WOMEN IN THE HISTORY OF VARIABLE STAR ASTRONOMY

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Dedicated to the memory of

CLINTON BANKER FORD

1913 - 1992

Without whose generous patronage
the Directors of the AAVSO

Margaret Walton Mayall 1949 to 1973
Janet Akyüz Mattei 1973 to the present

could not have accomplished all they did
to guide the AAVSO into the modern SPACE AGE

CONTENTS

Abstract	1
The Pre-Photographic Years	1
Enter: The Women at Harvard	2
Statistics of Discovery	6
Photometry	13
Interpretation of Light Curves	16
Spectroscopy	24
Birth to Death of Variable Stars	33
The Role of the AAVSO	44
Acknowledgements	55
References	55
Name Index	61

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Abstract

Until the application of dry-plate photography to astronomy very few women were involved in astronomical observations. Then, from the mid 1880s to the mid 1950s, women, especially at Harvard College Observatory, contributed more data on variable stars than did their male counterparts. By 1959 women had discovered over 75% of the 14,708 named variable stars then known. Williamina Fleming discovered spectral peculiarities by which certain types of variables could be recognized; Henrietta Leavitt discovered the period-luminosity relation for Cepheids; and others contributed to the amassing of statistical data on types of variability, periods, and space distributions. In more recent years, especially beginning with Cecilia Payne-Gaposchkin, more emphasis has been put on theoretical studies for interpreting why the stars vary as they do.

1. The Pre-Photographic Years

A. Ribière's "Les Femmes dans la Science" (1897; Davis 1898) included some 600 women of whom about 100 were at least somewhat involved in astronomy. However, very few dealt with variable stars. Prior to the application of dry-plate photography to astronomy only three bear mention. St. Hildegard (1098-1179) claimed divine visions, one of which is intriguing: "As blood moves in the veins and makes them pulsate, so do the stars move and send forth pulsations of light" (Davis 1898). Could this really be an unlikely twelfth century forerunner of the pulsation theory? Mary Somerville (1788-1872) wrote profusely on the astronomy of her time, but she does not seem to have made any observations or contributed any independent theories on variable stars. She did, however, call attention to the discoveries that had already been made (Somerville, 1834). She pointed out one likely deterrent for women to pursue science: "The British laws are adverse to women.... The law in the United States is in some respects even worse, insulting the sex, by granting suffrage to the newly emancipated slaves, and refusing it to the most highly-educated women of the Republic" (Somerville 1876). In the States, Maria Mitchell seems to have been the first woman actually to have made observations of two variable stars, Algol and Mira. Her observations of minima of Algol, December 1853 to October 1856, were published in the *Astronomical Journal* (Mitchell 1856). She observed Mira in 1857 and 1858 (Belserene 1983), but it seems these observations were not made with a view to increasing the knowledge about these stars so much as to test her own abilities. She did not publish these observations and they are not included in E. C. Pickering's compilation of visual observations of variables made through 1887 (Pickering 1890). They are, however, consistent with those of her contemporary, more experienced male astronomers.

2. Enter: The Women at Harvard

For well over three centuries Harvard University had adamantly refused to admit women either as students or employees other than clerical or domestic. But in the 1880s Professor E. C. Pickering (1846-1919), Director of the Harvard College Observatory, felt the need for cheap but intelligent and dedicated people to examine the hundreds upon hundreds of spectrum and chart plates he was acquiring under the Henry Draper Memorial (Hoffleit 1991). Believing that men might soon tire of the tremendous amount of routine work that would be involved, he turned to women, anticipating that they would have the patience and perseverance to stick with the jobs. Women more than lived up to his expectations, making discoveries of major importance.

Williamina P. Fleming (1857-1911) was employed in 1881 to aid in the work of stellar spectral classification. She noted numerous peculiar spectra that would not fit into the regular sequence. Some of these belonged to variable stars, and thus she established the fact that Mira type variables and novae could be discovered by means of but a single spectrogram. By 1890 she had discovered seven Mira-type stars and one nova by means of their spectra. Ultimately she discovered over 300 variables and ten novae, one of which, Z Cen in the galaxy NGC 5253, was many years later found to be a supernova. (In her day no distinction could be made between novae and supernovae, as nothing was as yet known about the absolute magnitudes of any variables.)

In 1888 Antonia Maury (1866-1952), niece of Henry Draper, was engaged to classify the spectra of the naked-eye stars of the northern hemisphere. She set up an independent system of her own, including more criteria than were being used by Pickering and Mrs. Fleming. In particular, she introduced notations for describing the relative sharpness of spectral lines. Her c-characteristic, indicating the spectra with the sharpest lines, proved valuable for differentiating the highest luminosity stars from the run-of-the-mill. Of the 17 stars she designated as c-stars, ten are now recognized as variable or suspected variables. From the doubling of lines in the spectrum Miss Maury discovered the second spectroscopic binary, βAurigae in 1889, a short time after Pickering discovered the first, ζUrsae Majoris.

Spectroscopic binaries thereafter became her chief interest. She was the first to determine orbits for the spectroscopic binaries βAurigae, μ^1 Scorpii (the third SB to be discovered, by Solon Bailey at Harvard), and V Puppis. All three of these turned out also to be eclipsing binaries, the first an Algol type, the others βLyrae type. Her favorite star became βLyrae (discovered as a variable star by Goodricke in 1784) whose spectral variations she monitored throughout most of her life. She attempted in vain (as did her successors) to interpret the complex spectral changes and correlate them with photometric variability. She was the most original thinker of all the women Pickering employed; but instead of encouraging her attempts at interpreting observations, he was only irritated by her independence and departure from assigned and expected routine.

Annie Jump Cannon (1863-1941) came to the observatory in 1896 where her primary function was spectral classification. In the course of this work she, like Mrs. Fleming, discovered several hundred variable stars. In addition, she was intensely interested in variable stars and observed them both visually and photographically. Moreover, she kept up-to-date a bibliographical card catalogue that had been started by W. M. Reed between 1897 and 1900. He had compiled about 15,000 references of all published observations of variables (Pickering 1903). From 1900 until 1940 Miss Cannon brought the number to about 150,000. This card catalogue proved immensely useful, especially to anyone discovering variables to make sure they had not been previously discovered elsewhere, and to correlate the Harvard estimates of brightness with those determined elsewhere. This card catalogue antedated the *Geschichte und Literatur des Lichtwechsels* (G.u.L.)(Muller und Hartwig 1918), and was continued throughout her life-time, sometimes including references overlooked in the G.u.L.

Most famous for her accomplishments in the field of variable stars was Henrietta Leavitt (1868-1921) whom Pickering employed in 1902. One of her chief tasks was the discovery of variable stars in the Magellanic Clouds and the determination of their periods of variation. The vast majority of the variables in the Clouds proved to be of the δCepheid type. On the basis of the first 25 periods she determined in the Small Magellanic Cloud she discovered a period-luminosity relation (Pickering 1912), the longer periods corresponding to the brighter variables (Figure 1). As the depth of the Cloud is small in comparison with its distance, this implied an intrinsic relation. She did not have the means for calibrating the apparent to absolute magnitudes, a difficult task performed later by others. But the significance of the apparent relation, also soon confirmed for the Large Magellanic Cloud, was quickly apparent, namely that once the relation could be calibrated to absolute magnitudes, then the distance to any Cepheid could be ascertained from a comparison of its

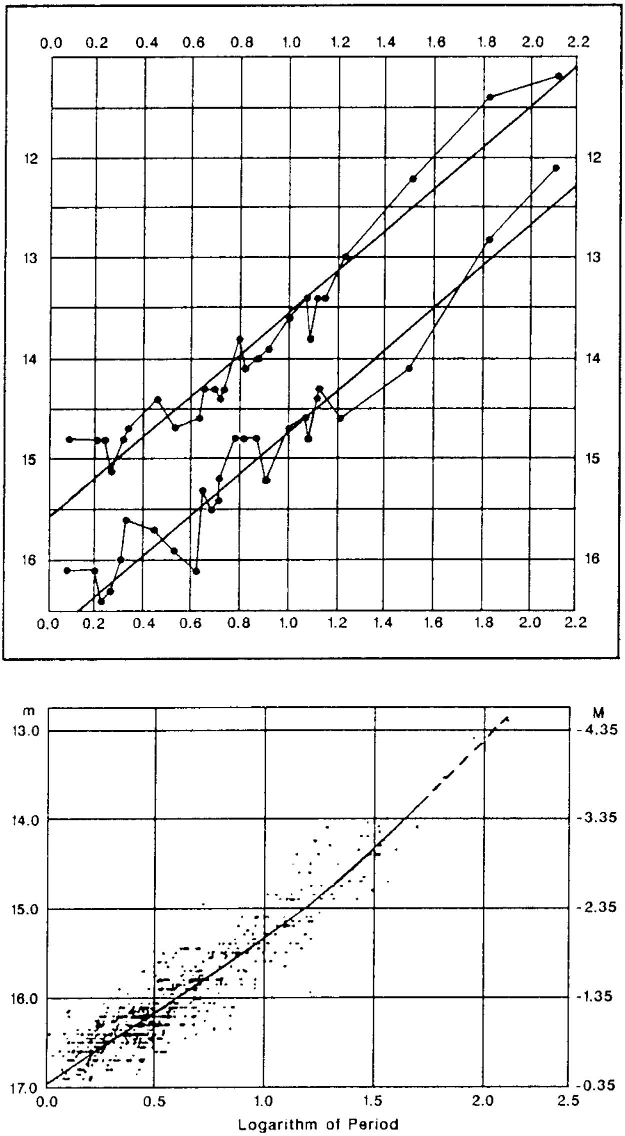

Figure 1. Upper diagram: Henrietta Leavitt's original 1912 period-luminosity curves for the *Small Magellanic Cloud,* for maximum and for minimum light (Pickering 1912).

Lower graph: the period-luminosity relation for mean magnitude, about 1946. From *Harvard College Observatory: The First Century,* p. 58, Cambridge, 1946.

apparent with the absolute magnitude. (The problems with interstellar absorption were not yet understood, nor their importance even anticipated.) By an intercomparison of chart plates Miss Leavitt discovered some 2400 variables, mainly in the Magellanic Clouds.

In 1930 Harlow Shapley published his *Star Clusters,* in the preface of which he gave credit to graduate student Helen Sawyer for investigations of magnitudes in clusters. In 1927 Miss Sawyer attended a meeting of the American Astronomical Society where she was shocked (Sawyer Hogg 1973a) to hear Jan Schilt state that he was tired of hearing astronomers talk about the period-luminosity relation in globular clusters; there were too few known Cepheids in the clusters for any such relation to have any real meaning. This inspired Helen to examine the existing literature, from which she had to agree that Schilt was right. She then examined the vast collection of Harvard plates on clusters, and thus became launched upon her life-long career. Since 1939 at the David Dunlap Observatory, Mrs. Helen Sawyer Hogg (1905-1993) contributed innumerable papers on globular clusters including three editions of a catalogue of variables in globular clusters; the third in 1973 (Sawyer Hogg 1973b) contained well over two thousand variables, many discovered by herself, with periods for 1313.

Table 1. Variables Other than Novae Discovered before 1800

Year	*Name*	*Type*	*Max.*	*Min.*	*Discoverer*
1596	Mira	M	2.0	10.1	D. Fabricius
1667	Algol	EA	2.1	3.4	G. Montanari
1670	R Hya	M	3.5	10.9	Suspected by Montanari [1]
1676	X Sgr	δCep	4.8	5.8	Suspected by E. Halley [2]
1686	χCyg	M	3.3	14.2	O. Kirch
1780	R Leo	M	4.4	11.3	J. A. Koch
1784	βLyr	EB	3.2	4.4	J. Goodricke
1784	δCep	δCep	3.5	4.4	J. Goodricke
1784	ηAql	δCep	3.5	4.4	E. Pigott [3]
1787	44i Boo	EW	5.8	6.4	W. Herschel
1795	αHer	SRc	2.7	4.0	W. Herschel
1795	RCrB	RCrB	5.7	14.8	E. Pigott
1795	R Sct	RVa	5.9	7.9	E. Pigott

[1] Rediscovered by G. P. Maraldi, 1704
[2] Rediscovered by J. Schmidt, 1866
[3] Possibly already discovered by J. Byrgius, 1612

3. Statistics of Discovery

Before the investigations initiated at Harvard by Pickering, variable stars were considered rare phenomena. The majority of those discovered visually were novae. Figure 2 shows the progress of discoveries from 1600 to 1982. By 1800 only 13 variables (Table 1) other than novae had been detected, in contrast with 137 novae (Table 2).

Of the novae, before 1880 none were discovered by women; between 1880 and 1934, 36 by women, 33 by men. Table 3 summarizes the rapid proliferation of discoveries of all types of variables in contrast to a factor of only four for novae between 1600 and the present. Under the supervision first of Pickering until 1919, then until 1953 by his successor Harlow Shapley (1885-1972), the tremendous increase in numbers of variables was primarily due to women employed for this purpose.

Table 2. Discovery of Novae

Year	*Number*	*Total T*	*Log T*
2296 BC	1	1	0
2241	1	2	0.30
1400	1	3	0.48
600 -0 BC	9	12	1.08
AD 0 -1000	61	73	1.86
1000 -1500	43	116	2.06
-1550	1	117	2.07
-1600	4	121	2.08
-1650	7	128	2.11
-1700	8	136	2.13
-1750	0	136	2.13
-1800	1	137	2.14
-1850	2	139	2.14
-1875	4	143	2.16
-1900	18	161	2.21
-1925	42	203	2.31
-1950	64	267	2.43
-1975	73	340	2.53

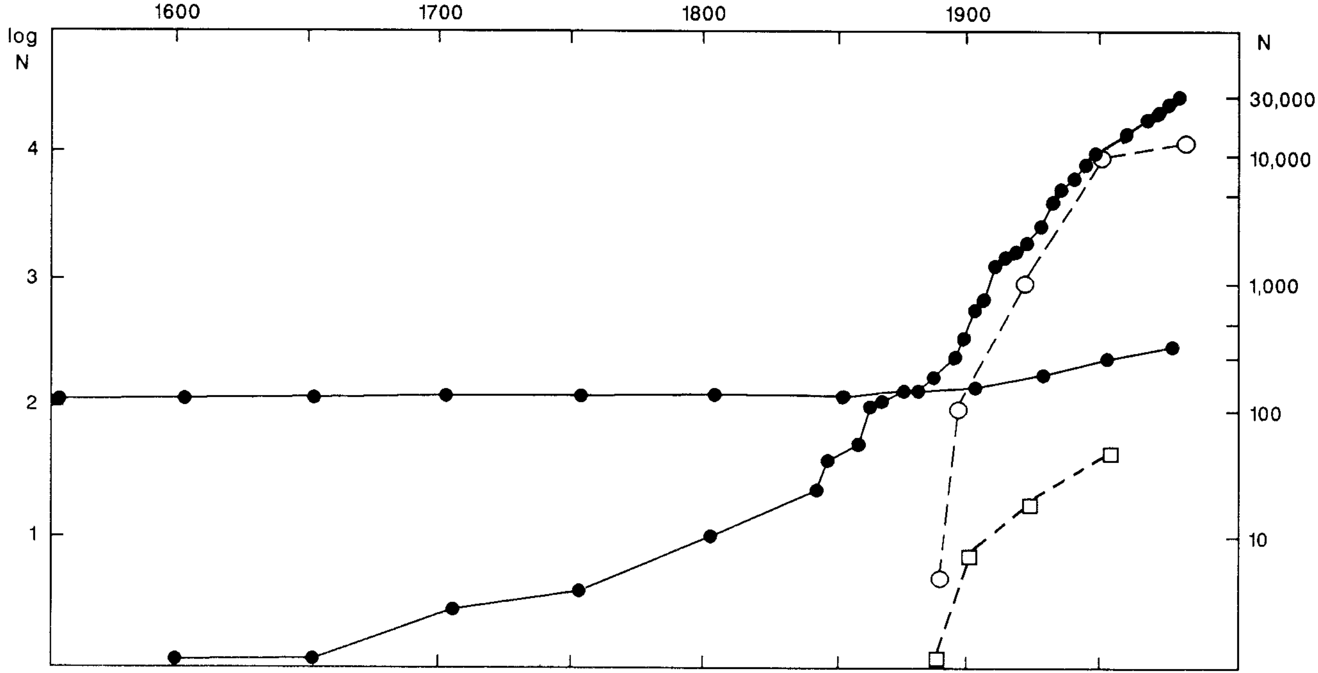

Figure 2. The proliferation of discoveries. Nearly horizontal curve for novae; other dots for all other variables. Open circles the variables, and open squares the novae discovered by women astronomers.

Table 3. Numbers of Known Variables

Year	*Var*	*Novae*	*SN*	*Pulsars*
1600	1	121		
1700	5	136		
1800	13	137	5-10	
1880	200	146		
1900	1000	161		
1950	11000	267		
1982	28450	467	400	300

Several techniques were available for making discoveries, as outlined in Table 4. Pure chance accounted for all the discoveries prior to 1880. A. Safarik (1829-1902) in the 1880s noted that several red stars were variable and proceeded to examine other red stars for variability, discovering several new variables. The method used at Harvard for the vast majority of its discoveries was called the positive-negative method. A negative was placed over a slightly enlarged positive of a plate taken at a different time. Variables stood out as having either too large or too small a white halo surrounding a black negative image (Figure 3). Stereocomparators and especially blink microscopes (Figure 4) were widely used at other institutions, and to a lesser extent at Harvard.

In 1903 and 1907 Annie J. Cannon compiled two catalogues of all the then known variables and indicated the discoverers. The 1903 catalogue contained 1227 entries of which 200 or 16% had been discovered by women; the 1907 edition contained 1957 of which 504 or 26% had been found by women. The first catalogue of the *Geschichte und Literature des Lichtwechsels,* published in 1922, also indicated the discoverers. Among its 2054 entries, 56% were attributed to women. Of the 12,500 variables discovered at Harvard between 1886 and 1956, 80% had been found by women. Hence this proved to be a field for women, but primarily at Harvard. Table 5 lists the Harvard women who discovered in excess of 1000 variables, and women elsewhere who discovered more than 100. Outside Harvard, only Russian women are represented. In 1988 Vera Rubin presented a paper on Soviet lady astronomers at the Baltimore meeting of the IAU. This was based on a compilation of names by Alla Massevitch and A. K. Terentjeva (1988). Of the 43 women mentioned eleven had worked on some aspect of variable stars.

Table 4. Discovery Techniques

1. Pure Chance
2. Systematic Visual Search:
   e.g., Safarik in 1880-1888 examined red stars for variability.
3. Photographic Searches:
   a. Looking back and forth between plates
   b. Superposition of plates
   c. Multiple exposures for finding short period variables
   d. Positive-Negative method
      Preferred at Harvard
   e. Stereocomparators
      i. Left eye on one plate, right on other
      ii. Optical paths merged: both eyes see the two plates superposed.
   f. Blink comparator
      Pulfrich 1902; others
4. Spectroscopic
   a. Pickering 1881 looked for peculiar spectra with a direct vision spectroscope.
   b. Fleming inspection of photographic spectrograms:
      1887 discovered red variables
      1893 discovered novae

Table 5. Women Who Discovered the Most Variables

1. At Harvard College Observatory, Over 1000:

	Approx.
H. Leavitt	2400
H. Swope	2000
D. Hoffleit	1270
E. H. Boyce	1180

2. At Other Observatories, Over 100:

L. Ceraski	180	Moscow
P. Shajn	150	Simeas
E. Parsamian	> 200	Byurakan

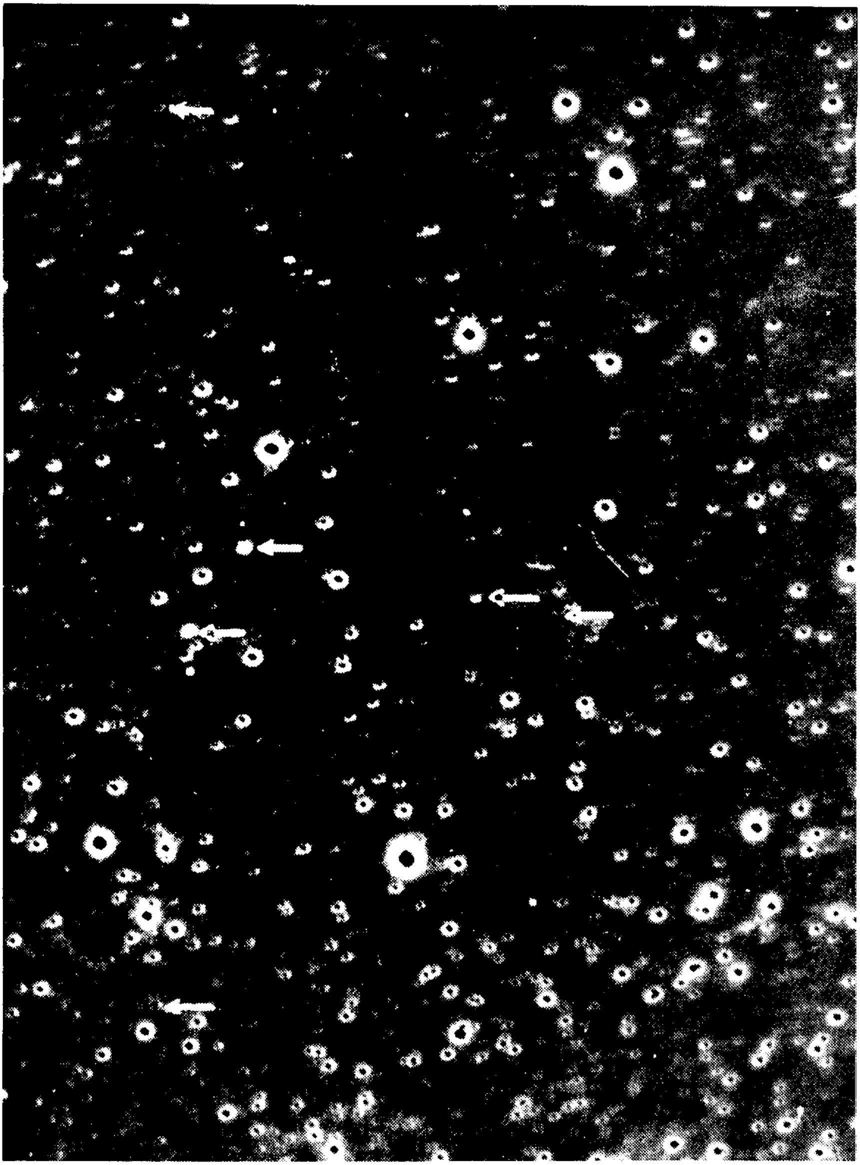

Figure 3. Discovery of variables by superposition of negatives on positives. From Campbell and Jacchia, *The Story of Variable Stars*, p. 7, Philadelphia, 1941.

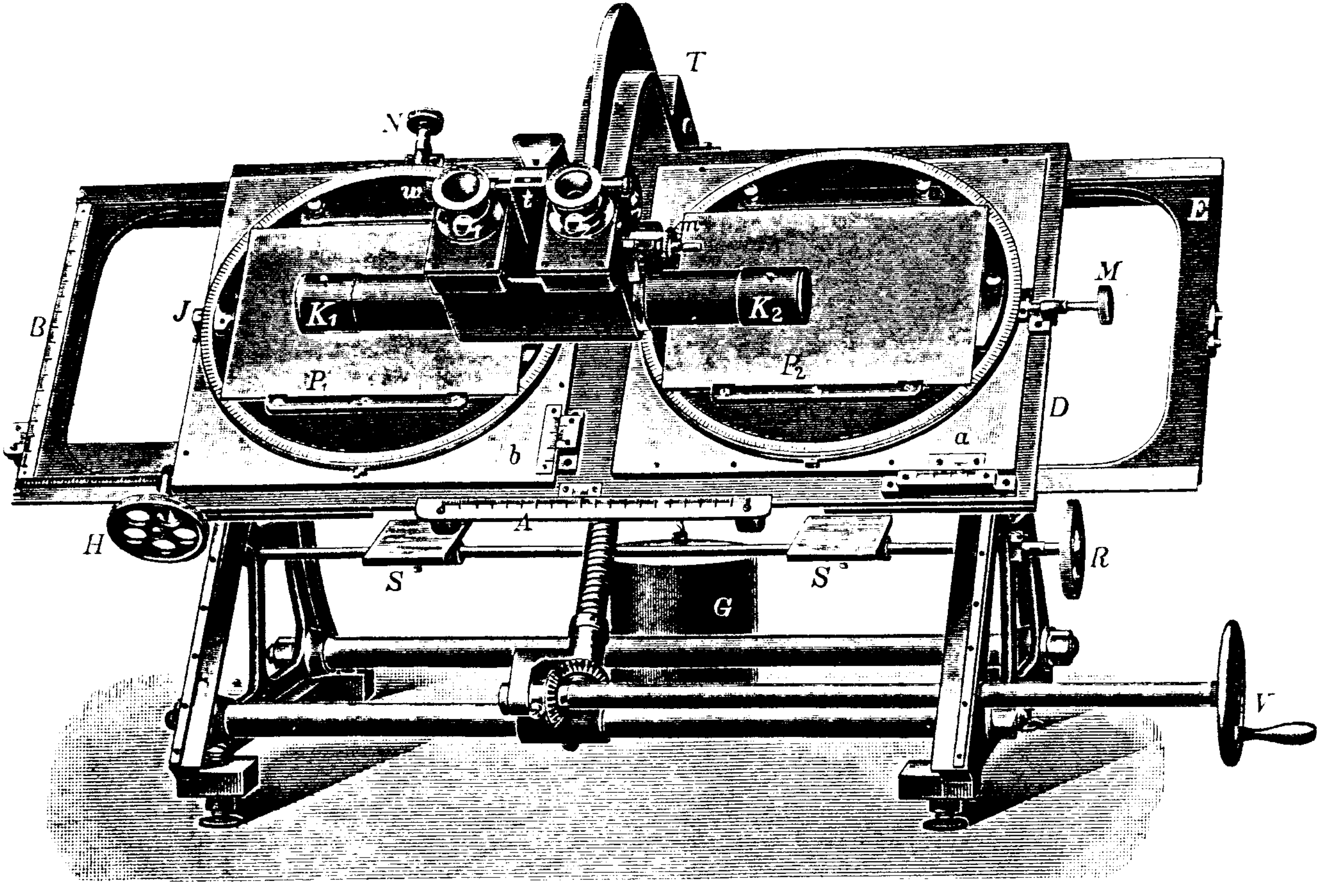

Figure 4. An early model of a stereocomparator. From *Zeitschrift für Instrumentenkunde,* 22, p. 76, 1902.

In an *Index of Observations of Variable Stars* covering visual observations from 1840 through 1887, Pickering (1889) cited the different observers. None of the visual observers were women, but Table 6 shows that there were interested male variable star observers in countries besides Russia and the United States. After 1880, women in numerous countries entered the fields of variable star discovery and research. The *Jahresbericht* between 1930 and 1968 annually listed the names of those who had contributed observations or computations on the variable stars cited in the references. A sampling of five years indicates approximately one out of every twelve contributors was a woman. P. Stroobant (1907, 1931) and F. Rigaux (1959) had compiled directories of observatories and their personnel, upon which Table 7 is based. Through the mid-1930s most of women's work on variables was carried out at Harvard. Of the women listed in the 1959 observatory directory, nearly half of those recognized as working on variable stars were American - nine out of twenty. Of these nine only three were from Harvard. The other countries were represented by just one or two variable star astronomers each. Clearly, at Harvard after the retirement of Harlow Shapley in 1952, the search for variable stars was no longer considered a priority field for either men or women. By 1956 a total of 14,700 variables were contained in the *General Catalogue of Variable Stars* (GCVS). Of these about 10,000 or 68% had been discovered by Harvard women. By the time of the most recent GCVS, 1987, the women had been obliged to go into other work, so their total number of discoveries did not increase perceptibly, whereas men at other institutions, especially in Holland, increased their efforts. Now, of the 28,400 catalogued variables, those found by Harvard women amount to only 35%, mainly their pre-1935 discoveries.

Table 6. Visual observers 1840-1887 (All Male)

Argentina	5	Austria	1	Canada	1
England	7	Germany	5	Greece	1
Holland	1	Ireland	2	Russia	1
Sweden	1	U.S.A.	12		

Not included in the above statistics are pulsars. The first was discovered by radio techniques in 1967 by Jocelyn Bell, a graduate student at Cambridge University, England. She found three more, and by now others have discovered about 450.

Table 7. Women Who Worked on Some Aspect of Variable Star Astronomy

Year	*Countries*	*All Women Astronomers*	*In Var.*	*HCO*
1907	9	56	18	14
1931	12	134	25	19
1959	24	124	20	3

4. Photometry

Pickering in 1880 proposed classifying variable stars into five groups as shown in Table 8. This is the system adopted by Miss Cannon in her general catalogues of variable stars in 1903 and 1907. Besides ordinary long period variables, Group II included stars now known as dwarf novae, SS Cygni, U Geminorum and the Orion type star, T Tauri. Class IV included not only Cepheids and RR Lyrae stars but also βLyrae stars, probably because they changed brightness continuously, unlike the Algol type.

Table 8. The Pickering System of Classification of Variable Stars

I.	Novae
II.	Variables of Long Period
III.	Small Range or Irregular
IV.	Variables of Short Period
V.	Algol Type

For determining light curves and types of variation, standards of magnitudes had to be determined. For visual work Argelander (1799-1875) had advocated estimating on an arbitrary scale the number of steps between a comparison star brighter than the variable and the number between the variable and a fainter comparison star. A step corresponded approximately to the minimum difference that an observer could readily distinguish, about 0.2 magnitude. Ptolemy (2nd century A.D.), in the first catalogue of the bright stars, had assigned magnitudes from first to sixth. Later it was found that a difference of five magnitudes corresponded to a factor of approximately 100 in brightness, and Pogson in 1850 defined this scale mathematically, a difference in magnitude $\Delta m = 2.5119 \log(I_2/I_1)$, where I indicates intensity of light. Subsequently various photometers were designed to measure the intensities as accurately as possible, starting with the Zöllner photometer in 1860. Pickering, between 1877 and 1885, devised several photometers with which visual stellar magnitudes were determined.

With the introduction of photography somewhat more sophisticated procedures were in order. Mrs. Fleming set up magnitude sequences for each of the 222 long period variables she had discovered on the basis of their spectra. Then Pickering advocated the determination of magnitude sequences in 48 Harvard Standard Regions uniformly distributed over the globe. Mrs. Fleming (1917) selected the sequence stars and determined their spectral classes as well as their magnitudes. These magnitudes were later revised by Miss Leavitt (1917b).

The most important work on standards of magnitudes was proposed by J. C. Kapteyn (1851-1922) in 1906, the Plan of Selected Areas (Kapteyn 1906). He envisioned getting as many types of information as possible for the stars in 206 areas (ranging from 40'x40' to 80'x80', depending on galactic latitude) distributed uniformly over the sky. Harvard Observatory assumed responsibility for determining magnitude sequences in each of the regions. Then Harvard personnel determined the magnitudes of all the measurable stars in each region by interpolation within the sequences. Henrietta Leavitt was in charge of the sequence determinations. Most importantly, she was in charge of the North Polar Sequence, against which all the other sequences would be calibrated either directly or, for the southern regions, by secondary standards for the southern regions in fields available to both northern and southern observers. The North Polar Sequence was completed in 1917 for 96 stars ranging from photographic magnitude 2.69 to 21.14 (Leavitt 1917a). The sequences for the Selected Areas, most reaching to magnitude 15pg, were published between 1917 and 1924 (Pickering *et al.* 1917-24). Later Mount Wilson astronomers measured the magnitudes in all the northern Selected Areas, using plates taken with the 60-inch reflector, giving magnitudes ranging to better than 18pg. They also determined small systematic corrections to the Harvard sequences (Sears *et al.* 1930). The indefatigable Miss Leavitt (1919, 1924, 1930) also determined the magnitudes for 204 Astrographic Zones. In all she supplied 369 sequences, most reaching 15th magnitude, which were so essential for variable star as well as for other investigations. Table 9 indicates the Harvard women who published in all about 900 sequences, a total unmatched by men.

Cecilia Payne-Gaposchkin in 1937 felt that for statistical purposes not enough stars had been examined on a sufficiently homogeneous system. She proposed (what became known as the Milton Bureau, named after the funding organization) that all the known variable

Table 9. Harvard Women - Authors of Sequences

	Ref.		*No.*
W. P. Fleming	1	For Variables with Md Spectra	222
	2	Harvard Standard Regions	49
H. S. Leavitt	3	North Polar Sequence	1
	4	Harvard Standard Regions (revised)	49
	5	Selected Areas	115
	6-8	Astrographic Zones	204
A. D. Walker	9	Sequences for 13 Novae	13
C. H. Payne	10	Pg and Pv for Harvard Standard Regions	49
F. W. Wright and C. H. Payne	11	In Taurus	54
F. W. Wright	12	Ten Eclipsing variables	10
	13	Atlas Stellar Variabilium	42
	14-15	Eclipsing Stars	69
C. Payne-Gaposchkin	16	Red mag. for Harvard Stand. Reg.	12
	17	RV TAU Variables	14
		Miscellaneous var. and novae	Many
V. McKibben	18	Small Magellanic Cloud	15
Total			>870

1. *Ann. Harvard Obs.*, **47**, 1, 1907.
2. *Ann. Harvard Obs.*, **71**, 27, 1917.
3. *Ann. Harvard Obs.*, **71**, 47, 1917.
4. *Ann. Harvard Obs.*, **71**, 233, 1917.
5. *Ann. Harvard Obs.*, **101**, i, viii, 1917.
6. *Ann. Harvard Obs.*, **85**, 1, 1919.
7. *Ann. Harvard Obs.*, **85**, 143, 1924.
8. *Ann. Harvard Obs.*, **85**, 157, 1930.
9. *Ann. Harvard Obs.*, **84**, 189, 1923.
10. *Ann. Harvard Obs.*, **89**, 1, 1931.
11. *Ann. Harvard Obs.*, **89**, 81, 1933.
12. *Harvard Bull.*, No. 891, 10, 1933.
13. *Harvard Bull.*, No. 892, 22, 1933
14. *Ann. Harvard Obs.*, **89**, 171, 1937.
15. *Ann. Harvard Obs.*, **89**, 201, 1940.
16. *Ann. Harvard Obs.*, **89**, 123, 1937.
17. *Ann. Harvard Obs.*, **108**, 13, 1940.
18. *Ann. Harvard Obs.*, **113**, 1, 1943.

stars with amplitudes over 0.25pg and brighter than 10.0pg at maximum be observed on the extensive series of Harvard patrol plates, all reduced as accurately as possible to the same magnitude system. This huge project was completed in 1952, involving over two million observations on 2017 variables, an average of 100 estimates per star (Payne-Gaposchkin and Gaposchkin 1952).

During Harlow Shapley's directorship at the Harvard College Observatory, he pursued the study of the variables in the Magellanic Clouds, with the assistance of numerous women, especially Mrs. Virginia McKibben Nail. When Shapley retired, Mrs. Gaposchkin appropriated all the Harvard work on the Magellanic Clouds, and with her husband, Sergei Gaposchkin, determined new periods and revised previous determinations. This massive work could be accomplished more expeditiously than under Shapley as modern computing facilities became available. They compiled periods and published the light curves of 2148 variables in the Large Cloud and 1612 in the Small (Gaposchkin 1972; Payne-Gaposchkin 1971; Payne-Gaposchkin and Gaposchkin 1966a). Meanwhile Paul W. Hodge and Frances W. Wright (1967, 1977) had carried out the stupendous task of identifying all the variables, most of them previously identified only by somewhat crude x,y coordinates on the Harvard plates, identifications that indeed became dubious as more and more variables were discovered in crowded regions. For the Large Magellanic Cloud Hodge and Wright (1967) published about 80 charts 1.25° square, in both blue and yellow; and for the Small Cloud, similar charts for about 100 fields, 1.33° square (Hodge and Wright 1977).

The bulk of the accomplishments of women in variable star photometry has been photographic. They have contributed relatively little, in comparison with the men, in the more modern fields of photoelectric photometry and TV applications. An outstanding exception has been the Crimean astronomer, Valentina Prokofyeva (1929-), who in the 1950s designed and built an IR photometer and since 1961 has been engaged in the calibration and photometric processing of TV images of stars. In 1966 she began regular TV observations of variable stars, and with co-workers at the Crimean Astrophysical Observatory could observe 16-17th magnitude stars to an accuracy of $\pm$0.10 to $\pm$0.15m (Prokofyeva 1970). The equipment was advantageous for the discovery of faint novae and supernovae which could be detected close to very bright stars (Abramenko and Prokofyeva 1967).

5. Interpretation of Light Curves

Once light curves have been determined for variable stars, the next step is to explain why they vary. Two theories were prevalent in the nineteenth century, but some astronomers went to great effort to explain all the types of light curves as due to the same cause, either star spots, analogous to sunspots, or as eclipsing binary systems. For example, the Loomises at Yale attempted to find a common interpretation of the light curves of such diverse stars as Algol, Mira, and ηCarinae (Hoffleit 1984), favoring the star spot hypothesis. The British Agnes Clerke (1842-1907) did not observe variables nor enunciate new theories for them. However, between 1885 and 1905 she wrote several treatises (Clerke, 1885-1905) in which she gave insightful comments on the work of others, pointing out the problems that needed to be solved. By the turn of the twentieth century the following seven hypotheses had been offered to account for stellar variation: the sunspot analogy, binary stars, stellar collisions, meteor impacts, involvement in nebulosities, passage through cosmic clouds, and tidal disruptions. None of these seemed acceptable for all of the types of light curves observed. Except for the binary interpretation of Algol type variables, Miss Clerke found no theory for intrinsic variables to be satisfactory; for U Geminorum, in particular, she concluded, "Nothing is certain except uncertainty" (Clerke 1903, 366).

In passing, one may recall Sir Norman Lockyer's (1890) meteoritic hypothesis according to which stars are formed by the collision of swarms of meteors. While Shapley and Payne (1928) in a much later article do not comment on Lockyer's text, they do present spectroscopic evidence of the impact of meteors on stars. Starting with statistical evidence of the impact of meteorites on the Earth, they estimated the quantity that must fall on the sun. They then examined the spectra of early type stars for possible evidence of meteorite infall. In particular they found wide cyanogen bands not characteristic of early type spectra, and Doppler shifts differing from normal stellar radial velocity, indicating high velocities of impact.

A pulsation theory had been proposed by G. August D. Ritter (1826-1908) as early as 1878, but this seems to have been discredited or overlooked until Harlow Shapley (1914), dissatisfied with the then current theory that Cepheid variables were binary systems, independently suggested the pulsation theory in 1914; and Eddington put it on a sound mathematical basis in 1918 and 1926 (Eddington 1919, 1926). Helena Kluyver (1935-41) adopted higher order terms for better agreement between theory and observation.

The Cepheid variables formed the basis of a Berlin Ph.D. dissertation by Margarete Güssow (1896-19..?) (Güssow 1924). She compiled a list of all known Cepheids with periods under 50 days: 174 variables, including those of RR Lyrae type, which had been assumed to be the shortest period Cepheids. On the basis of Shapley's calibration of the period-luminosity relation, she found that these stars could be divided into two well defined groups: those with periods under a day, and those over a day. Table 10 shows in what respects Güssow found that the two groups we now call δCepheids (Population I) and RR Lyrae stars (Population II) differ. Of 40 well observed stars, twelve (most of them RR Lyrae type) had changing periods.

Table 10. Güssow's Two Groups of Cepheids

Group	*Amp.* *m*	*(M-m)/P*	*Sp.*	*RV k/s*	*P.M.* "
δCep	0.75	Steep	F - K5	12.2 ± 1.8	< .04
RR Lyr	0.95	Steeper	B - F5	113. ± 35.	> .10

One star that Güssow found to have properties deviating from the other Cepheids was the 17 day W Virginis, much later identified as the type star for Population II Cepheids. It was not until about two decades after Güssow's thesis that it was discovered that stars, that in their broader features appear alike, differ in some respects, depending on whether they belong to the spiral arms (Population I) or the halo (Population II) of the galaxy. A few stars, like W Virginis, had baffled astronomers. In 1922 six stars now known to be of the W Virginis type had already been discovered (Müller u. Hartwig, 1922), but periods had been determined for just two, W Vir, 17.27^d, and SW Tau, 1.584^d. (Güssow did not specifically mention SW Tau.) On the basis of their periods, the light curves of W Virginis stars do not resemble the typical δCephei variables. After the discovery of Populations I and II (Baade 1944), and the differences between the stars in the two groups, the mystery was finally solved. After World War II, Walter Baade (1893-1960) hired Henrietta Swope, previously the most successful discoverer of variable stars at Harvard, to come to Mount Wilson to work on the variables he had discovered, first in the Andromeda nebula (Baade and Swope 1955, 1963, 1965) and then in several dwarf galaxies (Baade and Swope 1961; Swope 1968). In Andromeda the variables of the two populations could readily be distinguished; the dwarf galaxies showed only Population II variables. Baade and Swope succeeded in determining two period-luminosity relations in the Andromeda galaxy (Figure 5), finally proving that the W Virginis type, period for period, average over two magnitudes fainter than the classical Cepheids.

Güssow's list of Cepheids included only two stars with periods between 0.7 and 1.5 days. The periods of both eventually turned out to have been spurious and have been revised: for UZ Cas, from 0.81 to 4.26; for R Mus, from 0.88 to 7.51 days. This seemed to indicate a

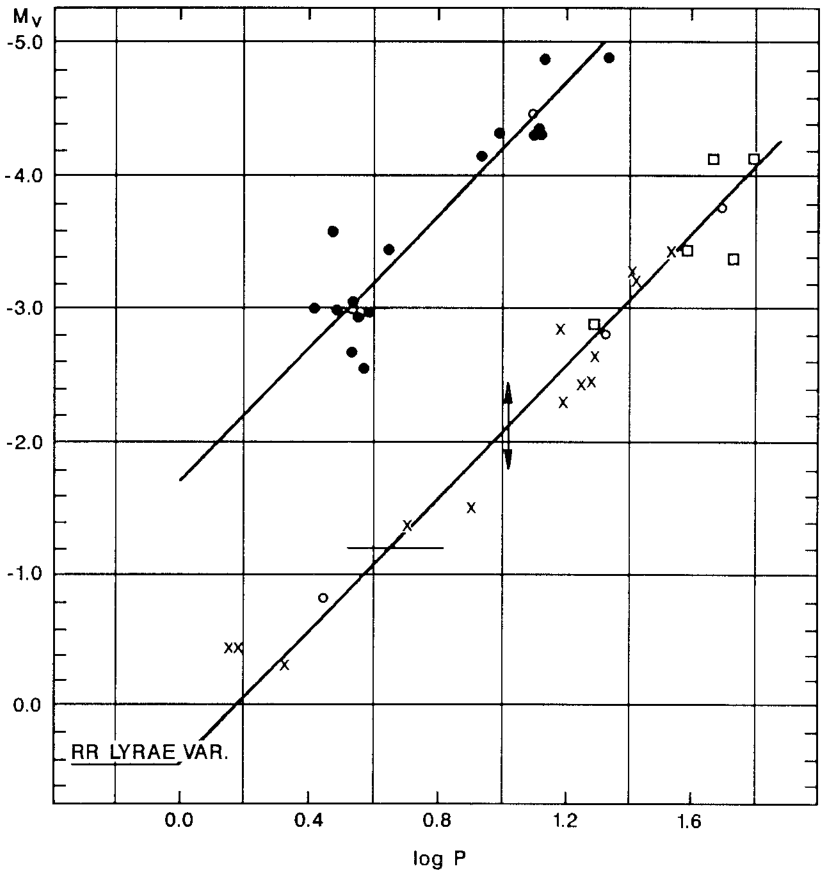

Figure 5. Period-luminosity relations in Andromeda galaxy for Population I, upper plot, and Population II, lower plot (Baade and Swope, *Astron. J.*, 68, p. 453, 1963).

zone of avoidance of periods in this interval. However, significant advances in regard to the faint extensions of period-luminosity relations came about from the investigations of the Magellanic Clouds at Harvard. In 1964 the Gaposchkins (Payne-Gaposchkin and Gaposchkin 1966b) pointed out (Figure 6) that four selected variables in the Small Magellanic Cloud (SMC) with periods between one and four days and sinusoidal light curves were about half a magnitude brighter than the normal Cepheids of the same period but which show asymmetric light curves. In a more extensive analysis of all the known and newly discovered variables in the SMC, Payne-Gaposchkin and Gaposchkin (1966a, p. 167) extended the period-luminosity relations to stars with periods down to a third of a day, but with appreciable magnitude scattering. They also found three W Virginis type stars in the SMC. Then in 1971 Dessy and Laborde (1971) discovered many 17-18 magnitude variables in the SMC with periods 0.2 to 1.5 days; and recently Horace Smith and collaborators (Smith *et al.* 1992) examined a 1.3 square degree area in the SMC, and found 133 new variables with magnitudes down to fainter than 20.0B, revealing at least 35 with periods between 0.7 and 1.5 days. These stars definitely lie on an extension of the Population I period-luminosity relation and are not the ordinary Population II RR Lyrae stars. The relation splits into two well defined branch sequences for stars with periods under six days. The two branches, substantiating Payne-Gaposchkin's discovery of over 25 years ago, are separated by less than a magnitude. Smith points out that the stars in the fainter sequence are pulsating in the fundamental mode while those in the brighter, do so in the first overtone mode.

Meanwhile, in 1968, Henrietta Swope pointed out several variables in dwarf galaxies with periods 0.9 to 1.5 days, and commented that they appeared to lie between the period-luminosity relations for Populations I and II. More work for faint variables in other galaxies is needed, especially in Andromeda, as well as in dwarf galaxies, to establish whether or not Population II RR Lyrae stars can also be divided into two separate sequences, as well as to substantiate Miss Swope's inference that the dwarf galaxies do show stars between the more numerous normal Population I and II sequences.

Güssow had concluded her thesis stating that 170 stars were sufficient for statistical purposes, believing that there was "No need to look for more variables." Rather, she advocated getting better data on those already discovered. The need for better data remains indisputable. However, had Dr. Shapley and others abided by Güssow's decision and abandoned their searches for more variables, not only would much of our knowledge about the differences between variables of different Populations have been long delayed, but some new and peculiar types of variables, for example those listed in Table

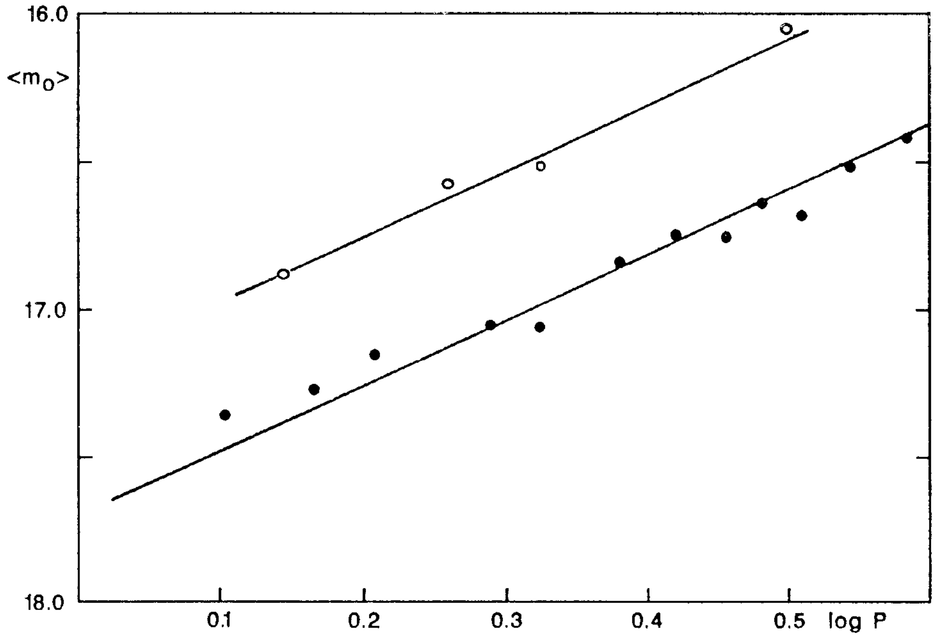

Figure 6. Period-luminosity relations in the Small Magellanic Cloud for Cepheids with periods under four days. Lower plot for stars with sharp rises to maximum and comparatively large amplitudes, compared with the upper plot for stars with smaller amplitudes and nearly sinuous light curves. Reprinted from *Vistas in Astronomy,* 8, Payne-Gaposchkin and Gaposchkin, "Relation of Light Curve to Period for Cepheids in the Small Magellanic Cloud," p. 194, 1966, with permission from Pergamon Press Ltd., Headington Hill Hall, Oxford.

11, having amplitudes sufficiently great to have been found photographically, might never have been discovered.

From 1928 through the 1930s Frida Palmer at the Lund Observatory contributed significantly to the understanding of variables with late type spectra, particularly those that had been designated as irregular. She began with the determination of positions, using a Repsold meridian circle, for the ultimate purpose of determining proper motions by comparisons of her new positions with older catalogues (Palmer 1931). From Prager's catalogue of variable stars for 1930 she compiled a list of 259 stars whose variations showed no regular periodicity. She examined their galactic distribution and array of spectral types. The spectra of the majority differed from those of the Mira types mainly by the general absence of the emission lines that are characteristic of the Mira stars. From the determination of the proper motions she planned to determine the absolute magnitudes of the irregular variables. Her 1931 paper was an abstract of what she planned for her Ph.D. thesis.

Table 11. Rare Types of Variables

Type	*Discovery of Type Star*	*Numbers 1922*	*1990*	*Amp*	*Sp.*	*Rem.*
FU Ori	1939	0	3	to 6^m	Ae - Gpe	1
S Dor	1924(Sp)	3	15	1 - 7	B - Fpec	2
SX Phe	1952	1	15	to 0.7	A2 - F5	3

1. Slow, irregular; nebulosity
2. Eruptive; nebulosity. ηCarinae, P Cygni.
3. Periods 1 to 1.5 hours.

Completed in 1939, her thesis (Palmer 1939) is an exemplary investigation of the then available relevant data on these stars. She found that the light curves of numerous of the stars originally classified as irregular could be interpreted as interference patterns of two or more pulsation periods simultaneously active in the stars. She computed theoretical light curves to demonstrate the complexity of the resulting patterns that would arise from interfering constant periods, illustrating the resemblance between the observed and theoretical curves. Culling the literature, she produced a list of 56 "Irregular variables with multiple periods." It is interesting to note that while most of the stars with multiple periods had originally been classified as irregular, in the current GCVS their types have been revised as follows:

SRa	SRb	SRc	SRd	RV	Cep	Nl	Total
5	33	7	2	7	1	1	56

To her thesis Miss Palmer appended a list of 182 proper motions she had determined for variable stars. Although the vast majority were for the red irregular or semi-regular variables relevant to her thesis, she included some others for which she had previously determined positions and proper motions (23 with spectral classes earlier than K). In 1945 she published (Palmer 1945) an additional list of proper motions for 98 red variable stars. Her lists still constitute probably the largest homogeneous set of proper motions for red variable stars other than Mira type -- data vital for the determination of both absolute magnitudes and space distributions. Estimating corrections for light absorption, Miss Palmer found mean visual absolute magnitudes of -2.77 at maximum, -1.27 at minimum light. These values are fainter than those for most of the irregular variables found in other galaxies, particularly the Magellanic Clouds, -3.46 at maximum and -2.02 (LMC) or -2.56 (SMC) at minimum. Palmer's investigation spans a wide range of variable sub-types from what we now know as both Population I and II. Modern determinations of the corresponding absolute magnitudes of the different groups range from slightly brighter than 0.0 to $-7.0M_V$ (see Figure 6 in Hoffmeister *et al.* 1984). Palmer's proper motion data, while impressive, were not yet adequate for subdivision into smaller groups, as she herself was aware.

The pioneering work of Frida Palmer is seldom, if ever, cited. With the advantage of hindsight, it is now obvious that she was dealing primarily, not with irregular variables as she assumed, but with clearly semi-regular stars. Nowadays very few stars are classified simply as irregular, and apparent irregularity in the light curves can often be resolved, as she did, into constant but interfering components. For the 182 variables in her catalogue of proper motions, the currently accepted types of variation are distributed as follows:

SR	M	Lb,Lc	Cep	RV	cst	EA	RCrB	RR	In	TOTAL
105	30	21	5	2	8	7	1	2	1	182

In 1935, of the 182 variables, 74 had been classified as irregular, of which only 25 are still classified as such, namely the 21 of class Lb or Lc, R Coronae Borealis, two components of the eclipsing binaries, and one Orionis type In.

In 1961 H. L. Alden and V. Osvalds (1961) determined the proper motions of 366 long period variables, mainly of the Mira type. Osvalds and Marguerite Risley (1905-1990) then combined these observations with available radial velocity data on 324 Mira type to determine space velocities and absolute magnitudes.

6. Spectroscopy

In England, from the time of their marriage in 1875, William and Margaret Huggins effectively collaborated in their pioneering investigations of the spectra of planets, novae, and emission nebulosities. Huggins had been the first, in 1866, to observe the spectrum of a nova, T CrB. When Nova Aurigae flared in 1892, Huggins studied the photographic spectrum while Margaret examined the visual, their joint efforts thereby covering the widest available range of wave lengths (Huggins and Mrs. Huggins 1892). It is said that the word *astrophysics* was coined in honor of Huggins' early work. In 1897 Queen Victoria conferred Knighthood of the Order of Bath upon William Huggins, "for the great contributions which, with his gifted wife, he had made to the new science of astro-physics" (Richardson 1967).

As Mrs. Fleming had pointed out in 1890, the fact of variability for some classes of stars could be ascertained from the appearance of but a single spectrogram, particularly of the Mira-type and novae. Soon it became apparent that some spectral characteristics varied in phase with the light curves. Besides the Harvard pioneers, Fleming, Maury, and Cannon, numerous other women in Europe and America contributed observations of the spectra of variable stars (Table 12). Special mention should be made of Margaret Walton Mayall's classification of the spectra of thirty classical Cepheids, covering the entire light curves. In collaboration with Mary Howe Baker they correlated the spectral variations with the light curves and, for 17 of the stars with radial velocities available from Mount Wilson or Lick Observatory publications. This appears to be the first paper to give such complete coverage (Figure 7). Their period-spectrum relation (Figure 8) shows small scatter except among periods longer than fifteen days (Mayall and Baker 1940).

Previously, in 1928, Jan Schilt, then at Yale, examined the available properties of 71 stars presumed to be Cepheids with periods between about 2 and 46 days (Schilt 1928) and concluded that there must be more than one period-luminosity relation. He based his conclusion mainly on the presence or absence of the c-characteristic in the published spectral classes. This conclusion was strongly and legitimately refuted by H. Shapley and C.H. Payne (1930) who pointed out that the c-characteristic had been applied only to the earlier spectral classes; and that most of the stars for which it had not been recorded were too faint to reveal that distinction on long exposure objective prism plates. Indeed, more recent classifications

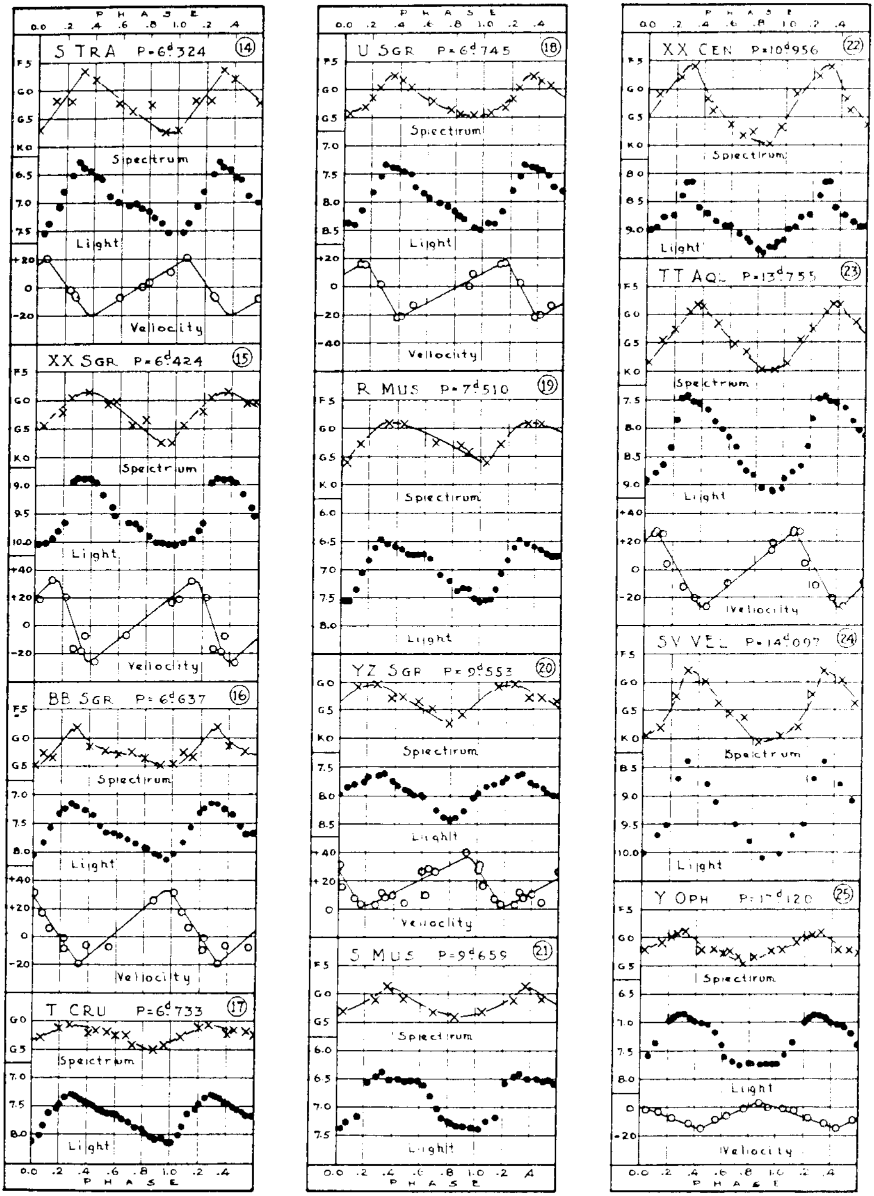

PLATE II

Figure 7. Sample page from Mayall and Baker (*Harvard Circ.*, No. 436, 1940) showing spectrum, light, and radial velocity variations of Cepheids.

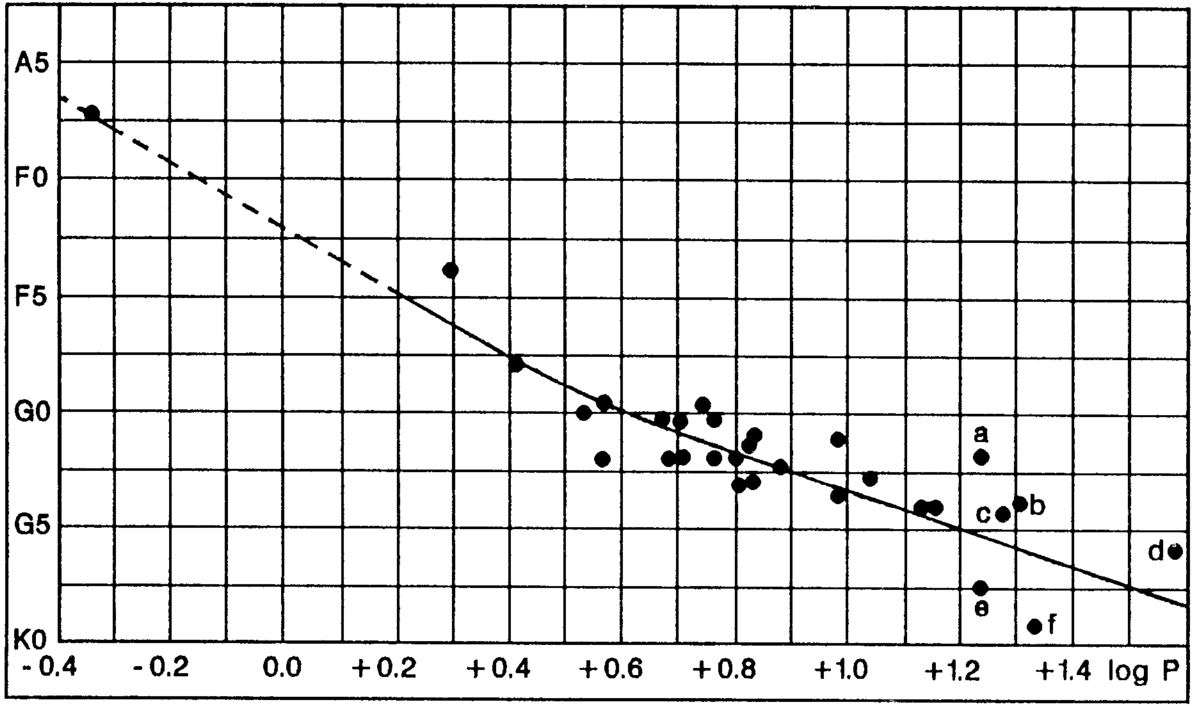

Figure 8. Period-spectrum relation by Mayall and Baker (*Harvard Circ.*, No. 436, 1940).

indicate the c-characteristic for 20 of the 46 stars on Schilt's list that were not so classified in 1928. Current assignments of the class of variability reveal that five of the 71 stars on Schilt's list are not Cepheids but eclipsing, RV Tau, or SR types; one is the Population II star, W Virginis.

Table 12. Women Stellar Spectroscopists Interested in Variable Stars, (not complete).

Name	*Country*	*Spectroscopic Specialty*
M. Huggins (1848-1915)	UK	Novae
W. Fleming (1857-1911)	USA	Classification
A.J. Cannon (1863-1941)	USA	Classification
A. Maury (1866-1952)	USA	βLyrae and other spectroscopic binaries
V. Hase (1899-1954)	USSR	γCas; carbon stars
I. Lehmann-Belanovskaya (1881-1945)	USSR	Novae, δCep, ζGem
C. Burwell	USA	Novae
C.H. Payne-Gaposchkin (1900-1979)	USA	Constituent atoms and molecules. Novae and SN
M.W. Mayall (1902-)	USA	Classification
H.A. Kluyver	Netherlands	RR Lyr
M. Hack (1922-)	Italy	βLyrae
E. Kostyakova (1924-)	USSR	Var. Planetary nebulae
N.G. Roman (1925-)	USA	Symbiotic Sp. of AG Dra
E. Parsamian (1929-)	USSR	Hα emission stars
T. Lozynskaya (1936-)	USSR	SN and stellar winds
N. Houk (1940-)	USA	Sp. var., Mira type, General Classification
N. Tshuvaeva	USSR	Magnetic variables

Figure 9 shows Schilt's plot of the relation between the logarithm of the period and spectral class of the stars for which no c-characteristic had been recorded. Had he included the ones with c-characteristic (Figure 10), the overall picture would scarcely have differed. What in fact is more interesting is the forked appearance of the diagram for periods greater than ten days. Shapley and Payne pointed out that "The spectral classes beyond ten days show a large dispersion," and "The distribution in the sky is less restricted for these periods." They failed to point out that the large dispersions were suggestive of Schilt's inference that more than one class of variable

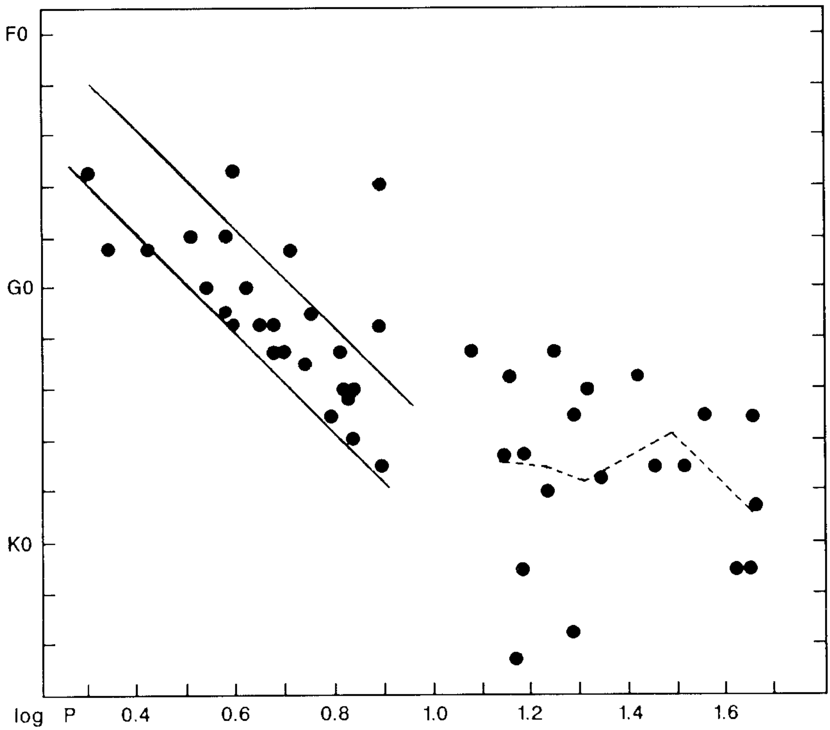

Figure 9. Jan Schilt's period-spectrum relation for Cepheids not showing the c-characteristic on plates available in 1928, together with his predictions (*Astron. J.*, 38, 197, 1928) which read, "The large range in spectral types indicates the possibility that we have to do with more than one group of stars, which, having the same order of periods, are of different surface temperatures, and which may have rather different masses and absolute magnitudes."

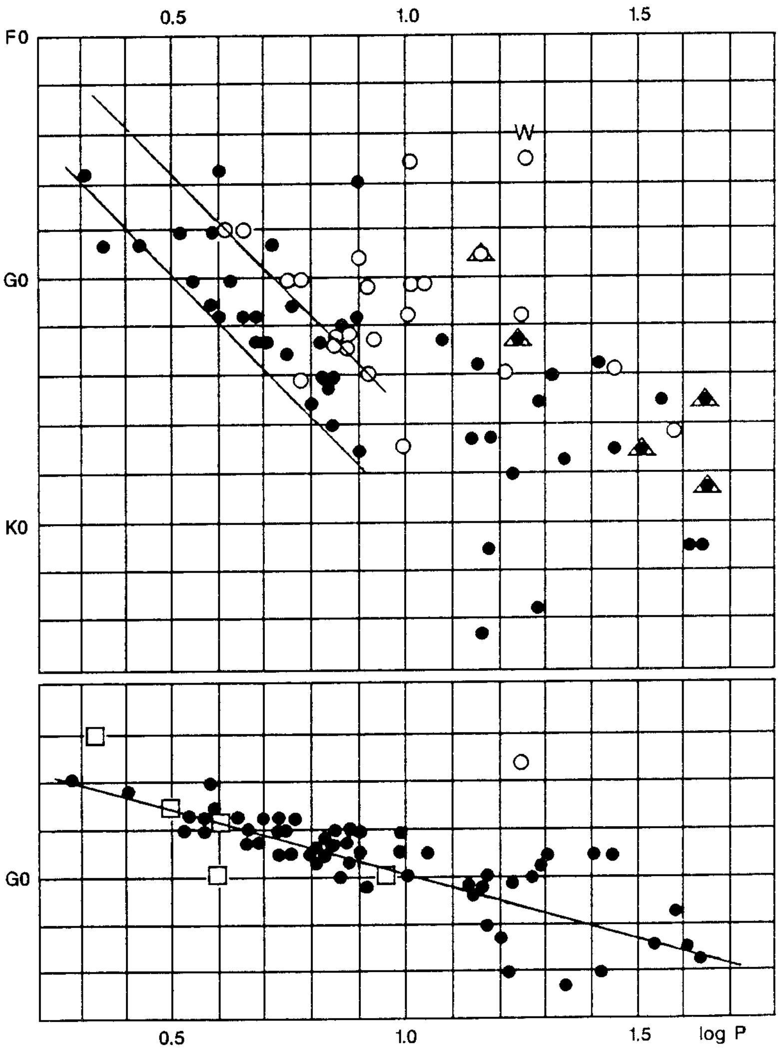

Figure 10. Upper plot, all of Schilt's data added to Figure 9. Circles are for stars for which he found the c-characteristic; triangles for stars no longer considered to be Cepheids.

Lower plot, same stars as in upper graph (except for the omission of the non-Cepheids) but with modern median spectral classes from the GCVS. The open circle represents the Population II star, W Virginis. The open squares are for stars with ambiguous population designation.

might be involved. The spectra available to Schilt were generally of low quality and not necessarily mean or median values, as complete coverage of the entire light cycle was not available. A replot with modern MK types covering the entire cycle of Schilt's stars does show a splitting of the relation between about 15 and 35 days (Hoffleit 1992). In Figure 11 this relation is shown for all the Cepheids in the recent edition of the GCVS (Kholopov 1985-87) with periods longer than ten days and for which a spectral range of at least four divisions is quoted. What are plotted are the median spectral class (half way between earliest and latest) against log P. Dots represent classical Cepheids, open circles W Virginis type. For the classical Cepheids with periods between 15 and 35 days the splitting of the sequence seems to be confirmed. Moreover, the stars on the lower branch have larger amplitudes, a steeper rise to maximum light, and, for the few examples available, lower metallicity than those in the upper, or earlier branch.

In the Small Magellanic Cloud Arp (1960) found a similar relation between color index and log P. Hence a splitting in the period-luminosity relation might also be expected. For the galactic Cepheids few absolute magnitudes are available that are independent of the established mean period-luminosity relation which depends heavily on the Magellanic clouds and variables in open clusters. For the Small Magellanic Cloud the Gaposchkins (Payne-Gaposchkin and Gaposchkin 1966a) show that the spread of apparent magnitudes amounts to 1.5 magnitudes with at most only a slight suggestion of a splitting at about 15 to 25 days. The period-luminosity relation for the data given by Mrs. Payne-Gaposchkin (1971) for the Large Magellanic Cloud shows a spread of nearly two magnitudes, but no suggestion of a splitting into two branches. In a later paper (1974) she does discuss amplitudes and colors and shows that the absolute magnitude is not determined simply by the period but must also include a term dependent on the intrinsic color of the star, which in turn is correlated with metallicity. The most beautiful demonstration of the dispersion in the period-luminosity relation for the Small Magellanic Cloud and the nearly scatter free period-luminosity-color relation is shown by the pair of figures (Figure 12) published by the South African observers, Martin, Warren, and Feast (1979). Their relation is expressed by $M_V = \langle V \rangle - 2.70 (\langle B \rangle - \langle V \rangle)$. The formula differs slightly among other galaxies.

Finally, in regard to Schilt's speculation in regard to more than one period-luminosity relation, the work of many investigators, including especially Mrs. Gaposchkin, indicates not discrete, well separated sequences but rather either a closely knit family of curves or better, an intrinsic dispersion of absolute magnitudes, not correlated with accidental errors but with metallicity, the brightest

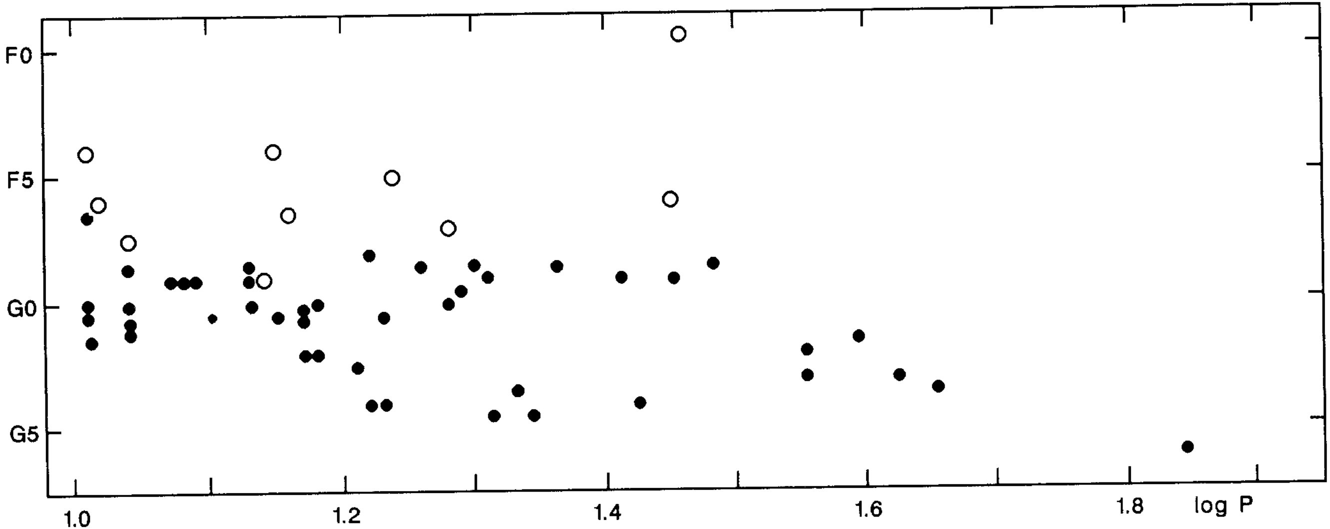

Figure 11. Median Period-Spectrum relation for all Cepheids (dots) and W Virginis stars (open circles) with published spectral classes varying over 3 divisions in the GCVS.

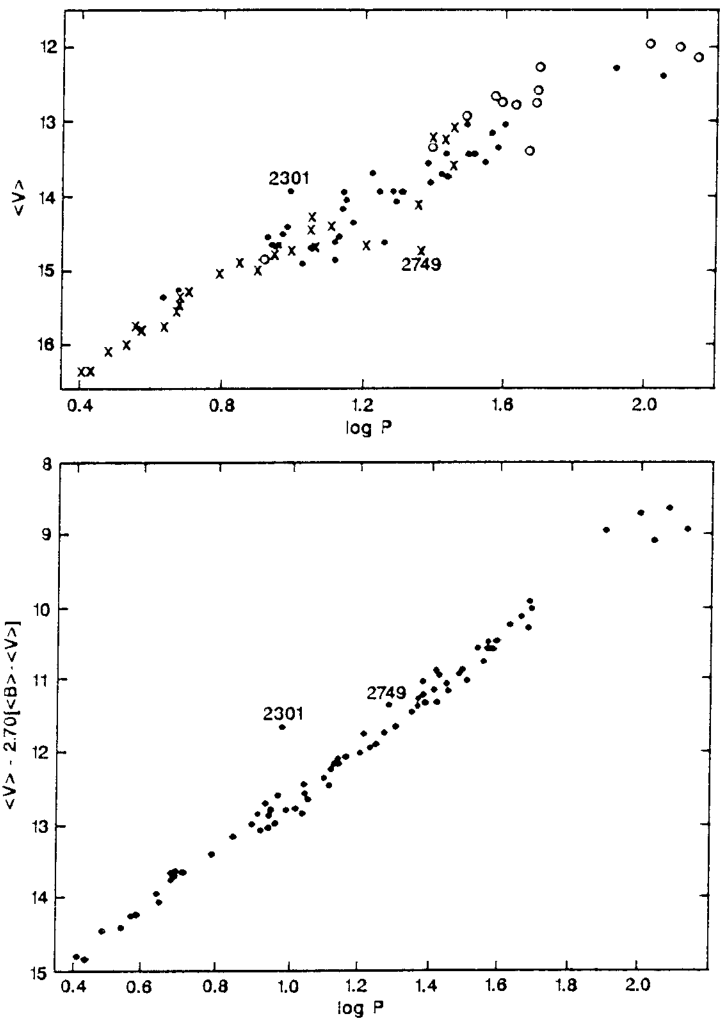

Figure 12. Upper graph, period-luminosity relation for Small Magellanic Cloud.

Lower graph, their period-luminosity-color diagram for the same stars. Ordinates are V_0 - 2.70 (B-V).

From Martin *et al.*, "Multicolour photoelectric photometry of Magellanic Cloud cepheids - II. An Analysis of *BVI* observations in the LMC, *Mon. Not. Roy. Astron. Soc.*, 188, pages 143 and 146, 1979, with permission from Blackwell Scientific Publications, Oxford.

absolute magnitudes for any period revealing the highest metallicity (Butler 1978).

Treatises by lady astronomers that deal with the various observational aspects of variable star astronomy are listed in Table 13.

Table 13. Treatises by Women Embracing Observational Aspects of Variable Star Astronomy

C. H. Payne,	*Stellar Atmospheres,* Harvard Observatory Monographs, No. 1, published by the Observatory, Cambridge, Mass., 1925.
	The Stars of High Luminosity, Harvard Observatory Monographs, No. 3, McGraw-Hill Book Co., Inc., New York and London, 1930.
C. H. Payne-Gaposchkin and S. Gaposchkin,	*Variable Stars,* Harvard Observatory Monographs, No. 5, published by the Observatory, Cambridge, Mass., 1938.
C. H. Payne-Gaposchkin,	*Stars in the Making,* Eyre-Spottiswoode, London, 1953.
	Variable Stars and Galactic Structure, Athlone Press, London, 1954.
	The Galactic Novae, North Holland Publishing Co., Amsterdam, 1957.
	Stars and Clusters, Harvard University Press, Cambridge, Mass. and London, England, 1979.
In Russian:	
N. N. Sytinskaya,	*Absolute Photometry of Celestial Bodies,* Verlag Shdanow-Staatsuniv., Leningrad, 1948.
V. Prokofyeva,	"Application of Photoelectron Imaging Techniques," *Methods of Investigation of Variable Stars,* ed. V. B. Nikonov, volume 5 of *Unstable Stars and Methods for their Investigation,* ed. B. V. Kukarkin, Moscow, 1971.
T. A. Lozinskaya,	*Supernovae and Stellar Wind,* Nauka, Moscow, 1986.

7. Birth to Death of Variable Stars

In her "Problems of Astrophysics" in 1903 Agnes Clerke stated, "Long ago it became evident to observation that nebulae were the matrices of stars. Stars visibly nebulous are then in the earliest stage of growth. So much, at any rate, may be assumed without sensible risk of error. Again, radiating globes necessarily condense with the efflux of time. As heat, the source of their expansive vigor, is dissipated, their particles succumb to gravity, which suffers no waste. They contract; the same quantity of matter occupies in them a continually diminishing space, and acquires a proportionately more substantial consistence" (Clerke 1903, p. 271).Her inference that the helium stars (earliest spectral type) are the youngest was a good beginning for modern theories of evolution; but the time was not yet ripe for further speculations.

Henry Norris Russell in his 1914 elaborate discussion of the "Relations Between the Spectra and Other Characteristics of the Stars" (Russell 1914, p. 342) proposed a theory of stellar evolution, stating:

> The giant stars then represent successive stages in the heating up of a body, and must be more primitive the redder they are; the dwarf stars represent successive stages in its later cooling, and the reddest of these are the farthest advanced. We have no longer two separate series to deal with, but, a single one, beginning and ending with class M, and with the class B in the middle, - all the intervening classes being represented, in reverse order, in each half of the sequence.

Variable stars were not specifically mentioned. It was fully a quarter of a century before this beautifully simple theory had to be abandoned after the announcement of the "carbon cycle" by H. Bethe (Russell 1939) showing how hydrogen could be converted to helium. This achievement was first enthusiastically presented by Russell himself at a meeting of the American Philosophical Society. Atomic theory of the conversion of hydrogen to helium and ultimately to heavier elements at the core of stars finally proved that stellar evolution progressed in almost the reverse order from Russell's early theory. And the HR diagram for variable stars reached a degree of complexity scarcely anticipated. The Gaposchkins were quick to apply the Bethe theory to variable stars (Payne-Gaposchkin and Gaposchkin 1942).

In 1957 in the final chapter of her *The Galactic Novae,* Payne-Gaposchkin gave a summary of the theories of evolution of novae and supernovae current at that time, declaring that the conclusions were "tentative if not speculative" (p. 385). Four years later, at a symposium on variable stars held at the 50th anniversary meeting of the AAVSO in 1961, Cecilia Payne-Gaposchkin (Figure 13) briefly reviewed the history of theories of stellar evolution especially as applied to variable stars (Payne-Gaposchkin 1961). Color-magnitude diagrams for clusters aided tremendously in the interpretation of relative ages of different categories of stars. Open clusters are young systems in which

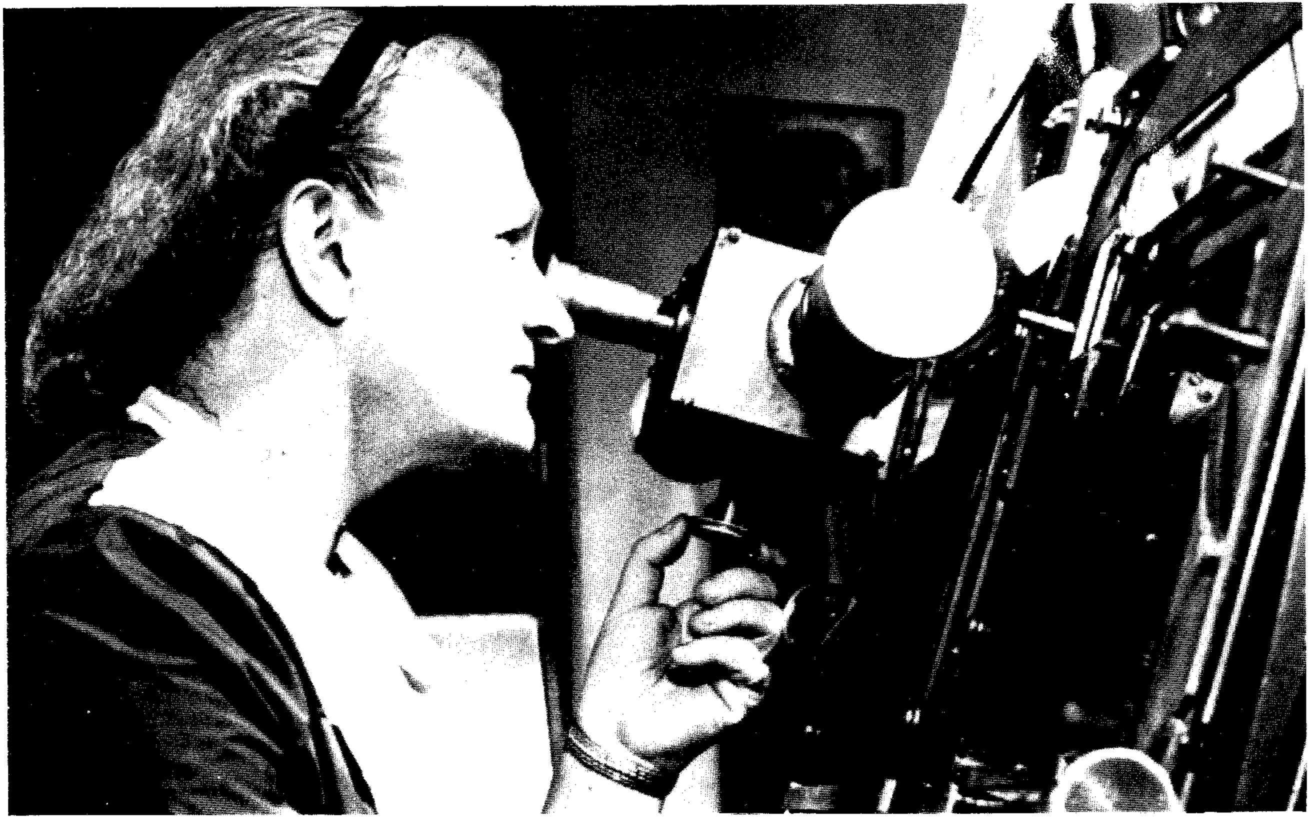

Figure 13. Cecilia Payne-Gaposchkin at blink microscope, about 1946. (Courtesy of K. Haramundanis.)

T Tauri, βCanis Majoris, classical Cepheids, and semi-regular red giants are found. Globular clusters, on the other hand, are old systems containing RR Lyrae, RV Tauri, and W Virginis stars as well as long period variables. She concludes:

> This very brief outline points to extreme youth for T Tauri stars, youth for βCanis Majoris stars and rather greater age for Cepheids. Next in age come the RR Lyrae stars, the red variables, and finally the U Geminorum stars and the novae. On the supernovae nothing can at the moment be concluded, and the R Coronae Borealis stars present an unsolved enigma for the evolutionary standpoint.

Thanks to SN 1987A in the Large Magellanic Cloud, the problem of the evolution of supernovae is now better understood (See Percy *et al.* 1992), but R CrB stars remain somewhat of a puzzle.

Toward the end of her life Cecilia Payne-Gaposchkin wrote an article, "The Development of Our Knowledge of Variable Stars" (Payne-Gaposchkin 1978). She summarized Russell's 1918 inferences on stellar evolution and commented on the major changes that had occurred in the intervening years. She noted that the application of nuclear physics to the study of the sources of stellar energy and the development of computer techniques led to the calculation of evolutionary tracks. No longer could it be assumed, as Russell had, that most variable stars are giants and that all intrinsic variability was a sign of extreme youth. Variability occurs in successive stages of stellar evolution, from early youth to dying old age. Starting from the condensation of nebular matter, the earliest recognition as a star puts it to the right and slightly above the main sequence in the HR diagram. When finally formed the star reaches the main sequence, where it spends the greater part of its life. Then as the hydrogen burning at its core progresses the star eventually leaves the main sequence, the more massive and hotter stars leaving first; the cooler red stars at a later age. They progress along various evolutionary tracks all toward the upper right hand parts of the diagram. The more massive, becoming Cepheids, pass back and forth several times through what is known as the Hertzsprung gap or instability strip. Payne-Gaposchkin describes the course of nearly all the known types of variables from main sequence to red giant stages, then entering nova or nova-like stages they move to the left and lower parts of the HR diagram ending as white dwarfs. (Her 1978 paper does not mention neutron stars or black holes.) Throughout her paper Payne-Gaposchkin stresses the role of variables in open and globular clusters, and the positions of the variables in the individual HR diagrams for interpreting the evolution and ages of the different types of variables. She also pointed out that metallicity, although relatively high in open and very low in globular cluster stars, differs significantly from star to star and thus requires a third dimension to be added to the HR diagrams. R Coronae Borealis stars, enigma of the past, she classifies along with supernovae as catastrophic, in contrast to normal novae as cataclysmic. She comments:

> It seems that the composition and structure of the R Coronae Borealis stars can only be the results of the loss of the outer portions of an evolved star, leaving an almost hydrogenless nucleus rich in heavy elements. The transition from supernova to pulsar may involve an equally abrupt event. Abrupt or not, both processes seem likely to be irreversible.

In two papers on pulsating helium stars (not cited by Payne-Gaposchkin) Virginia Trimble (1972, 1973) discusses the properties of R Coronae Borealis stars, some of which have been found also to show periodic pulsations, in particular RY Sgr. Almost sixty years after Russell's paper which Payne-Gaposchkin was analyzing, she concluded that there had accrued a great deal of information on the causes of stellar variation. While knowledge on the cataclysmic had reached a plateau, much "still remains mysterious."

Finally her last important treatise, *Stars and Clusters*, was published shortly before her death in 1979. This contains a gold mine of information on variable stars, both observational and theoretical, including profound speculations on the ages of stars, stressing in particular that apparent senility, in stars as in people, is not necessarily correlated with chronological age. For example, she cited (Payne-Gaposchkin 1979, p. 198) stars of smallest mass, pre-main sequence stars only about seven percent of the mass of the sun, that are still very young in terms of developmental age, whereas in chronological age they may be as old as the globular clusters, older than most types of variable stars. The more massive stars evolve off the main sequence faster than the low mass stars. Adopting a picturesque terminology attributed to Martin Schwarzschild, she calls these pre-main sequence stars "featherweights." Table 14 summarizes the development of stars of increasing mass. The featherweight stars are by far the youngest in experience, but actually the oldest, living longest on the main sequence; the heavyweight live spendthrift lives, passing through exciting experiences leading to early exhaustion.

Double stars play an important role in the evolution of variable stars. Novae, in particular, are revealed as double. Mrs. Gaposchkin, investigating the light curves of R Aquarii, Z Andromedae and AX Persei, (Payne-Gaposchkin and Boyd 1942; Payne-Gaposchkin 1946) and correlating them with available spectroscopic data, is presumably the first to have proposed that these are Mira type stars with blue companions that have outbursts like recurrent novae (see Struve

Table 14. The Life Cycles of Stars

	Mass/sun	*Development*
Featherweight	0.07	Pre-main sequence
Lightweight	4	Main sequence toward red giant (including Mira, W Vir, RR Lyr), then toward blue spectra, finally becoming white dwarfs
Middleweight	8-9	From main sequence to blue supergiants, to Cepheids, to catastrophic collapse (SN), to neutron stars, pulsars
Heavyweight	9-1000	Collapsing stars ending as black holes

1951). In *Stars and Clusters* she calls attention to several stars she wished would be observed extensively in the hope that they might become novae: double stars with spectral characteristics common to novae or dwarf novae at minimum light (cited in Hoffleit 1979). At the time, most of these were recorded in the GCVS as probable ex-novae and in the recent 1987 version as eclipsing with a white dwarf companion, or NL (nova-like). But none of the six stars Mrs. Gaposchkin cited (TT Ari, EM Cyg, VV Pup, VZ Scl, RW Tri, and UX UMi) has as yet revealed a typical nova outburst. TT Ari has been more profusely observed in recent years and is now classified as Z Cam type.

Examples can be found of almost all types of variables that are components of double stars. However, Payne-Gaposchkin points out (1979 p. 217) that novae and nova-like stars are the only variables that are always binary systems. Generally one component is a red giant the other a white dwarf. Moreover, she stated that novae and nova-like variables are not like other variables: their variations do not stem from their inner nature, but from the presence of a close companion, material from a main sequence or cool red giant flowing over to the white dwarf. However, when it comes to double stars, she advocates caution in the application of evolutionary theories. The time scale is not clear; all she can state (1979 p. 231) is that "the nova phenomenon is something that can overtake any binary that consists of a white dwarf and a main sequence star, provided the components are close enough together to permit active physical contact."

In an article "Past and Future of Novae" (Payne-Gaposchkin 1977, p. 28) discussed the space distributions of novae and their probable frequencies. She speculated that there should be over 100,000 ex-novae now brighter than nineteenth apparent magnitude, and "these ex-novae should lie preferentially in the direction of the galactic center. They would be rapid erratic variables of small range, many should be blue stars, and in addition a substantial fraction should be eclipsing variables of very short period. A systematic attempt to find such stars in the 400 square degrees around the position of the galactic center would be of great interest." In the 1987 version of the GCVS, among the over 4000 variables in Sagittarius, very few appear to be what Mrs. Gaposchkin hoped would be found. However, it seems no systematic search had been undertaken and the older photographic searches in that crowded region would hardly have revealed many small amplitude variables. The NSV, the *New Catalogue of Suspected Variable Stars* (Kholopov *et al.* 1982) does list several hundred suspected variables within $\pm 10^{\circ}$ of the galactic center. But the majority of these, discovered by A. Terzan at Haute Provence between 1964 and 1973, are in and near globular clusters in the galactic center region. Mrs. Gaposchkin makes no specific reference to these.

More Mira variables are known than any other types with the possible exception of RR Lyrae stars. The Miras seem intermediate in distribution between Populations I and II (Hoffleit 1951). Their spectra, combining high excitation bright lines and overlying molecular clouds, still presented a riddle. Mrs. Gaposchkin described them as "in some ways the least understood of variable stars" (Payne-Gaposchkin 1979, p. 177). Later, at the 75th Anniversary of the AAVSO, Lee Anne Willson (1986) presented stellar models showing the evolutionary tracks of stars of 1, 3, and 7 solar masses from the main sequence to red giant asymptotic branch Mira stars (Figure 14). A program initiated by Margarita Karovska at the Harvard-Smithsonian Center for Astrophysics in 1991 promises to throw further light on these visually most observed but still not completely understood stars (Mattei 1991; Karovska 1992).

Richard Larson (1972) computed evolutionary tracks for the collapse of an interstellar cloud to a pre-main sequence star, indicating that this might take up to ten million years. Mrs. Gaposchkin (1979 pp.40-41) summarized the life span of stars evolving from the "zero age" main sequence, based on models by I. Iben (1967). Table 15 shows the life-span on the main sequence and the total evolution time to the tip of the red giant branch.

A star of one solar mass may have spent thousands of million years on the main sequence, longer for smaller mass, shorter for more

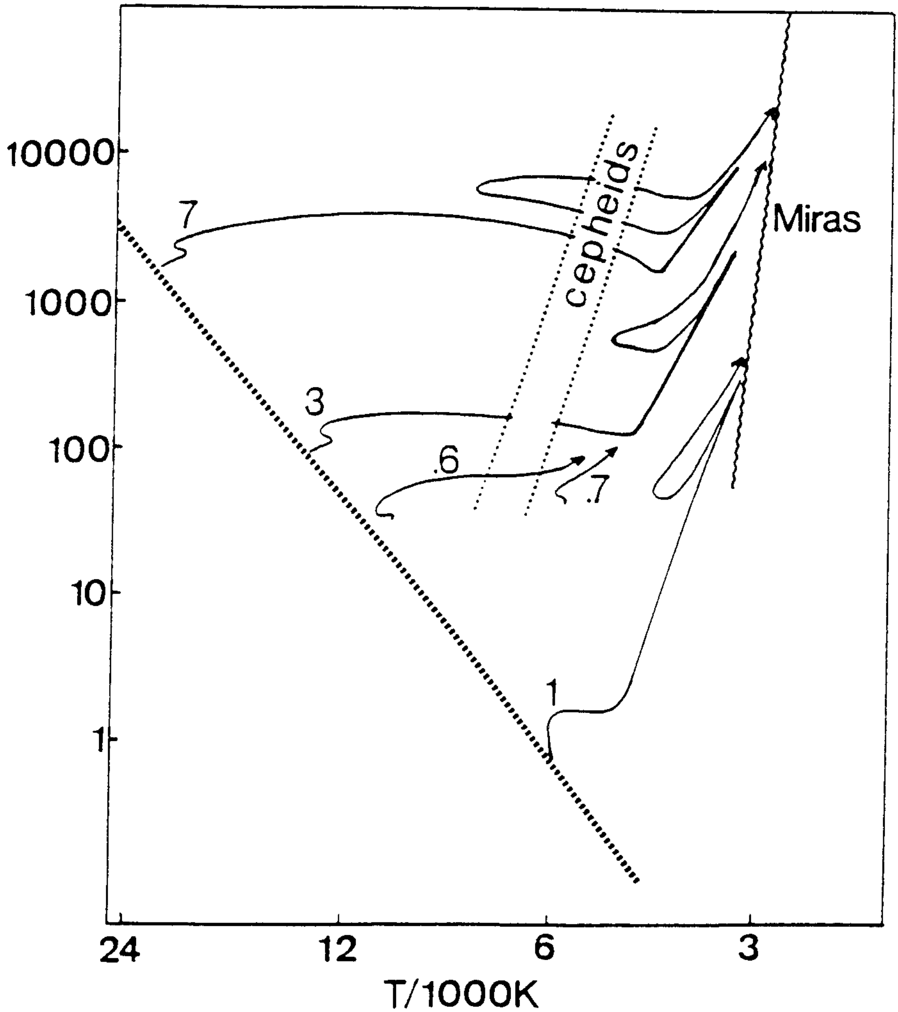

Figure 14. Evolutionary tracks of stars that might become Mira Variables. From L. A. Willson, *J. Amer. Assoc. Var. Star Obs.*, 15, 233, 1986.

Table 15. Evolution of Stars of Different Mass

	(times in millions of years)		
Solar Mass	*On Main Sequence*	*To Red Limit*	*% time on Main Sequence*
50	<1		
15	10	12	83
5	65	87	75
3	221	323	68
1	7000	11357	62
0.7	10000?		

massive protostars. Then, as shown for Mira stars in Willson's graph, it progresses to the red giant region of the HR diagram. The time to reach the Mira stage depends on the original mass and whether or not the star passes through the Hertzsprung gap where Cepheids are found. As a Mira star, it remains in that stage for about a million years, losing mass until only the core of the original star remains. It has then become a planetary nebula, the central star finally a white dwarf, in the lower left corner of the HR diagram. This part of the HR diagram is sometimes referred to as the stellar graveyard; "old folk's home" might be better; indeed, Mrs. Gaposchkin refers to these stars as "senile" stars. While a star still shines, even though dimly, it should not yet be called dead! Black holes, like the invisible companion of Cygnus X-1, discovered in 1971 (Tananbaum *et al.* 1972), have been called dead stars. But, although invisible, the fodder flowing into them from their visible companions suggests some sort of cloistered activity -- not dead but voracious cannibals lurking in the dark!

Supernovae, for relatively short times exhibit the most spectacular increases in brightness, some 20 magnitudes. As the core has consumed all its elements lighter than iron, the star suddenly explodes, shedding not only its outer shell but almost completely destroying itself. What remains is a neutron star, or binary pulsar.

Payne-Gaposchkin speculates (1979, p. 214) on what would happen if a close binary consisting of two massive stars would coalesce. Would the system become one "heavyweight" and eventually a supernova? She points out that two spectroscopic binaries, DH Cep, listed as an elliptical variable, and SZ Cam, eclipsing, might be candidates for such a supernova event. In the case of DH Cep Batten (1989) notes that IUE spectrograms indicate mass-loss. These stars deserve watching.

Cecilia Payne-Gaposchkin's contributions both as an educator and as a researcher into the observable properties of variable stars, their internal constitution, and evolutionary processes, as well as her evaluations of the research of others, are too numerous to review in detail. Interested readers are referred to the extensive bibliography (over 300 items) supplied by her daughter for Cecilia's autobiography (Haramundanis 1984).

Since 1970 many papers have been written on stellar evolution. Besides Payne-Gaposchkin, numerous women astrophysicists have published relevant articles on the evolution of variable stars. Virginia Trimble has probably contributed more than anyone else to the understanding of supernova evolution, and Tatyana A. Lozinskaya has been similarly productive. Theirs is modern history and I shall limit this section to citing the women and the titles of some of their extensive contributions (Table 16). The majority are concerned with novae and supernovae.

Table 16. Contributions Since 1970 by Women on the Evolution of Variable Stars

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V. P. Arkhipova, Moscow.
On the Evolution of Novae (Arkhipova and Mustel 1975).

Erika Böhm-Vitense, University of Washington, Seattle.
Stellar Structure and Evolution, a text book (1992).

France A. Cordova, Pennsylvania State University.
Accreting Degenerate Dwarfs in Close Binary Systems, (Cordova and Mason 1983).

Anne P. Cowley, Arizona State University.
A Binary Model for the Symbiotic Star AG Pegasi (Cowley and Stencel 1973).
Relation of the X-Ray Sources Sco X-1 and Cyg X-2 to Old Novae (Cowley and Crampton 1977).

E. V. Ergma, Estonia.
Convection in Stars (Ergma and Massevitch 1971).
Carbon Burning with Convective URCA Neutrinos (Ergma and Paczynski 1974).
Presupernovae I - Components of Binaries (Ergma and Tutukov, 1976a).
Evolution of Carbon-Oxygen Dwarfs in Binary Systems (Ergma and Tutukov 1976b).
Evolution of a Degenerate Component in a Close Binary System (1979).
Hydrogen and Helium Burning in the Degenerate Envelopes of C-O Dwarfs (Ergma and Tutukov 1979).

L.N. Ivanova, Moscow.
Pulsation Regime of the Thermonuclear Explosion of a Star's Dense Carbon Core, (Ivanova *et al.* 1974).

Susan Kleinmann, University of Massachusetts at Amherst.
The Spatial, Temporal, and Photometric Properties of AGB Stars (1989).

Table 16, continued.

Tatyana A. Lozinskaya, Moscow.

Interferometry of the Supernova Remnant W28, indicating an age of 60,000 years for the remnant (1974).

Evolution of Supernovae Remnants with a Central Pulsar (1986).

Relation Between Supernova Type and Their Remnants (Lozynskaya and Chugaj 1987).

Wolf-Rayet Stars as Progenitors of Supernovae Producing Cassiopaeia A-Type Supernova Remnants (1988).

Supernovae and Stellar Wind in the Interstellar Medium, a text book containing many references to her own work as well as that of others (1992).

Alla G. Massevitch, Moscow.

Evolution of Stars with $\geq$ *8 Solar Masses* (Massevich and Tutukov 1974).

Waltraut C. Seitter, Germany.

Model of a Nova Outburst on the Basis of Measurements on V1500 Cygni (1977).

Beatrice M. Tinsley, Yale.

What Stars Become Supernovae (1975).

Masses of Supernova Progenitors (1977).

Stellar Lifetimes and Abundance Ratios in Chemical Evolution (1979).

Virginia Trimble, University of Maryland and University of California at Irvine.

Pulsating Helium Stars (1972).

Helium Red Giants (1973).

Masses of DB Degenerate Dwarfs (1979).

Supernovae. Part I: The Events (1982).

Supernovae Part II: The Aftermath (1983a).

A Field Guide to the Binary Stars (1983b).

Supernovae as a Cosmological Tool (1983c).

Binary Progenitors of Supernovae (1984).

Supernovae and Pulsars (1985a).

The Crab Nebula and Related Supernova Remnants (1985b).

Supernovae: an Impressionistic View (1986).

1987A: The Greatest Supernova Since Kepler (1988).

Neutron Stars and Black Holes in Binary Systems (1991a).

The Origin and Abundances of the Chemical Elements Revisited (1991b).

Lee Anne Willson, Iowa State University.

Mira Variables (1986).

Stellar Mass Loss and Pulsation (1989).

Cepheid Evolution with Pulsationally-Driven Mass Loss (Brunish and Willson 1989).

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8. The Role of the AAVSO

When the AAVSO was first organized in 1911 women were in a minority, but a minority as active and inspiring as the most prominent of the male pioneers. Among the first six observers who expressed an interest in joining was only one woman, Dr. Anne S. Young, Director of the Mount Holyoke Observatory (Olcott 1911a). In William Tyler Olcott's first *Monthly Report of the AAVSO* (Olcott 1911b) he listed seven new members, including Dr. Carolyn Furness, Director of the Vassar Observatory, and Miss Helen M. Swartz of South Norwalk, Connecticut. At the November 10, 1917, meeting of the AAVSO (see Figure 15) a constitution was drawn up and it was noted that anyone joining by December 31 would be considered a Charter Member. Eight women availed themselves of this opportunity. All the women charter members are listed in Table 17, eleven out of about 90 members. In 1918 honorary memberships were conferred upon the professional astronomers Annie J. Cannon, Solon Bailey, and Henry Norris Russell and, in 1919, upon Henrietta Leavitt of period-luminosity fame. To the Honor Roll of the Association in 1918 was also added the name of Mary. H. Vann who, in the interests of World War I efforts, had become a volunteer YMCA worker abroad. Miss Vann had been the first recipient of the Pickering Memorial Fellowship for Women at Harvard Observatory, a fellowship established by the Nantucket Maria Mitchell Association in appreciation of the efforts of Pickering in fostering research at the Maria Mitchell Observatory.

Table 17. Women Charter Members of the AAVSO

Year Elected	*Name*	*Affiliation or Location*
1911	Caroline Furness	Director, Vassar College Observatory
	Helen M. Swartz	South Norwalk, Connecticut
	Anne S. Young	Director, Observatory, Mount Holyoke College
1912	Psyche R. Sutton	Assistant to Miss Furness
1913	Jessamine White	Assistant to Miss Furness
	Mary E. Wilson	Topeka, Kansas
1914	Grace Buffum	Dudley Observatory
	Mabel A. Dyer	Dudley Observatory
1916	Fanny Ludke	Shandon, California
	Alice E. Taylor	Geneva, New York
1917	Leah Allen	Wellesley College

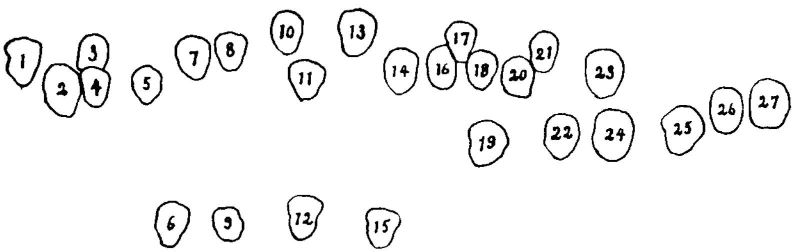
Table 17, continued.

1917	Dorothy Block	Harvard College Observatory
	Lillian Brewster	Andover, Massachusetts
	Isabella Conant	Wellesley, Massachusetts
	M. Alberta Hawes	Harvard College Observatory
	Susan Raymond	Harvard College Observatory
	Dorothy Reed	Kennebunk, Maine
	Alice M. Swing	Coconut Grove, Florida
	M. H. Vann	Harvard College Observatory
	Ada Weber	Cincinnati, Ohio
	Ida E. Woods	Harvard College Observatory

The founders of the Maria Mitchell Association had established an Astronomical Fellowship in 1912 to enable a woman to spend half a year at the Maria Mitchell Observatory, the other half at any major observatory. Margaret Harwood (1885-1979), an assistant at the Harvard Observatory, was the first (and only) recipient. She did photographic work on variable stars and light curves of variable asteroids, with Harvard Professors Pickering and Bailey as her mentors. In 1916 she was appointed the first Director of the Maria Mitchell Observatory, a title she held until her retirement in 1957. In view of her fine early work and in appreciation of Pickering's substantial support of the budding observatory, the Nantucket organization initiated a fund drive, resulting in the gift of the endowment of the Pickering Memorial Fellowship at Harvard (Jones and Boyd 1971). Miss Vann was interested in variable stars and became a charter member of the AAVSO. Before leaving Harvard in 1918, she contributed 129 AAVSO observations. Miss Harwood joined the AAVSO in 1919 and at various times became active in numerous capacities -- sponsoring several Nantucket members, acting as chairman of the nominating committee, as a member of the Council, and as hostess at the 1930 annual meeting.

Miss Louise F. Jenkins joined the Association in 1919. (She was later to become famous for her collaboration with Director Frank Schlesinger of Yale on the determination of stellar parallaxes and the compilation of the "Yale Catalogue of Stellar Parallaxes" ultimately producing updated compilations.) Before leaving for missionary work in Japan in 1920 she had collaborated with Professor Anne S. Young at Mount Holyoke College on the determination of proper motions of 34 long period variable stars (Young and Jenkins 1920). For making visual observations of variable stars for the AAVSO she took with her to Japan a 3-inch refractor belonging to Charles Elmer of the AAVSO, and between 1921 and mid-1923 procured 164 observations.

Formal Organization Meeting of the American Association of Variable Star Observers, Cambridge, Massachusetts, November 10, 1917.



1. Miss B. H. Vann
2. F. H. Spinney
3. W. J. Delmhorst
4. Miss D. W. Block
5. Mrs. E. T. Brewster
6. L. Campbell
7. Professor A. S. Young
8. Miss S. Raymond
9. Miss L. Allen
10. J. J. Crane
11. Miss D. Reed
12. Miss A. J. Cannon
13. Professor E. C. Pickering
14. E. S. McColl
15. Miss H. S. Leavitt
16. E. T. Brewster
17. Professor S. I. Bailey
18. W. T. Olcott
19. Miss I. E. Woods
20. Rev. T. C. H. Bouton
21. D. H. Wilson
22. H. R. Schulmaier
23. M. J. Jordan
24. A. B. Burbeck
25. Miss I. F. Conant
26. F. L. Ducharme
27. W. H. Reardon

Figure 15. The 1917 organizational meeting of the AAVSO. Eleven ladies present. From *Popular Astron.,* 26, op. 64, 1918.

Then, during the Tokyo earthquake of 1923 the telescope was destroyed (Sakuma 1985). Miss Jenkins was the first woman variable-star observer in Japan. There she taught at a girls' school, mainly English and Bible, but informally also discussed astronomy with her students and founded an astronomy club (Eaton 1920; Sakuma 1983).

By the time of the fiftieth anniversary of the AAVSO in 1961, Curtis Anderson tabulated observers and their total number of observations. 1554 observers had contributed 1,948,707 observations (Anderson undated). Of the observers, 166 were women who contributed from 1 to 9769, totaling over 34200 observations. Six women contributed over 1000 each (Table 18). In the same interval twenty-five men contributed over 10,000 observations each, the largest numbers by Reginald de Kock of South Africa, 117,157 between 1934 and 1961, and Cyrus Fernald of Maine, 104,444 between 1937 and 1961.

Table 18. Women Contributing Over 1000 Observations

	1961	*1986*	*Years*
Harriet Bigelow	1071		1929-33
Rosina Dafter	3517		1935-56
Alika Herring	1038		1948-55
Ida Horton		3053	1963-69
Carolyn Hurless	1097	78678	1959-86
Winifred M. Kearons	9769		1925-51
Diane Lucas		12146	1960-76
Betty P. McMillan		2179	1982-86
Vicki Schmitz		2356	1964-69
Clara Somogyl		1200	1970-73
Ursula Surawski		25418	1974-78
Donna J. Hughes-Sventek-Bloom		2745	1976-85
Bela Szentmartoni		2058	1974-79
MaryJane Taylor		5313	1971-81
Carolyn L. Womack		2902	1982-86
Anne S. Young	4157		1912-44
TOTAL (16 women)		157,600	

The membership list for 1975 indicated that 930 men and 67 women were members, only about 7% women. (About 150 of the women contributing observations by 1961 were either deceased or no longer members by 1975.) A list of observers and their numbers of observations was published at the time of the 75th anniversary (Mattei

1986). The number of women had increased to about 280 among a total of 4015 observers (still only 7% women). Of the more than 5.5 million observations, the total by the sixteen women, each of whom contributed over 1000, is 157,600, while that for the six men who contributed over 100,000 each is 764,556. The numbers exceeding 1000 for women observers together with the years in which the contributions were made are noted in Table 18. The men with more than 100,000 observations are listed in Table 19.

Table 19. Men with Over 100,000 Observations

	1961	*1986*	*Years*
Thomas A. Cragg		107805	1945-86
Reginald P. de Kock	117157	160777	1934-73
Cyrus F. Fernald	104444	134582	1937-75
Wayne M. Lowder		108809	1943-86
Edward S. Oravec		120460	1943-86
Leslie C. Peltier		132123	1918-80
TOTAL (6 men)		764,556	

On numerous occasions women were elected to the Council of the AAVSO and in several instances served as President (Table 20). They also contributed many articles to AAVSO publications and presented papers at the regular meetings of the society. The *Journal of the AAVSO* was started in 1972. Among the first twenty volumes there are over 720 papers of which 31% are authored by women. They have also served as hostesses to meetings held at their institutions (Table 21), outside of Cambridge where most of the Annual Meetings are held.

Table 20. Women Presidents of the AAVSO

	Elected
Anne S. Young	1922, 1923
Alice Farnsworth	1929, 1930
Harriet W. Bigelow	1931, 1932
Helen Sawyer Hogg	1939, 1940
Marjorie Williams	1947
Martha Stahr Carpenter	1951, 1953
Dorrit Hoffleit	1961, 1962
Martha Hazen	1991

Table 21. Hostesses at Meetings

Hostess	*Year*	*Institution*
Carolyn Furness	1921 S	Vassar College
Anne S. Young	1924 S	Mount Holyoke College
Harriet W. Bigelow	1926 S	Smith College
Carolyn Furness	1928 S	Vassar College
Margaret Harwood	1930 S	Maria Mitchell Observatory
Leah Allen	1932 S	Hood College
Anne S. Young	1935 S	Mount Holyoke College
Maud Makemson	1941 S	Vassar College
Marjorie Williams	1946 S	Smith College
Leah Allen	1947 S	Hood College
Anne S. Young	1948 S	Mount Holyoke College
Dorrit Hoffleit	1958 S	Maria Mitchell Observatory
Dorrit Hoffleit	1966 F	Maria Mitchell Observatory
Carolyn Hurless	1968 S	Lima, Ohio, Astronomical Society
Dorrit Hoffleit	1969 F	Maria Mitchell Observatory
Dorrit Hoffleit	1972 F	Maria Mitchell Observatory
Dorrit Hoffleit	1977 F	Maria Mitchell Observatory
Emilia P. Belserene	1983 F	Maria Mitchell Observatory
Lee Anne Willson	1984 S	Iowa State University

S = Spring, F = Fall

A scholar of note, but rarely cited, is Dr. Helen L. Thomas (Figure 16) (see Hoffleit 1981). From 1934 to 1937 she was secretary to Leon Campbell, the first Recorder of the AAVSO. She not only did whatever secretarial duties were required, but organized the library of the AAVSO, and also did some variable star observing. Later she assisted the Gaposchkins in their Milton Bureau work. Importantly, in 1948 she wrote a thesis, "Early History of Variable Star Observing to the XIX Century." For this she was awarded the first Radcliffe Ph.D. in the Department of the History of Science. Only two men at Harvard had already won the doctorate in the history of science, including the subsequently famous Professor I. B. Cohen of Harvard. For her thesis she delved into and translated an early Arabic text.

Finally, the AAVSO has had only three Directors to date (1993), one man and two women. The first, Leon Campbell, did not hold that title, although he carried out his job at Harvard in the capacity of Director of the AAVSO. His title was "Recorder" to which was later (1931) added the "Pickering Memorial Astronomer". An endowment

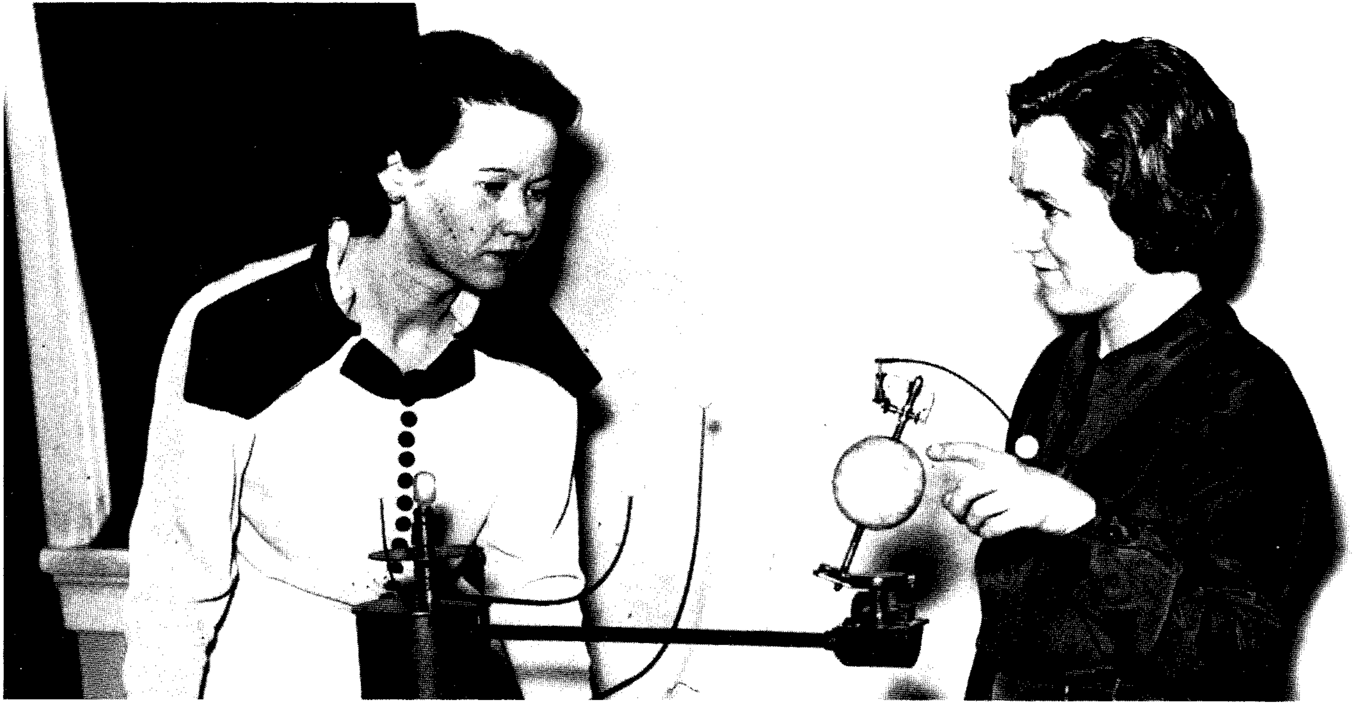


Figure 16. Helen L. Thomas (right) and Sylvia Mussells at Harvard Observatory about 1935, demonstrating the model planetary system for explaining the solar system, especially for children. Leon Campbell, whom Helen Thomas assisted for several years, in addition to his work with the AAVSO was in charge of public Open Nights and programs for school children. (From AAVSO Archives.)

had been raised through a fund drive by Harvard Observatory and the AAVSO, the interest from which was to be used "to promote the study of variable stars" (see Figure 17). When Mr. Campbell retired in 1949 Margaret Walton Mayall became the Recorder and Pickering Memorial Astronomer. But soon hard times followed. The eviction of the AAVSO from Harvard in 1953 has been recorded by R. Newton Mayall (1961). (See also Robinson 1990.) Margaret was deprived of the title Pickering Memorial Astronomer and concurrently of her salary, which had been derived from that source. The AAVSO, for whom the endowment had been raised, was given only that segment of the funds contributed by the members of the AAVSO, approximately $7000. Such drastic measures seemed destined to destroy the AAVSO. Only a person of high principles and determination could overcome the inevitable difficulties. But Margaret was blessed with strong convictions, industry, the moral support of her husband, and frequent financial support from Secretary Clinton Ford, a modest man who never revealed the extent of his munificence. Ironically, the person most responsible for evicting the AAVSO from Harvard, eight years later wrote a touching letter of appreciation of the AAVSO on the occasion of its golden anniversary (Figure 18).

Under Mrs. Mayall's Directorship (she was accorded the title Director in 1956) IBM punch-card equipment was introduced for storing and analyzing variable star observations; in 1972 a new publication, the *Journal of the AAVSO,* was started; and the membership continued to grow. When Mrs. Mayall retired in 1973 she was succeeded by Dr. Janet Akyüz Mattei, a lady of great enthusiasm and drive. She replaced the punch-card machines with more modern electronic computers and progressively acquires newer, faster models. Some 3300 variable stars are on the AAVSO visual observing program and the observers contribute between 20,000 and 22,000 observations every month. In addition Mrs. Mattei has gotten the AAVSO involved in photoelectric and CCD observations, and projects concerned with outer space. The AAVSO supplies NASA with vitally needed data on variable stars to be correlated with data at other wave lengths, for example X-ray and gamma ray, obtained from space vehicles HEAO, IUE, Hipparcos, and others (Mattei 1992).

The AAVSO will also be involved in the program described by Margarita Karovska of the Harvard-Smithsonian Center for Astrophysics for "International Cooperation for Coordinated Studies of Mira Variables," the collection and analysis of observations designed specifically for "better understanding of the pulsation process in Mira-type variables and to a determination of the effects of these pulsations on the atmospheric structure, temperature scale, and mass-loss rates" (Karovska 1992).

Through good times and bad Clinton Ford gave the AAVSO much

The Edward C. Pickering Memorial Fund

Mr. Leon Campbell, who for many years has been Recording Secretary of the American Association of Variable Star Observers, and the chief Harvard Observatory representative in that Association, has been appointed Pickering Memorial Astronomer. With the assistance of a clerk he will have entire supervision of the observational work of the Association and discuss the data accumulated by its members.

Ten years ago it was proposed that the Association memorialize its founder, Professor Edward C. Pickering, by raising a fund to be known as the "Edward C. Pickering Memorial Fund." It was resolved that the income derived from this fund should be used to promote the study and observation of Variable Stars. Many friends of Professor Pickering in this country and abroad contributed to the fund. The Rockefeller Foundation and Harvard University made the most important contributions.

At a meeting of the Association held at the Harvard College Observatory on October 17, 1931, it was announced that the proposed fund had been completely subscribed and that the memorial has been officially established. The appointment of Mr. Campbell as Pickering Memorial Astronomer was made by the Observatory with the advice of the Council of the Association. In the list of officers of the Association Mr. Campbell retains the position of Recorder.

A room is to be equipped and set apart in the Harvard Observatory as headquarters of the Variable Star Association, and a bronze tablet suitably inscribed will attest the establishment of the Memorial.

The members of the Association and the many friends and colleagues of Professor Pickering have reason to be proud of their achievement. It is not only a fitting memorial to a distinguished astronomer, but it affords a greater opportunity of extending our knowledge of Variable Stars.

WILLIAM TYLER OLCOTT, *Chairman.*

Figure 17. Terms of the endowment for a Pickering Memorial Astronomer. From *Popular Astron.*, 39, 619, 1931.

TO MEMBERS OF THE AAVSO

I greatly regret that an unexpected and urgent conference in Denver makes it impossible for me to welcome you personally to the Harvard College Observatory, at the meeting celebrating your fiftieth anniversary. I am glad, however, that I had the opportunity of being with some of you yesterday evening.

Of these fifty years I have myself been a member of the AAVSO for forty-three. And I have had the pleasure and privilege of meeting and knowing many of the early greats: William Tyler Olcott, Dave Pickering, Charles McAteer, Ernest Yalden, Charlie Elmer and-of-course-our beloved late recorder Leon Campbell. They were wonderful people who encouraged the efforts of a beginning amateur. My first scientific contributions were observations of variables, made at a small observatory of the University of Denver. By chance, I shall be visiting there this very morning. I delivered my first scientific paper at a meeting of the AAVSO at Harvard.

I rejoice at the growth and progress of your great organization. And hope that the next fifty years will be even more fruitful.

Welcome to Harvard! My best wishes for a most successful meeting!

(Signed) Donald H. Menzel

Figure 18. Donald Menzel's tribute to the AAVSO upon its 50th anniversary. From *AAVSO Abstracts*, October 9, 1961.

Figure 19. Margaret Mayall, Dorrit Hoffleit, and Janet Mattei, February 27, 1993, at a tribute to the memory of Clinton B. Ford. (Courtesy of Monsignor R. E. Royer.)

needed support, both moral and financial, and through his generous will, continues to provide for this, his favorite astronomical organization.

9. Acknowledgements

I am gratefully indebted to Tanja Foulds and Michael Saladyga for much help in editing the References to a uniform system, compiling the Index, and preparing the original manuscript for photo-offset. Bill Sacco of the Yale Photographic Department has provided good photographs from old pictures and Charles Scovil has enhanced original line drawings using his computer. Finally, I thank Janet Mattei for encouragement in carrying out this project. It has been privately funded.

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Name Index

Alden, H. L., 23
Allen, Leah, 44, 46, 49
Anderson, Curtis, 47
Argelander, F., 13
Arkhipova, V. P., 42
Arp, H. C., 30
August, G., 17
Baade, Walter, 18
Bailey, Solon, 3, 44, 45, 46
Baker, Mary Howe, 24-26
Batten, A. H., 41
Bell, Jocelyn, 12
Belserene, Emilia P., 49
Bethe, H., 34
Bigelow, Harriet, 47, 48, 49
Block, Dorothy, 45, 46
Böhm-Vitense, Erika, 42
Boyce, E. H., 9
Brewster, Lillian, 45, 46
Buffum, Grace, 44
Burwell, C., 27
Byrgius, J., 5
Campbell, Leon, 46, 49, 51-53
Cannon, Annie Jump, 3, 8, 13, 24, 27, 44, 46
Carpenter, Martha Stahr, 48
Ceraski, L., 9
Clerke, Agnes, 17, 33-34
Cohen, I. B., 49
Conant, Isabella, 45, 46
Cordova, France A., 42
Cowley, Anne P., 42
Cragg, Thomas A., 48
Dafter, Rosina, 47
De Kock, Reginald, 47, 48
Dessy, J. L., 21
Draper, Henry, 2
Dyer, Mabel A., 44
Eddington, A., 17
Elmer, Charles, 45, 53
Ergma, E. V., 42
Fabricius, D., 5
Farnsworth, Alice, 48
Feast, 30, 32
Fernald, Cyrus, 47, 48
Fleming, Williamina, 1, 2, 3, 9, 14, 15, 24, 27
Ford, Clinton B., 51, 53-54, 55
Furness, Carolyn, 44, 49
Gaposchkin, Sergei, 16, 21, 30, 33, 34, 49
Goodricke, J., 3, 5
Güssow, Margarete, 17-18, 21
Hack, M., 27
Halley, E., 5
Harwood, Margaret, 45, 49
Hase, V., 27
Hawes, M. Alberta, 45
Hazen, Martha, 48
Herring, Alika, 47
Herschel, W., 5
Hodge, Paul W., 16
Hoffleit, Dorrit, 9, 48, 49, 54
Hogg, Helen Sawyer, 5, 48
Horton, Ida, 47
Houk, Nancy, 27
Huggins, Margaret, 24, 27
Huggins, William, 24
Hughes-Sventek-Bloom, Donna, 47
Hurless, Carolyn, 47, 49
Iben, I., 39
Ivanova, L. N., 42
Jenkins, Louise F., 45, 47
Kapteyn, J. C., 14
Karovska, Margarita, 39, 51
Kearons, Winifred M., 47
Kirch, O., 5
Kleinmann, Susan, 42
Kluyver, Helena, 17, 27
Koch, J. A., 5
Kostyakova, E., 27
Laborde, 21
Larson, Richard, 39
Leavitt, Henrietta, 1, 3-5, 9, 14, 15, 44, 46
Lehmann-Belanovskaya, I., 27
Lockyer, Sir Norman, 17
Loomis, 17

Lowder, Wayne M., 48
Lozynskaya, Tatyana A., 27, 33, 42, 43
Lucas, Diane, 47
Ludke, Fanny, 44
Makemson, Maud, 49
Maraldi, G. P., 5
Martin, W. L., 30, 32
Massevitch, Alla G., 8, 43
Mattei, Janet Akyüz, 51, 54
Maury, Antonia, 2-3, 24, 27
Mayall, Margaret Walton, 24-27, 51, 54
Mayall, R. Newton, 51
McKibben Nail, Virginia, 15, 16
McKibben, Virginia, see McKibben Nail
McMillan, Betty P., 47
Menzel, Donald, 53
Mitchell, Maria, 1
Montanari, G., 5
Mussells, Sylvia, 50
Olcott, William Tyler, 44, 46, 52, 53
Oravec, Edward S., 48
Osvalds, V., 23
Palmer, Frida, 22-23
Parsamian, E., 9, 27
Payne, C. H., see Payne-Gaposchkin
Payne-Gaposchkin, Cecilia, 1, 14-16, 17, 21, 24, 27, 30, 33, 34-39, 41-42, 49
Peltier, Leslie C., 48
Pickering, E. C., 2-3, 6, 9, 12, 13, 14, 44, 45, 46, 52
Pigott, E., 5
Pogson, 13
Prager, R., 22
Prokofyeva, Valentina, 16, 33
Ptolemy, 13
Pulfrich, 9
Raymond, Susan, 45, 46
Reed, Dorothy, 45, 46
Reed, W. M., 3
Ribière, A., 1
Rigaux, F., 12
Risley, Marguerite, 23-24
Ritter, D., 17
Roman, Nancy G., 27
Rubin, Vera, 8
Russell, Henry Norris, 34, 36, 37, 44
Safarik, A., 8, 9
Sawyer, Helen, see Hogg
Schilt, Jan, 5, 24, 27-30
Schlesinger, Frank, 45
Schmidt, J., 5
Schmitz, Vicki, 47
Schwarzschild, Martin, 37
Seitter, Waltraut C., 43
Shajn, P., 9
Shapley, Harlow, 5, 6, 12, 16, 17, 21, 24, 27
Smith, Horace, 21
Somerville, Mary, 1
Somogyl, Clara, 47
St. Hildegard, 1
Stroobant, P., 12
Surawski, Ursula, 47
Sutton, Psyche R., 44
Swartz, Helen M., 44
Swing, Alice M., 45
Swope, Henrietta, 9, 18, 21
Sytinskaya, N. N., 33
Szentmartoni, Bela, 47
Taylor, Alice E., 44
Taylor, MaryJane, 47
Terentjeva, A. K., 8
Terzan, A., 39
Thomas, Helen L., 49, 50
Tinsley, Beatrice M., 43
Trimble, Virginia, 37, 42, 43
Tshuvaeva, N., 27
Vann, Mary H., 44, 45, 46
Walker, A. D., 15
Walton, Margaret, see Mayall, Margaret
Warren, 30, 32
Weber, Ada, 45
White, Jessamine, 44
Williams, Marjorie, 48, 49
Willson, Lee Anne, 39-40, 43, 49
Wilson, Mary E., 44
Womack, Carolyn L., 47
Woods, Ida E., 45, 46
Wright, Frances W., 15, 16
Young, Anne S., 44-49