO data.

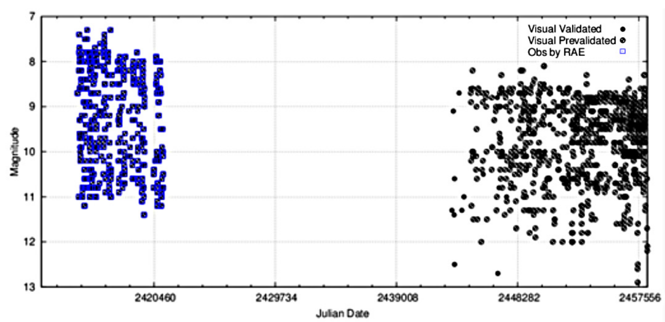

Figure 3. Light curve for U CrA from AAVSO data.

determined the period to be 330 days, close to the current value of 335.8 days. The cutoff in visibility of the star whenever it was fainter than about magnitude 11.2 is evident in the light curve. The light curve also shows that the first AAVSO observation of this star was submitted by Frank Bateson on March 17, 1957, so that the addition of Roberts' data permits study of the variability of S Hor extended by nearly sixty years.

The light curve for U CrA (Figure 3) similarly shows the cutoff at around magnitude 11.2, so that like many other long period variables Roberts was unable to determine the date of minima with any accuracy. The first AAVSO observation after Roberts was by Thomas Cragg on April 23, 1977, so that Roberts' data permits investigation of the variability extended by almost eighty years!

Initial inspection of the light curve for U CrA might indicate that the magnitude at maximum is slowly becoming fainter, and with that in mind the author visited Boyden during April 2019 to investigate Roberts' notes, including his charts and comparison sequences, more closely. A number of pages were found labelled "Comparison stars," with differing values over the years, and the table in Appendix B gives the values for the first and last of these pages. These show that while the comparison magnitudes were similar at the brighter end, the sequence is around 0.6 magnitude brighter in later years at the fainter end. More importantly, comparing with current values (AAVSO and GSC), his sequence is found to be around one magnitude brighter across the entire range, and probably explains the differences at maximum shown in Figure 3.

With the extension provided by his data in mind, all of the light curves of long period variables observed by Roberts would probably benefit from further scrutiny to determine whether amplitudes and periods have changed. A comprehensive review is required to compare Roberts' sequences to accepted modern magnitudes for all stars he observed. In regard to periods, Eddington and Plakidis (1929) referred previously to the complications in determining periodicity in long period variables by superposed irregularities, so that periods of these stars may appear to increase or decrease by several percent on time scales of decades. This would explain the differences found, for example, in S Hor, whereas the period in R Cen appears to be decreasing secularly (Anon. 2019). It should be remembered that in many cases there are large gaps between Roberts' and later AAVSO observations, which fact needs to be taken into account when investigating periods.

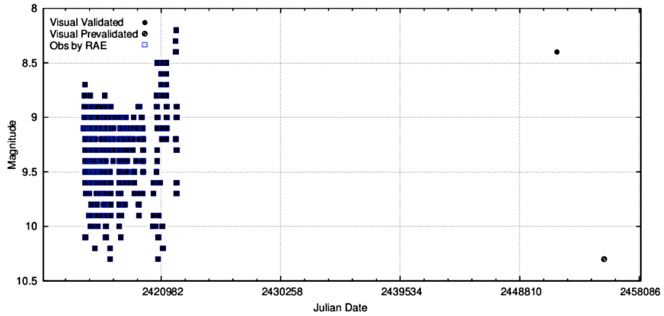

Figure 4. Light curve for Z Hya from AAVSO data.

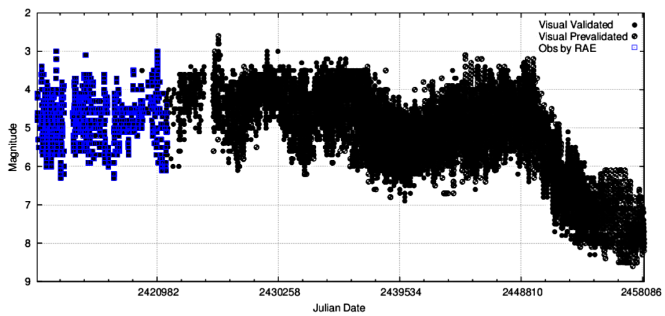

Figure 5. Light curve for L2 Pup from AAVSO data

4.2. The semi-regular variables: Z Hya and L2 Pup

In all, Roberts observed ten semi-regular variables. An example is the variable star Z Hya, which was well observed by Roberts, but the star seems to have been neglected afterwards, with virtually no observations in the AAVSO database, as Figure 4 shows. The GCVS gives the type as SRB, with a V range of 8.8 to 9.8 and period 75 days. The star is mentioned by Ashbrook (1942) as being previously published as irregular, but she concludes it to be semi-regular with a period of about 75 days, from which, no doubt, the GCVS value is derived. Roberts found a visual range of 9.2 to 10.0 and comments:

> Light variations irregular. The rise to a maximum is rapid, but not continuous. Innes finds minima more distinctly marked than maxima; from observations of minima he also deduces a period of 53 days. In order to connect his observations with those made at Lovedale I have taken the probable period 52.5 days. A longer period, 62 days, would satisfy the Lovedale observations alone. (Roberts 1901a)

Very clearly Z Hya needs more attention before comparing the current classification with the behavior found by Roberts.

Another star for which Roberts data extends the period of observation by around two decades earlier is the semi-regular star L2 Pup (Figure 5).

He derived a mean period of 140.15 days and a visual range of 3.4–4.6 at maximum to 5.8–6.2 at minimum, but also commented:

> Variation subject to irregularities both as regards to limits and period. The form of the light-curve is also dissimilar for different periods, the star sometimes taking longer to rise to a maximum than to fall to a minimum. (Roberts 1901a)

In recent years the range of variability has become ever fainter, a process that started ca. 1992. Prior to that the light curve shows a broad dip, preceded by two or three dips of shorter duration. Bedding *et al.* (2005) analyzed the light curve for 1927–2005, and concluded the existence of two independent mechanisms: gradual dimming due to circumstellar dust, and pulsations within the star. Others have indicated that the pulsation amplitude varies cyclically on a time scale of thousands of days (Anon. 2019). The addition of Roberts' observations extends the data by nearly eight thousand days earlier, and may contribute to the further understanding of the evolution of this star.

4.3. The eclipsing variables: V Pup, RR Cen, and X Car

Roberts was well known for his observations of eclipsing stars, which make up 20% of the stars he observed, and the following are three examples. Roberts (1905) prepared his own charts and determined magnitudes of comparison stars for all three using the Oxford wedge photometer.

V Pup is classified as EB/SD, with a period of 1.4544859 days, V range from maximum 4.35 to 4.92 at primary minimum and 4.82 at secondary minimum (Samus *et al.* 2017). It was well observed by Roberts, who derived a period of 1.454475 days (1901a), but then appears to have been neglected until more recent times. Examination of the light curve in Figure 6 would indicate that Roberts observed both the maxima and minima to be fainter than listed in the GCVS, and also appears to show a peculiar decrease in the maximum magnitude during the period of Roberts' observations.

In an effort to explain these discrepancies the author investigated Roberts' notes. His chart and sequence are shown in Appendix C and indicate his sequence for V Pup was generally 0.2–0.5 magnitude fainter than the current AAVSO sequence, which explains the differences seen in Figure 6. What is not explained is the difference in magnitude when the star was at maximum light. For V Pup there is a single set of determinations of comparison magnitudes, which Roberts appears to have used invariably, unlike many other stars where he appears to have made ongoing determinations over a number of years. Therefore the apparent variation in maximum magnitude for V Pup remains to be explained.

The discovery of RR Cen as a variable star by Roberts was announced in *The Astronomical Journal*, No. 378 (Roberts 1896c), originally referred to as LAC. 5861, and is the star which he observed on the most occasions, with 2,289 observations in the AID. The GCVS gives its type as EW, period 0.6056845 day and V range 7.27 at maximum to 7.68/7.63 at minimum.

Roberts (1896d) published his results, deriving a period of 0.3028 day, and commented:

> The new short period variable in Centaurus recently announced in the *A.J.* no. 378, is one of considerable interest, as its type of variation is quite distinct from that of the other short-period variables discovered here. Its ascending period is almost exactly of the same duration as the descending period, a fact which relates the star indirectly to those of the *Algol-type*, and directly to *U Pegasi*. This is of extreme importance, as it materially strengthens the opinion expressed by Dr. Chandler that *U Pegasi* probably belongs to a new type of short period variable. (Roberts 1896d)

While Roberts' period appears to be exactly half that of the GCVS period, inspection of the light curve also indicates some apparent discrepancies between Roberts' and recent observations, and both historical and current data would benefit from closer scrutiny (Figure 7).

Another eclipsing star for which there are apparent discrepancies between Roberts and more recent AAVSO data is X Car (Figure 8).

The star is classified as EB, varying from 7.80 to 8.67 V with a period of 1.0826311 days. The range is very close to that observed by Roberts, but the star has been poorly observed since, apart from two sparse campaigns, with one set of data clearly discordant. A search of the archives produced Roberts' hand-drawn chart, but no indication of the magnitude sequence he used. X Car would benefit from closer scrutiny in order to clarify its current behavior.

4.4. Two stars paid particular attention: S Ara and κ Pav

Roberts was particularly interested in these two variables, believing that eclipses were somehow involved in the variability, and continued observation long after he had ceased observing other variable stars. Regarding S Ara (type RRAB) he commented: "the variation of this star is exceedingly remarkable," and published his Light curve of S Arae (Roberts 1901b) in which he derived a period of 0.4519 day and visual range 9.53 to 10.84, compared with the GCVS period of 0.4518587 day and V range 9.92 to 11.24. On this basis S Ara must have been at the very limit of visibility in the 3¼-inch

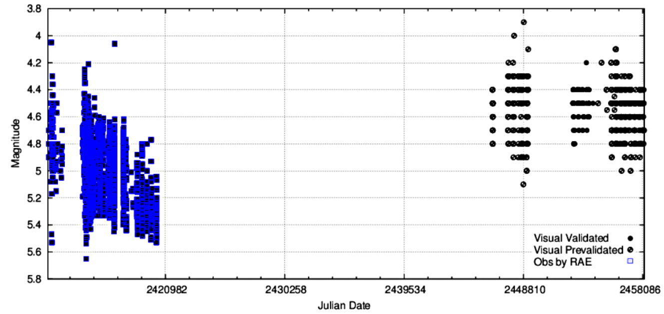

Figure 6. Light curve for V Pup from AAVSO data.

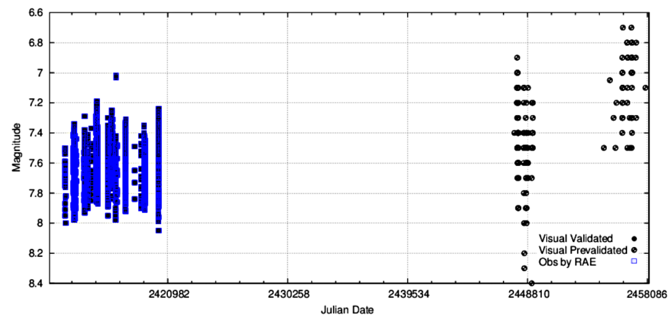

Figure 7. Light curve for RR Cen from AAVSO data.

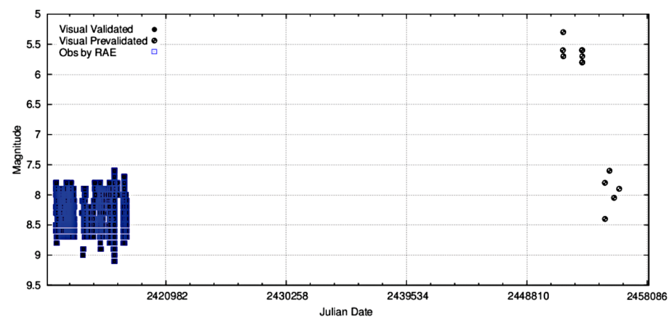

Figure 8. Light curve for X Car from AAVSO data.

when at minimum. Later he published a more complete study in which he concluded:

> 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 (Roberts 1911b)

Again the light curve at maximum (Figure 9) shows some variation, which might be explained by the sequence shown in Appendix D. His notes contain one page marked "Comparison Stars," which is a table with changing values for the numbered stars on his rough chart for the years 1901–1914. If the star marked "2" is considered, for example, its magnitude increased from 9.58 in 1901 to 9.22 in 1914, an increase of 0.36 magnitude over the period Roberts observed S Ara, and he presumably used this comparison star when S Ara was near maximum brightness. Whether or not he later adjusted his final estimates to compensate for these fluctuations in comparison star magnitudes is not clear, but it is possible the differences in magnitude at maximum are due to inconsistencies in the comparison magnitudes used over the years. Whatever Roberts concluded, there appear to be no visual observations of S Ara in the AID since he made his last observation.

The second star which Roberts continued to observe long after ceasing others is κ Pav, and like S Ara, he also believed the variability was due to eclipses. This conclusion may have been influenced by the announcement (Wright 1903) that κ Pavonis is a binary star, and Roberts apparently found confirmation of this in explaining the light curve from his observations (Figure 10). He concluded:

> The striking peculiarity of the light curve of *κ Pavonis* is what appears to be a secondary phase, nearly midway between principal minimum and principal maximum.... Now a curve of this form suggests eclipse. (Roberts 1911c)

Inspection of the AAVSO light curve (Figure 11) shows Roberts observed the range slightly wider than others. Plotting light curves in this fashion also highlights erroneous observations in the AID, such as the two points at magnitude 1 and 2, which can be used to improve the reliability of the AAVSO data.

4.5. Two final stars in need of clarification, S Aps and T TrA

The bright R Coronae Borealis star S Aps has been very well observed over the years (Figure 12), but in Roberts' time the mechanism of variability was not understood.

He commented: "Maximum not distinctly marked; increasing and decreasing rate of variation slow and apparently equal. Decreasing phase irregular" (Roberts 1901a). He was only able to monitor S Aps when it was bright, which he observed as brighter than others, but nonetheless, he captured three fades due to the now well-understood mechanism. In an effort to explain the difference in magnitude when S Aps is bright, Roberts' comparison sequence will be investigated to see how it compares with the modern sequence.

As a final example of Roberts' observations, both the historical and current data for T TrA need further scrutiny. The light curve is shown in Figure 13, and shows variations of more than one magnitude.

The GCVS and Hipparcos data, however, give the star as being of constant magnitude, while AAVSO and ASAS-SN data suggest a rapid variable with no discernible period. The spectral type is B9IV, a type not normally associated with large, rapid variations (Anon. 2019). Roberts himself says:

> Gould considered this star to vary between the limits $7^{M}.2$ to $7^{M}.4$, in a period of about 1 day (U.A. p. 260). Lovedale observations do not confirm this variation.... It is possible that the apparent variation may be really due to position error; this would be fulfilled in a period of one day. (Roberts 1901a)

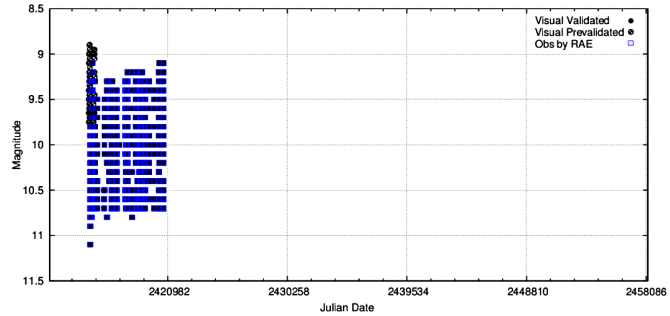

Figure 9. Light curve for S Ara from AAVSO data.

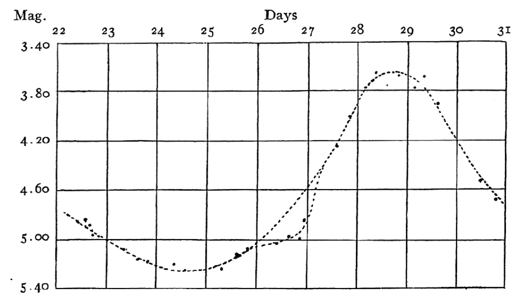

Figure 10. Roberts' light curve for κ Pav.

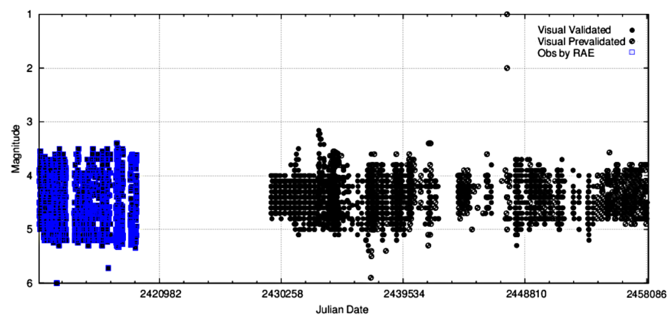

Figure 11. Light curve for κ Pav from AAVSO data.

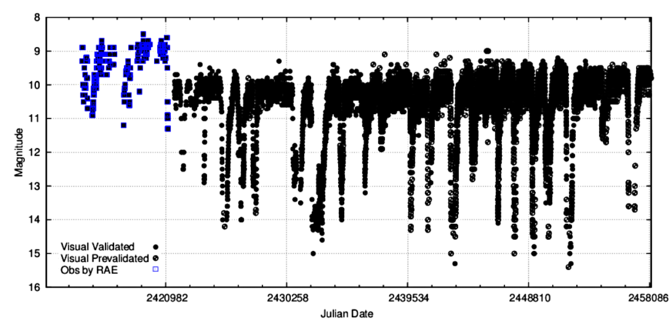

Figure 12. Light curve for S Aps from AAVSO data.

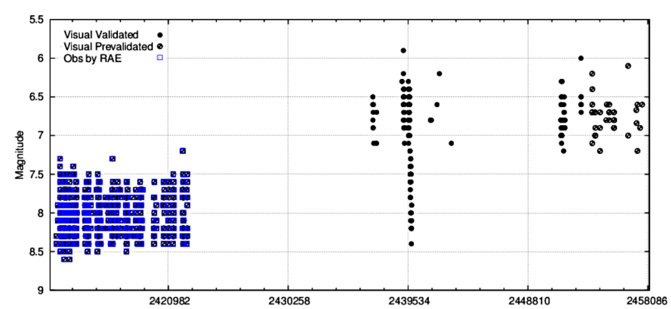

Figure 13. Light curve for T TrA from AAVSO data.

These facts are, however, not consistent with the final observations of Roberts', which show variability over the range 7.2 to 8.6, as well as observations already in the AID covering two periods, around 1966–1967 when the observed range was 5.9 to 8.4, and 1999–2016 when the observed range was 6.0 to 7.2. Roberts' observations and manuscript will be investigated to understand exactly how he arrived at his data, and the star will be observed by the author to clarify the nature of any current variability.

5. Conclusions

The addition of Roberts' observations expanded the AAVSO International Database by around 70,000 observations for 98 separate variable stars. More importantly it extended the database by several decades earlier for some southern variables, and may be useful in studying the longer term changes in variability of some stars. This paper provides a few examples of how Roberts' observations compare to the overall AAVSO observations and highlight some interesting aspects that need further scrutiny, as well as stars that have been neglected that could benefit from increased modern attention. There appear to be some differences in magnitudes at maximum and minimum light of some variables, which may be due to differences in comparison magnitude sequences. Similarly, it should be remembered that in some cases there are large gaps in dates between Roberts' and later AAVSO observations which could cause problems in period determination. A full review of Roberts' magnitude sequences is required before arriving at any conclusions on changes in an individual star's light curve parameters. The construction of light curves over such broad periods is shown to be a potentially useful quality control tool to highlight observations in the AAVSO database which may have been entered in error. Finally, Roberts' manuscripts remain unpublished, and the current digitization project under the auspices of the Centre for Astronomical Heritage will go a long way to opening up Roberts' observations for closer scrutiny.

6. Acknowledgements

The author gratefully acknowledges AAVSO Director, Dr. Stella Kafka, not only for motivation to write this paper, but also for persuading him (over a shared bottle of Chardonnay) to delve deeper into the treasure chest that Alexander Roberts left behind a century ago. The author also wishes to thank Sara Beck for providing the Julian dates of first observations in the AAVSO International Database used in compiling Appendix A, and Auke Slotegraaf for constructive comments and corrections to the original draft of this paper.

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Appendix A: Master list of variable stars observed by A. W. Roberts (RAE).

Long Period Variable Stars (55 stars)

Star	*Type*	*Period*	*Roberts First*	*AAVSO First*	*Difference*
R Cae	M	388.4	2412800.3	2421485.4	8685
R Car	*M*	*305.6*	*2411856.3*	*2407846.9*	*–4009*
S Car	M	150.3	2411856.3	2421417.2	9561
Z Car	M	383.6	2413308.3	2422030.0	8722
AF Car	M	447.6	2417946.4	2425505.5	7559
R Cen	**M**	**501.8**	**2411972.4**	**2421608.8**	**9636**
U Cen	M	220.0	2413311.4	2421405.3	8094
W Cen	M	200.4	2413742.4	2419224.9	5483
X Cen	M	312.0	2413728.4	2421405.3	7677
RS Cen	M	164.1	2414810.3	2419205.0	4395
RT Cen	M	255.0	2415032.6	2419215.0	4182
S Col	M	325.8	2414600.4	2421664.3	7064
T Col	M	225.8	2414570.5	2419770.7	5200
U CrA	**M**	**147.5**	**2414613.3**	**2443257.2**	**28644**
R Gru	M	332.0	2413427.3	2421475.2	8048
S Gru	M	401.5	2414598.4	2419254.0	4656
T Gru	M	136.5	2414593.4	2420039.7	5446
R Hor	M	407.6	2412800.3	2419298.0	6498
S Hor	**M**	**335.8**	**2414612.5**	**2435754.9**	**21142**
T Hor	M	217.6	2414930.3	2419298.0	4368
R Ind	M	216.3	2413803.4	2419254.0	5451
S Ind	M	400.0	2413803.4	2419254.0	5451
R Lup	M	235.6	2413657.3	2419832.0	6175
S Lup	M	339.7	2413657.3	2422170.2	8513
RS Mic	M	228.5	2414930.4	2441900.8	26970
T Nor	M	240.7	2414861.3	2419215.9	4355
R Oct	M	405.4	2412828.4	2421674.6	8846
S Oct	M	259.0	2414016.3	2421699.7	7683
T Oct	M	218.5	2413749.3	2425766.5	12017
R Pav	M	229.5	2413274.4	2419216.0	5942
T Pav	M	243.6	2413829.4	2419216.0	5387
U Pav	M	289.7	2414598.4	2436477.6	21879
R Phe	M	269.3	2413427.3	2419254.0	5827
S Pic	M	428.0	2413652.3	2419298.0	5646
R PsA	M	297.6	2413427.3	2413542.5	115
W Pup	M	119.7	2413586.3	2421480.5	7894
R Ret	*M*	*278.5*	*2412237.2*	*2401302.0*	*–10935*
RT Sgr	M	306.5	2413743.3	2419931.9	6189
RU Sgr	M	240.5	2413743.3	2421763.3	8020
RV Sgr	M	315.8	2414600.3	2421400.3	6800
RR Sco	M	281.4	2413282.4	2419506.0	6224
RS Sco	M	319.9	2412946.4	2419216.0	6270
RT Sco	M	449.0	2414670.6	2420339.7	5669
RU Sco	M	370.8	2413830.3	2421704.3	7874
RW Sco	M	388.4	2413742.5	2421692.3	7950
RZ Sco	M	156.6	2414895.4	2416966.7	2071
S Scl	M	362.6	2413045.3	2420064.7	7019
T Scl	M	202.4	2413787.4	2419330.9	5544
U Scl	M	333.7	2414570.3	2421479.2	6909
V Scl	M	296.1	2413787.4	2421701.3	7914
R Tel	M	467.0	2414727.6	2421782.2	7055
R Tuc	M	286.1	2413801.5	2421477.2	7676
S Tuc	M	240.7	2413747.4	2419298	5551
T Tuc	M	250.3	2416640.5	2421477.2	4837
W Vel	M	394.7	2414961.6	2419204.9	4243

Semiregular Variable Stars (10 stars)

Star	*Type*	*Period*	*Roberts First*	*AAVSO First*	*Difference*
RR Car	SRB	155.5	2413308.3	2419218.0	5910
T Cen	SR	90.4	2413047.3	2419270.9	6224
R Dor	SRB	338	2411861.3	2421685.2	9824
Z Hya	**SRB**	**75**	**2414966.6**	**2451697.6**	**36731**
S Pav	SRA	380.9	2413274.4	2421705.8	8431
S Phe	SRB	141	2413426.3	2437483.0	24057
R Pic	SR	170.9	2413652.3	2419415.0	5763
L2 Pup	**SRB**	**140.6**	**2411839.4**	**2419816.7**	**7977**
R Scl	SRB	370	2411972.4	2412726.5	754
Y Scl	SRB		2414612.4	2437555.0	22943

Eclipsing Variable Stars (7 stars)

Star	*Type*	*Period*	*Roberts First*	*AAVSO First*	*Difference*
R Ara	EA	4.42522	2412133.4	2445870.9	33738
X Car	**EB**	**1.0826311**	**2412507.3**	**2451593.5**	**39086**
RR Cen	**EW**	**0.6056845**	**2413029.3**	**2447795.5**	**34766**
V Pup	**EB/SD**	**1.4544859**	**2411921.2**	**2446401.3**	**34480**
RR Pup	EA/SD	6.4296333	2414897.6	2451511.4	36614
RS Sgr	EA/SD	2.4156832	2412324.4	2447681.5	35357
S Vel	EA/SD	5.9336475	2412865.3	2454472.8	41607

Delta Cepheid and Classical Cepheid Variable Stars (20 stars)

Star	*Type*	*Period*	*Roberts First*	*AAVSO First*	*Difference*
l Car	DCEP	35.55560	2411830.2	2417357.5	5527
U Car	DCEP	38.80942	2411856.3	2429026.2	17170
V Car	DCEP	6.696756	2412130.3	2434869.3	22739
Y Car	DCEP(B)	3.639760	2412633.4	2434517.3	21884
V Cen	DCEP	5.4940	2413029.3	2434513.4	21484
R Cru	DCEP	5.82575	2411942.3	2433776.2	21834
S Cru	DCEP	4.68997	2411942.3	2434587.3	22645
T Cru	DCEP	6.73331	2411942.3	2433776.2	21834
R Mus	DCEP	7.510211	2411857.4	2432029.6	20172
S Mus	DCEP	9.66007	2411882.3	2433776.1	21894
S Nor	DCEP	9.75411	2412264.2	2434561.5	22297
U Nor	DCEP	12.64371	2414896.3	2426423.7	11527
κ Pav	**CEP**	**9.09423**	**2411840.3**	**2429470.5**	**17630**
RS Pup	DCEP	41.3876	2414962.4	2430931.5	15969
RV Sco	DCEP	6.06133	2412974.4	2434564.4	21590
RY Sco	DCEP	20.31322	2414412.6	2435205.7	20793
R TrA	DCEP	3.389287	2411858.3	2427119.6	15261
S TrA	DCEP	6.32344	2412323.2	2434562.4	22239
T Vel	DCEP	4.63974	2412249.3	2433765.1	21516
V Vel	DCEP	4.370991	2412181.3	2434521.2	22340

Other Variable Stars (7 stars)

Star	*Type*	*Period*	*Roberts First*	*AAVSO First*	*Difference*
S Aps	**RCB**	**—**	**2414578.3**	**2421643.3**	**7065**
S Ara	***RRAB***	***0.4518587***	***2414962.3***	***2414853.9***	***–108***
RS Car	NA	—	NO OBS	2421566.3	
R CrA	INSA	—	2413743.3	2417117.6	3374
S CrA	INT	—	2413749.3	2419216.0	5467
T CrA	INSB	—	2414818.4	2419216.0	4398
T TrA	**CST**	**—**	**2412329.2**	**2436805.9**	**24477**

Notes: Stars are given according to the latest GCVS type (Samus et al. 2017). Stars observed within each classification are listed in order of increasing right ascension. Stars discussed further in the text are indicated in bold face. Stars for which Roberts was not the earliest observer are indicated in italics. The period is according to GCVS (Samus et al. 2017). Total stars observed for which estimates submitted to the AAVSO International Database = 98.

Appendix B: Roberts' chart and sequences for U CrA.

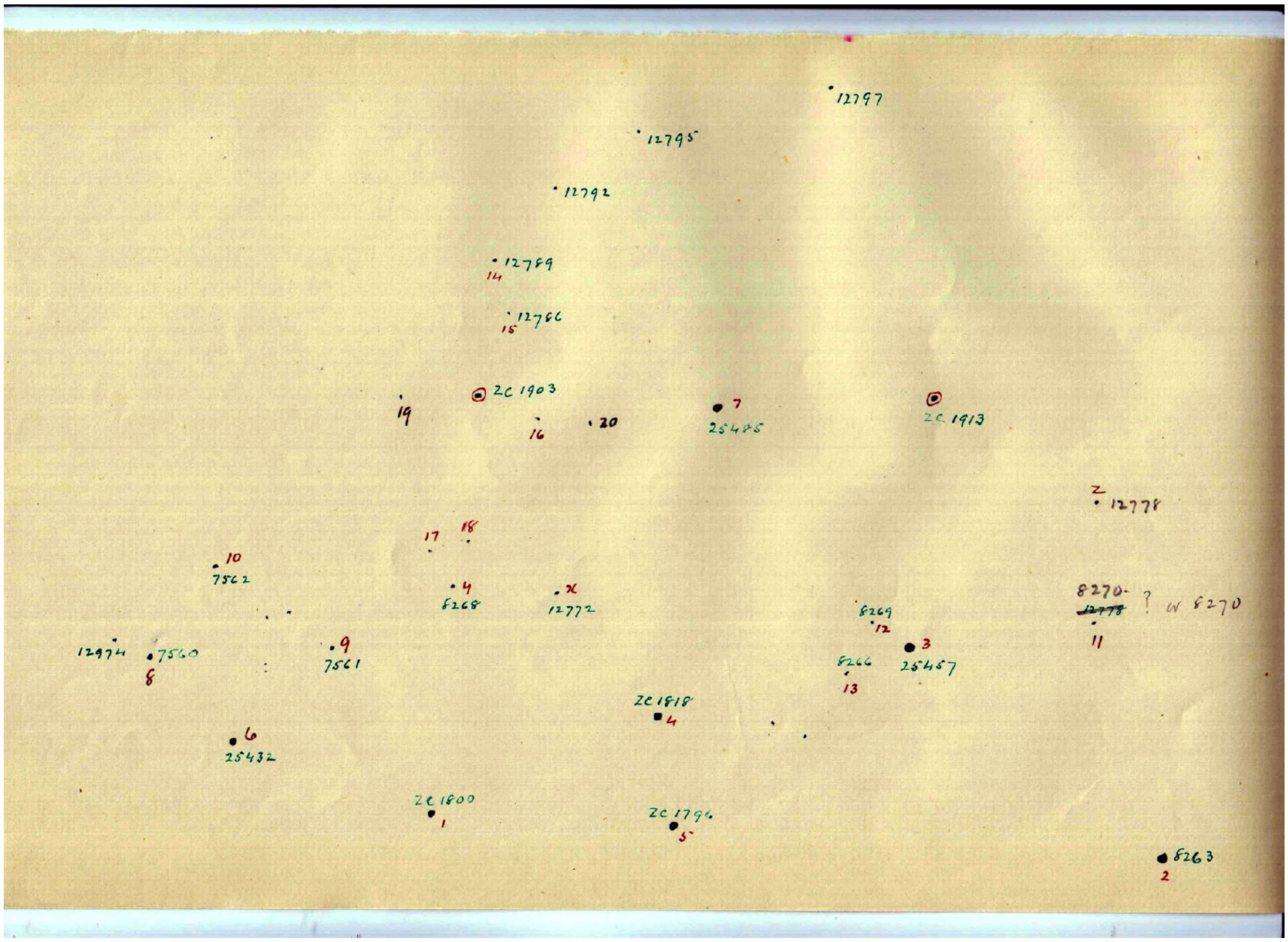

Figure 14. Roberts' hand-drawn chart for U CrA, marked as ZC1903. The star marked ZC1913 is the variable AM CrA (type SR, range 8.6–12.7).

Table 2. Roberts' and AAVSO comparison star sequence for U CrA. AAVSO sequence from chart reference X24407NE.

Star Label	*Roberts Sequence Frst*	*Roberts Sequence Last*	*AAVSO Sequence (GSC magnitude)*
1	6.54	6.60	(7.7)
2	6.95	6.76	—
3	7.00	7.00	8.4 (8.4)
4	7.33	7.30	(8.4)
5	7.41	7.38	(8.8)
6	7.39	7.35	(8.5)
7	7.99	7.94	(9.0)
8	8.83	8.74	9.6
9	9.31	9.24	—
10	9.40	9.31	10.2
11	9.58	9.01	—
12	10.34	9.71	—
13	10.47	9.88	—
14	11.05	10.44	10.9
15	11.50	10.89	—
16	11.62	11.01	—

Appendix C: Roberts' rough chart and sequence for V Pup.

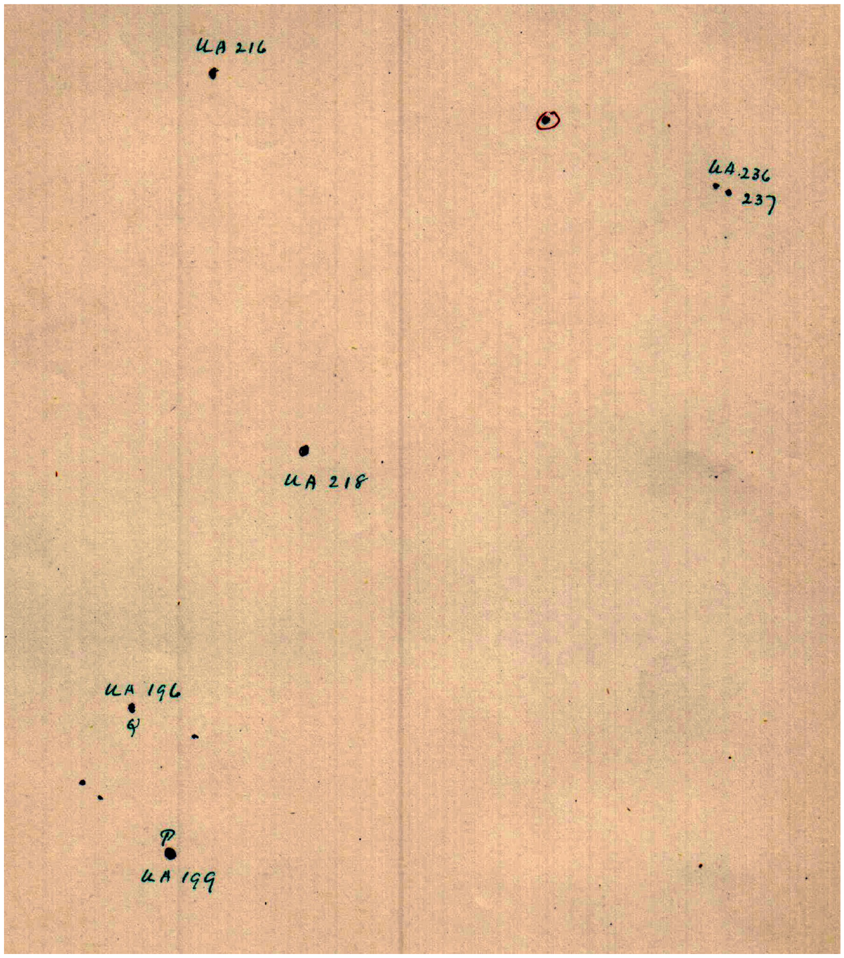

Figure 15. Roberts' hand-drawn chart for V Pup.

Table 3. Roberts' and AAVSO comparison star sequence for V Pup. AAVSO sequence from chart reference X24439AIT.

Star Label	*Roberts Sequence*	*AAVSO Sequence*[1]
UA196	5.2	4.7
UA199	4.3	4.1
UA216	5.0	4.6
UA218	4.5	4.2
UA236	6.4	6.0

[1] *AAVSO sequence from chart reference X24439AIT*

Appendix D: Roberts' charts and sequence for S Ara.

Figure 16. Robert's field for S Ara, as would be noted at the eyepiece.

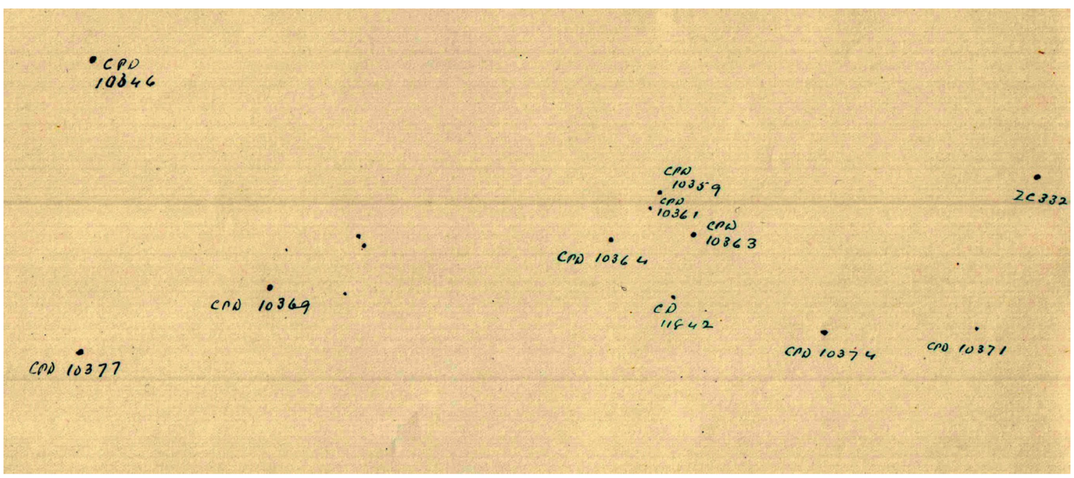

Figure 17. Roberts' hand-drawn chart for S Ara, labelled as CPD10361.

Table 4. Robert's adopted magnitudes for comparison stars for S Ara, which changed over the years as shown.

Star Label	*Star Name*	*Year* 1901	1905	1910	1914
1a	CPD10377	—	—	8.93	—
1b	CPD10369	—	—	9.33	—
2	CPD10371	9.65	9.45	9.33	—
3	CPD10363	9.58	9.45	9.42	9.22
4	CPD10374	9.80	9.81	9.77	9.55
7	CPD10359	10.50	10.47	10.57	10.49
8	CD11842	10.53	10.48	10.52	10.40
9	CPD10364	10.58	10.68	10.63	10.49

Note: 1a and 2 are in the same column of the table labelled "Comparison Stars," and have the same magnitude of 9.33. His original rough chart, however, identifies these as two different stars.