Digital Archiving: Where the Past Lives Again

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Abstract   The process of digital archiving for variable star data by manual entry with an Excel spreadsheet is described. Excel-based tools including a Step Magnitude Calculator and a Julian Date Calculator for variable star observations where magnitudes and Julian dates have not been reduced are presented. Variable star data in the literature and the AAVSO International Database prior to 1911 are presented and reviewed, with recent archiving work being highlighted. Digitization using optical character recognition software conversion is also demonstrated, with editing and formatting suggestions for the OCR-converted text.

1. Introduction

When AAVSO Science Director Dr. Matthew Templeton initiated the Harvard Annals Digitization Project in August of 2010, archival digitizing activity at the AAVSO had been going on for some time. AAVSO Technical Assistant Dr. Michael Saladyga has, for example, digitized over 94,000 variable star observations of the late AAVSO member Wayne Lowder. Since October 2009, the Eggen Digitization Team (George Silvis and others) has begun to capture hundreds of thousands of photoelectric observations of Olin Eggen from the 1950s into the 1990s. Brian Skiff of the U.S. Naval Observatory in Flagstaff, Arizona, has digitized past visual and photoelectric data from the literature. Recently, Bob Stine, Christian Fröschlin, Hunter Johnson, Andrew Rupp, and this author have contributed numerous pre-1911 archival observations to the AAVSO International Database (AID). This paper was written to aid in the future research into and archiving of older variable star observations.

Digital archiving is the process of capturing and recording past variable star observations from the literature and from archival sources, culminating with the entry of data into the AID. Digital archiving either involves the manual entry of data into a spreadsheet or using optical character reading (OCR) software to convert image data into text. Digitization using OCR conversion requires additional editing and not all sources of archival variable star data are appropriate for this methodology. Manual data entry and OCR digitization are discussed in later sections.

The archiving of older variable star observations has many benefits. In addition to completing the record of historical observations, it also allows for

astrophysical studies to be performed on long timescales. It provides historical data sets for important variable stars (Figure 1), class prototypes, and novae, sometimes dating back to just after discovery (Figure 2). It also allows for the study of variable star evolution, helping to document phenomena such as changes in period, amplitude, or rates of mass transfer.

2. The archiving process

The digital archiving process consists of the following steps:

- Select your project.
- Check for existing data in the AID.
- Locate and download your data using NASA ADS (for papers) or Google Scholar (for books).
- Obtain AAVSO observer codes for observers in your data set.
- Create your spreadsheet template and then digitize your data.
- Proofread the spreadsheet and email it to the AAVSO.
- The spreadsheet will be converted into a version of the AAVSO Extended Visual ASCII format and entered into the AID by the AAVSO staff.

Variable star data in the literature usually exist in four different forms. In most references (including most of the *Harvard Annals* data), the Julian dates (JDs) are given and the magnitudes exist in reduced format (Figure 3). In older references, the magnitude estimates may exist as unreduced "step" or "step pair" data and calendar dates are given with no JD conversion (Figure 4). In very rare cases, magnitude estimates may exist as "decimal step" or "grade" data (Figure 5). Decimal step data divide the interval between two comparison stars into a number of steps and record just a single observation, i.e. "a6.5b." When working with grade data, magnitudes must then be derived by regression of magnitude versus grade (tables of magnitudes and grades of the comparison stars are usually given within the paper). Photoelectric data for variable stars also exist in the literature from the late 1940s to the 1990s (no example shown) and may provide additional archival material.

3. The spreadsheet template

The main spreadsheet template is shown in Figure 6. It consists of twelve columns (nine of which are kept) and may be up to several thousand rows deep. The key columns are labeled Observer (C), Type (D), Star (E), Julian Day (F), Fainter than (G), Magnitude (H), Comment Codes (I), Uncertain (J) and

Comments (K). Columns C through K are the portions of the spreadsheet which are kept and emailed to AAVSO Headquarters. Columns A and B are the partial JD columns which are summed in Column G. Splitting the JDs and using cell addition can save valuable keystrokes. The Observer Code goes in Column C. Visual observations are denoted with a "V" in Column D. Observations that are "fainter than" or "uncertain" are denoted with a "1" in Columns G and J, respectively. Column K is the Comments column, where the reference for each observation is noted in NASA ADS format with the year, journal, volume number, and page number indicated, along with the digitizer's observer code. Column L is an error check column, where for a given JD, the previous JD is subtracted. A progression of positive numbers downward indicates error-free JD entry. When the spreadsheet data entry is finished, be sure to "Highlight" all of the summed JDs in Column F and do a "Paste Special" and "Values" over the same highlighted contents to preserve the numerical JD values and hit "Save." After a final error check, delete Columns A, B, and L, "Save" the Spreadsheet Template, and email it to AAVSO Headquarters for uploading to the AID.

4. Excel-based archival tools

4.1. A step magnitude calculator

In many cases in the literature, the magnitude of an archival observation is not reduced but is commonly given as a "step" estimate using two comparison stars. In the example shown in Figure 7, an estimate for the Mira variable R Leonis is given as "n5R" and "R2l"—n5R2l—where R represents R Leonis. R Leonis is five steps fainter than comparison star "n" and is two steps brighter than comparison star "l". When the magnitudes of comparison stars "n" and "l" are known, the resultant magnitude is equal to the fractional ratio of the step range to the true magnitude range of the comparison stars. The magnitude for R Leonis can be calculated by the following equation:

$$mR = (\text{Steps (n to R)} / (\text{Steps (n to R)} + \text{Steps (R to l)}) \times (l - n)) + n, \quad (1)$$

where mR is the magnitude estimate for R Leonis, Steps (n to R) and Steps (R to l) are the step parts of the magnitude, and l and n are comparison star magnitudes for l and n, respectively.

The solution for the magnitude for R Leonis is:

$$mR = (5 / (5 + 2) \times (6.48 - 5.84)) + 5.84 = 6.30 \quad (2)$$

The construction of this step magnitude spreadsheet is straightforward. Enter the comparison star names (Columns A and I) and sequence magnitudes (Columns B and H). Follow the instructions and enter the equations given in Figure 7. When step numbers (dark green) are entered in Columns D and F, the

magnitudes of the comparison stars (light green) and step numbers are displayed in the Logic Columns C and G and in row 14. The final reduced magnitude (yellow) is displayed in Cell E16.

4.2. An Excel Julian date calculator

In other instances, archival variable star data may give the dates of the observation in calendar format, commonly with GMT times. In these cases, the Julian date (JD) will need to be calculated. A JD with no heliocentric correction is calculated by the equation:

JD (referenced from October 15, 1582) = 367 × Year – INT (7 × Year + INT ((Month + 9) / 12)) / 4) – INT (3 × (INT ((Year + (Month – 9) / 7) / 100 + 1) / 4 + INT (275 × Month / 9) + Day of the Month + 1721028.5 + UTC Hr. / 24 + UTC Min. / 1440 + UTC Secs. / 86400   (3)

As opposed to using another software package to compute the JD, it can be calculated in Excel by using the equation given above, where the year, month, day of the month, and GMT times in hours, minutes, and seconds become specific cell inputs in Columns A through F, respectively, as shown in Figure 8. In this screen shot of the Excel spreadsheet, Cell J2 is highlighted and the Excel version of the JD equation is shown in the function window and here as Equation 4; the JD (Excel equation to be entered for Cell J2, [all numbers and text between the parentheses]):

"=367*A2-INT(7*(A2+INT((B2+9)/12))/4)-INT(3*(INT((A2+(B2-9/7)/100+1)/4)+INT(275*B2/9)+C2+1721028.5+D2/24+E2/1400+F2/86400"   (4)

Otherwise, this JD-calculating spreadsheet template in Figure 8 is similar to its counterpart shown in Figure 6.

When you are finished digitizing, be sure to "Highlight" all of the calculated JDs in Column J and do a "Paste Special" and "Values" over the same highlighted contents to preserve the numerical JD values and hit "Save." Columns A, B, C, D, E, F, and O can then be deleted, the spreadsheet template can then be edited, "Saved", and emailed to AAVSO Headquarters for uploading to the AID.

5. Digitizing suggestions and guidelines

Listed below are a list of suggestions and hints for digitization by spreadsheet entry:

• Research the AID and literature thoroughly.

• Correspond with AAVSO Headquarters (Dr. Matthew Templeton) before selecting of your project; digitize a complete paper, as opposed to doing partial digitization of a given reference.

• Obtain or request necessary AAVSO observer codes beforehand.

• Use a computer with a full-sized keyboard and keypad; use of an all-in-one generic laptop is not recommended.

• Use the "Copy" and "Paste" functions to create and fill the Spreadsheet Template.

• Review your archival article to understand the used of italics, observer abbreviations, and special symbols for "not seen" and "fainter than" observations.

• Record all data as presented in the journal or article.

• Omit "fainter than" and "not seen" observations if no comparison star data are given.

• Determine the photometric system of your paper, as the AAVSO uses the Harvard Photometric system; some papers or archival sources may use Schonfeld, Hagen ASV, or Potsdam photometric sequences; make a comment if the magnitude estimates are not on the Harvard system and enter the "Comment code" "K."

• Average multiple estimates made on the same JD (where no times are given) and make a note in the Comments column.

• Use the "additive columns" method to minimize JD keystrokes.

• Remember to "Copy," "Paste Special," and "Values" for saving JD's derived from mathematical cell operations.

• Check for errors in JD, magnitude, observer, star name, and page number.

• "Save" your work often and take breaks as needed to reduce fatigue.

• Enter Comments codes (Fainter than, Uncertain, etc.) as required.

• In the Comments column, enter the paper reference in ADS format with the page number (if the paper in listed by the ADS, otherwise use the standard AAVSO references format for books and other non-ADS references), your AAVSO observer code, and other comments.

• Run a JD-subtraction quality check to detect possible JD errors.

6. Review of variable star observation in the literature and archival sources

In 1890, Pickering presented and analyzed 125,720 variable star observations from the literature and those sent to Harvard College Observatory between 1837 and prior to 1888 from thirty-one worldwide observers and institutions (Pickering 1890). The observers and institutions identified in that paper

included: *Argelander, Backhouse, Baxendell (Sr. and Jr.), Chandler*, Duner, *Eadie*, Espin, *Harvard College Observatory*, Gore, Hartwig, *Hagen, Heis, Knott*, Lawrence, Markwick, National Observatory in Cordoba, Argentina, Oudemanns, Peck, Plassman, *Parkhurst, Schonfeld*, Sarafik, Shearman, *Sawyer, Schmidt*, Upton, Webb, Wilsing, *Zwack*, and *Zaiser* (observers in Table 1 are indicated here in italics). Until very recently, few observations prior to 1888 existed in the AID. Pickering (1890) is a key reference for variable star observations prior to 1888 and may be an important source for researching additional archival variable star observations.

Table 1 lists a number of variable star observation collections prior to 1911. A total of thirty-one individual sources from the literature and the AAVSO Archives are identified and summarized in the table. The individual columns going from left to right are: the paper, book or archival source; the observer(s); the number of observations (estimated observations are noted); the number of individual stars documented; the magnitude reduction status; the Julian Date conversion status, and the AAVSO digitization status as of this writing. All listed sources are detailed in the reference list. The variable star data sources that have been digitized and are currently in the AID are given in italics.

Table 1 represents over an estimated 222,000 variable star observations prior to 1911, of which over an estimated 39,000 have been digitized up to the present time. Of the 125,720 variable star observations known by Pickering to exist prior to 1888, over 100,000 remain to be digitized and an estimated 98,000 observations from 1888 to 1911 also remain to be digitized. Further research may yield tens of thousands of additional variable star observations.

Additional sources of variable star data include papers in journals of the past: *Astronomische Nachrichten, Astronomical Journal, Monthly Notices of the Royal Astronomical Society, The Observatory,* and others. While this paper mainly concerns itself with the pre-1911 observations, other sources of variable star data are equally important, including unpublished observations in Ph.D. dissertations, photoelectric observations in the literature from the late 1940s to the 1990s, and private collections of individual observatories and archives.

7. Digitization using optical character reading (OCR)

After the presentation of this paper at the AAVSO's Annual Meeting in 2011, the author began to investigate OCR digitization with the freeware program "FreeOCR Version 3.0", which is based on the Tesseract OCR engine. This Windows-based software shows promise with increased digitizing efficiency and accuracy relative to the previously described manual spreadsheet entry method. However, the resulting OCR converted text will have to be edited and formatted within Excel. Figure 9 shows a small highlighted selection of variable star data of RR Andromedae from Campbell and Pickering (1912; left) and the corresponding OCR output (right) using this software.

Several important points about OCR-converted text are noted:

• The thin vertical column lines of the source .pdf file do not affect the resulting OCR text output.

• Text conversion accuracy appears to be high, between 90 and 95%.

• The two-digit year data are offset from the remaining variable star data of the scanned output text; this is not a problem, since the text may be edited within Excel after "Copying and "Pasting."

• Some errors will result from the OCR-conversion process: the bold vertical column lines may introduce spurious text; some italicized and regular text may not be converted properly (C's may become G's, c's may become 0's, 3's or 6's may become 8's or 0's, etc.), decimal points may be skipped or converted to commas and blemishes on the original text file may result in spurious converted text.

The following steps are required to edit the OCR-converted text and to enter it into the standard spreadsheet template (Figure 6):

• Highlight and OCR-convert one column of variable star data at a time; trying to OCR convert an entire page of variable star data at once complicates the editing process.

• "Copy" data from the OCR text window and "Paste" the OCR text in column N or higher in the standard Excel spreadsheet template; the columns of the OCR-converted text should be automatically parsed into columns and rows of data in Excel.

• Edit the rows and columns of new OCR text in Excel as necessary, removing the spurious data, correcting errors, and maintaining the JDs, magnitudes, and observers in their respective columns.

• "Copy" and "Paste" your desired columns of data to their proper positions within the standard Spreadsheet Template as required.

• Use the cell-addition method to complete the JDs and replace any improvised observer abbreviations with their correct AAVSO Observer Code.

• Edit the "Fainter than" (usually expressed as italicized magnitude values) and "Uncertain" observations and cite the paper reference and submission details in the Comments column.

• Delete the originally "Pasted" OCR converted data within Excel and repeat the process.

The author has noted a potential 35% increase in efficiency in using OCR software for digital archiving when compared to manual spreadsheet entry, even with the additional editing steps. Corrections are readily made in Excel. The use of OCR digitization and the standard spreadsheet template following the suggestions and guidelines previously described are highly recommended on large data sets where JD's and magnitudes are already converted.

8. Conclusions

The archiving process, a spreadsheet template, suggestions, and Excel-based data tools have been reviewed and presented. Thirty-one sources of variable star data prior to 1911 have been identified and presented in tabular form. Of the 125,720 observations known to Pickering prior to 1888, over 100,000 observations still remain to be located and digitized. Over 98,000 archival observations from 1888 to 1911 have been identified and also remain to be digitized. Spreadsheet entry of data is not tedious by using the methods described. Digitization by optical character reading conversion is a very promising alternative to manual spreadsheet entry, but additional editing and formatting are required to get the variable star data into the standard spreadsheet template. However, manual spreadsheet entry of archival data needs to be used in cases when the conversion of calendar dates to JDs and/or step magnitudes are required. All archival variable star data have value, if we can locate and can capture them. This paper attempts to clarify the where and how of the digital archiving process.

9. Acknowledgements

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Table 1. A selection of variable star observations in the AAVSO Archives and in literature prior to 1911. Data sources in italics have been digitized and are currently in the AID.

Source[1]	Observer(s)	No. Observations	No. Stars	Magnitude Reduced	JD Converted	Status
Sawyer (1877–1892)[2]	Sawyer	5000[3]	unknown	no	no	not digitized
Chandler (1883–1884)[2]	Chandler	700[3]	unknown	yes	no	not digitized
Parkhurst (1883–1885)[2]	Parkhurst, J.	2000[3]	unknown	no	no	not digitized
Eadie et al. (1884–1885)[2]	Eadie, Hagen, Zaiser	1000[3]	unknown	no	no	not digitized
Eadie (1884–1890)[2]	Eadie	2000[3]	unknown	no	no	not digitized
Yendell (1888–1918)[2]	Yendell	30000[3]	unknown	mixed	mixed	not digitized
Pickering and Wendell (1890)	Pickering and Wendell	1057	165	yes	no	digitized by Paxson
Townley (1892)	Townley	1085[2]	37	yes	no	digitized by Paxson
Parkhurst and Pickering (1893)	Eadie and Parkhurst, H.	4800[3]	135	yes	no	not digitized
Pickering (1900a)	various	6300[3]	17	yes	yes	not digitized
Turner (1899)	Knott	6683	23	yes	no	digitized by Paxson
Pickering (1900b)	Argelander	4290	16	yes	yes	digitized by Paxson
Pickering (1900c)	Schonfeld	1535	31	yes	yes	digitized by Paxson
Pickering (1900d)	Schmidt	7070	5	yes	yes	digitized by Paxson
Valentiner (1900)	Schonfeld	37000[3]	118	no	no	not digitized
Hagen (1901)	Hagen et al.	3000[3]	52	no	no	not digitized
Guthnick (1901)[4]	various	6200[3]	1	no	no	not digitized
Wendell and Pickering (1902)	various	4400	58	yes	yes	digitized by Rupp and Fröschlin

[1] See reference list for more information. [2] In AAVSO Archives. [3] Estimated. [4] Observations of Mira only.

Table 1. A selection of variable star observations in the AAVSO Archives and in literature prior to 1911. Data sources in italics have been digitized and are currently in the AID, cont.

Source[1]	Observer(s)	No. Observations	No. Stars	Magnitude Reduced	JD Converted	Status
Hagen (1903)	Heis and Krueger	8500[3]	61	no	yes	not digitized
Pickering (1903)	various	3346	1	yes	no	digitized by Stine
Daniel and Reid (1903–1904)[2]	Daniel and Reid	500[3]	unknown	yes	no	not digitized
Pickering (1904)	Wendell	5000[3]	150	yes	yes	not digitized
Turner (1905)	Peek and Grover	4133	22	yes	yes	not digitized
Backhouse (1905)	Backhouse	2300[3]	49	no	no	not digitized
Campbell and Pickering (1907)	various	8400[3]	75	yes	yes	not digitized
Brook (1908)	Pogson	4210	31	yes	yes	digitized by Paxson
Wendell (1909)	Wendell	6900[3]	44	yes	yes	not digitized
Campbell and Pickering (1912)	various	21,950[2]	328	yes	yes	digitized by Paxson
Blagg, Turner (1912–1924)[5]	Baxendell	6953	30	yes	yes	digitized by Paxson
Fleming and Pickering (1912)	Fleming	20000[3]	107	yes	yes	not digitized
Furness (1913)	various	4800[3]	101	yes	yes	not digitized

[1] *See reference list for more information.* [2] *In AAVSO Archives.* [3] *Estimated.* [4] *Observations of Mira only.* [5] *Includes Turner (1912), Turner and Blagg (1914–1918), and Blagg (1924).*
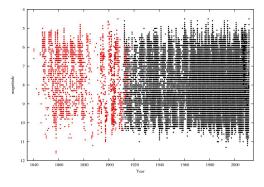
Figure 1. R Leonis observations in the AAVSO International Database. Black dots are data in AID prior to digitization project; red dots are observations digitized by the author to extend the light curve back to 1840.
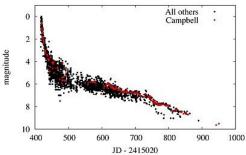

Figure 2. AAVSO light curve of Nova Persei 1901 No. 2 (GK Persei) digitized by Bob Stine from Pickering (1903). Black dots are pre-existing data; red dots are Stine-digitized data added to the AID.

Figure 3. Typical *Harvard Annals* format with JDs, reduced magnitudes, and observer identification (Campbell and Pickering 1912).

Figure 4. Step magnitude data of Schonfeld with calendar dates and times, but with no JD conversion (Valentiner 1900).

Figure 5. An example of decimal step data (in the Comparisons column) and grade data (in Column II) with calendar dates and JDs being given (Hagen 1901).

	A	B	C	D	E	F	G	H	I	J	K	L
1	JD 7	JD 4	Observer	Type	Star	JD	Fainter than	Mag	Comment Codes	Uncertain	Comments	JD check
2	2390000	4970	SEX	V	OMI CET	2394970	0	4.30	na	0	1900AnHar-33-107. Submitted by PKV.	
3	2390000	4971	SEX	V	OMI CET	2394971	0	4.30	na	0	1900AnHar-33-107. Submitted by PKV.	1
4	2390000	4973	SEX	V	OMI CET	2394973	0	4.40	na	0	1900AnHar-33-107. Submitted by PKV.	2
5	2390000	4974	SEX	V	OMI CET	2394974	0	4.40	na	0	1900AnHar-33-107. Submitted by PKV.	1
6	2390000	4975	SEX	V	OMI CET	2394975	0	4.40	na	0	1900AnHar-33-107. Submitted by PKV.	1
7	2390000	4981	SEX	V	OMI CET	2394981	0	3.90	na	0	1900AnHar-33-107. Submitted by PKV.	6
8	2390000	4987	SEX	V	OMI CET	2394987	0	4.20	na	0	1900AnHar-33-107. Submitted by PKV.	6
9	2390000	4990	SEX	V	OMI CET	2394990	0	3.80	na	0	1900AnHar-33-107. Submitted by PKV.	3

Figure 6. The standard spreadsheet template for capturing archival variable star observations. Columns C–K are sent to the AAVSO. Data for observer Julius Schmidt (observer code SEX) are shown.

	A	B	C	D	E	F	G	H	I
1	Comp.	m.	Logic	>	Var.	<	Logic	m.	Comp.
2	v	5.18	0.00		R		0.00	5.18	v
3	n	5.84	5.84	5	R		0.00	5.84	n
4	l	6.48	0.00		R	2	6.48	6.48	l
5	k	6.73	0.00		R		0.00	6.73	k
6	h	6.70	0.00		R		0.00	6.70	h
7	g	7.30	0.00		R		0.00	7.30	g
8	f	7.84	0.00		R		0.00	7.84	f
9	e	8.29	0.00		R		0.00	8.29	e
10	d	8.82	0.00		R		0.00	8.82	d
11	Alp	9.14	0.00		R		0.00	9.14	Alp
12	Bet	9.65	0.00		R		0.00	9.65	Bet
13	Gam	9.54	0.00		R		0.00	9.54	Gam
14			5.84	5.00			2.00	6.48	
15									
16				Estimate	6.30				

Figure 7. A Step Magnitude Calculator. Reduction of the step values "n5R" and "R2l" gives an estimated magnitude of 6.30.

In cell C3 is the equation of =if(D3>0,B3,0). Copy and paste from cells C2 to C13.
In cell G4 is the equation of =if(F4>0, H4,0). Copy and paste from cells G2 to G13.
In cell C14 is the equation of =Sum(C2..C13).
In cell G14 is the equation of =Sum(G2..G13).
In cell E16 is the equation of =D14/(D14+F14)*(G14-C14)+C14.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Year	Month	Day	GMT Hr.	Min.	Sec.	Observer	Type	Star	JD	Fainter than	Mag.	Comment Codes	Uncertain	Comments	JD Check
2	1880	10	23	9	5	0	KGB	V	U CEP	2408011.8785	0	8.10	na	0	MemRAS-52-7. Submitted by PKV.	
3	1880	10	23	10	25	0	KGB	V	U CEP	2408011.9340	0	9.00	na	0	MemRAS-52-7. Submitted by PKV.	0.0556
4	1880	10	23	10	47	0	KGB	V	U CEP	2408011.9493	0	9.05	na	0	MemRAS-52-7. Submitted by PKV.	0.0153
5	1880	10	23	11	7	0	KGB	V	U CEP	2408011.9632	0	9.10	na	0	MemRAS-52-7. Submitted by PKV.	0.0139
6	1880	10	23	11	39	0	KGB	V	U CEP	2408011.9854	0	9.00	na	0	MemRAS-52-7. Submitted by PKV.	0.0222
7	1880	10	23	12	30	0	KGB	V	U CEP	2408012.0208	0	8.95	na	0	MemRAS-52-7. Submitted by PKV.	0.0354
8	1880	10	23	12	44	0	KGB	V	U CEP	2408012.0306	0	8.80	na	0	MemRAS-52-7. Submitted by PKV.	0.0097
9	1880	10	23	13	7	0	KGB	V	U CEP	2408012.0465	0	8.60	na	0	MemRAS-52-7. Submitted by PKV.	0.0160

Figure 8. The spreadsheet template modified for Julian date calculation. See text for calculation equation.
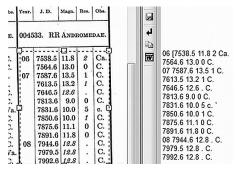

Figure 9. A comparison of RR Andromedae variable star data (Campbell and Pickering 1912) in an image file (left) versus its equivalent OCR converted output (right).