INTRODUCING MIRA VARIABLES

Janet Akyüz Mattei
AAVSO Headquarters
25 Birch Street
Cambridge, MA 02138

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Abstract

This brief summary on the observational properties of Mira-type variable stars introduces the talks given during the special Mira session at the 85th Annual Meeting of the AAVSO, on the occasion of the 400th anniversary of the discovery of Mira. The articles following this introduction each deal with specific observational and theoretical aspects of Mira variables, thus giving an overall picture of this important and abundant class of variables.

1. What are Mira variables?

Mira-type variable stars are very cool red giants with temperatures around 3000°K. They are very large—200 to 300 times the radius of the sun, and very luminous—3000 to 4000 times the luminosity of the sun. These post-main sequence, pulsating long period variables, with periods ranging from 150 to 1000 days, have large amplitudes of light variation of more than 2.5 magnitudes in the visual, and more than 1 magnitude in the infrared wavelengths.

Depending upon the abundance ratio of carbon to oxygen in their surface layer, Miras are of spectral types M, S, or C. M spectral type Miras have $C/O \leq 1$; S spectral type Miras have $C/O \sim 1$; and C type Miras (carbon stars) have $C/O \geq 1$. Their spectra show emission lines of hydrogen, Doppler shifts, and evidence of shock waves.

Miras have rapid mass loss of about 10^{-6} $M_{\odot}$/yr, giving them a major role in galactic evolution through enrichment of the interstellar medium in heavy elements. Through mass loss they avoid exploding as supernovae. Some Miras are progenitors of planetary nebula, while others evolve directly to the white dwarf stage.

Mira variables have extended atmospheres and a large number of them have circumstellar dust shells. They are close relatives of semiregular variables, and are sources of both hydroxyl (OH) and infrared (IR) emissions.

2. Period and shape of Mira light curves

The period—the time interval between two consecutive maxima (in days)—is a very important parameter in Mira variables, in that the period gives an indication of their size (and thus luminosity), as well as their age, initial metallicity, mode of pulsation, and evolution. Other important correlations between the period and other parameters include period versus amplitude, period versus IR excess due to circumstellar dust, and period versus mass loss.

The light variation of Mira variables is not strictly periodic in phase and amplitude, in that the individual period of a Mira variable may vary from one cycle to the next from the average period. In a significant number of Mira variables, the maximum brightness varies drastically from cycle to cycle, as can be seen in the light curves of R Cyg and R And (Figure 1).

In a considerable number of Mira variables, the visual light curves exhibit

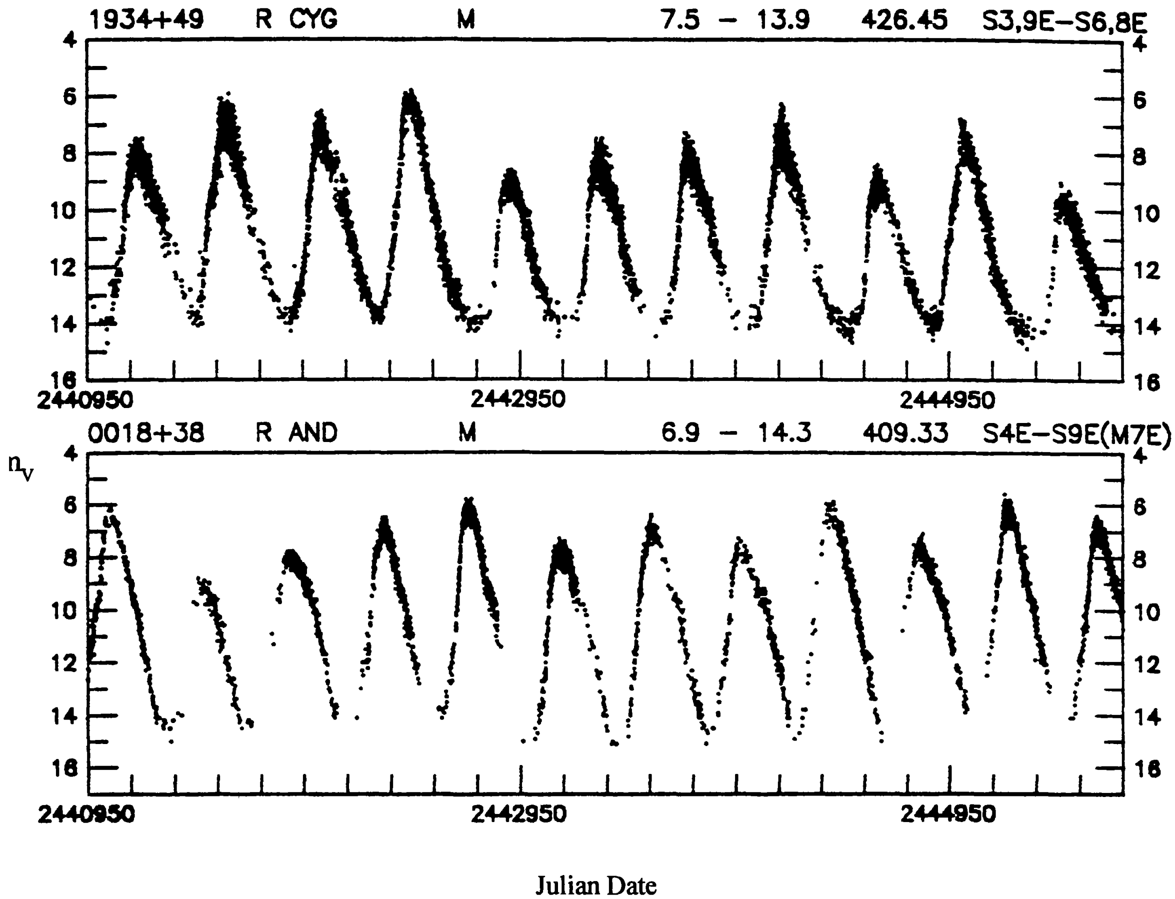


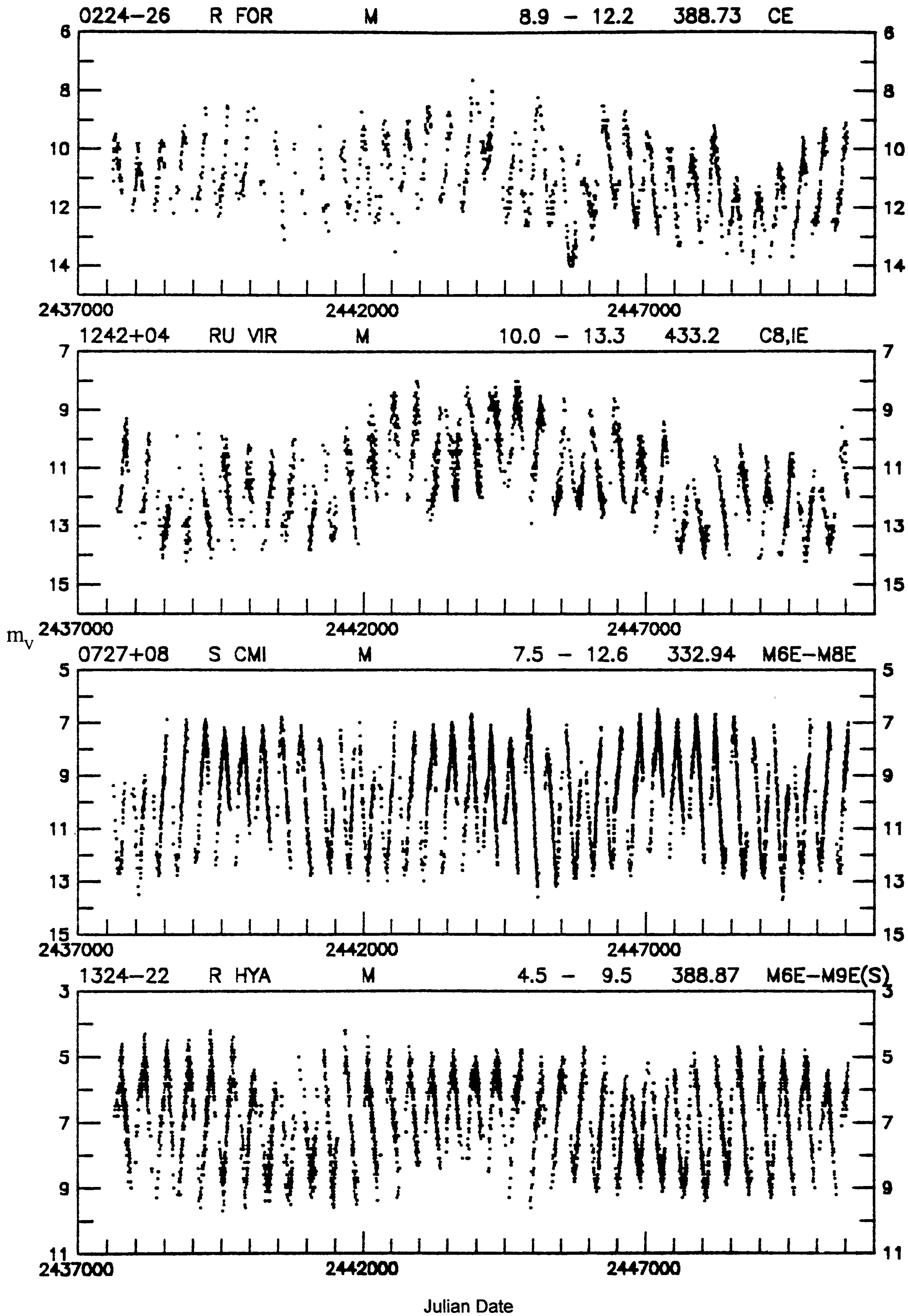
Figure 1. AAVSO light curves of R Cyg (top) and R And (bottom), examples of Mira variables for which the maximum brightness varies dramatically from cycle to cycle. Each point is an individual observation.

complex variations of both maxima and minima from cycle to cycle and also on a long-time scale, as can seen in the light curves of R For, RU Vir, S CMi, and R Hya (Figures 2a, b, c, d). Such multiperiodic modulation of light curves has been attributed to circumstellar dust shells (Barthès, Chevenez, and Mattei 1996).

There appears to be a correlation between the period and the shape of the light curve (Campbell 1955), in that Miras with periods less than 200 days have symmetrical light curves and small amplitudes, as in the case of X Cam, with a period of 145 days (Figure 3a). Mira variables with periods longer than 200 days have larger amplitudes and steeper rising branches of the light curve, as in Mira itself, with a period of 333 days (Figure 3b). Mira variables that have periods longer than 300 days have large amplitudes, and many show standstills or "bumps," particularly in the rising branch of the light curve, as can be seen in the light curve of χ Cyg, which has a period of 408 days (Figure 3c).

There appears to be another correlation between brightness at maximum and the interval from the previous cycle, in the sense that if the interval separating the maxima is less than the average period, the second maximum tends to be the brighter of the two, and vice versa (Harrington 1965; Wallerstein *et al.* 1985).

Mira variables are important in our understanding of stellar evolution and the kinematics of the galaxy. Long-term monitoring of these stars provides us with data to study various correlations and trends of the light curve parameters and period



Figures 2a–d. AAVSO light curves for (from top to bottom) R For (a), RU Vir (b), S CMi (c), and R Hya (d), Mira variables exhibiting complex variation of both maxima and minima from cycle to cycle and also on a long-time scale. Each point is an individual observation.

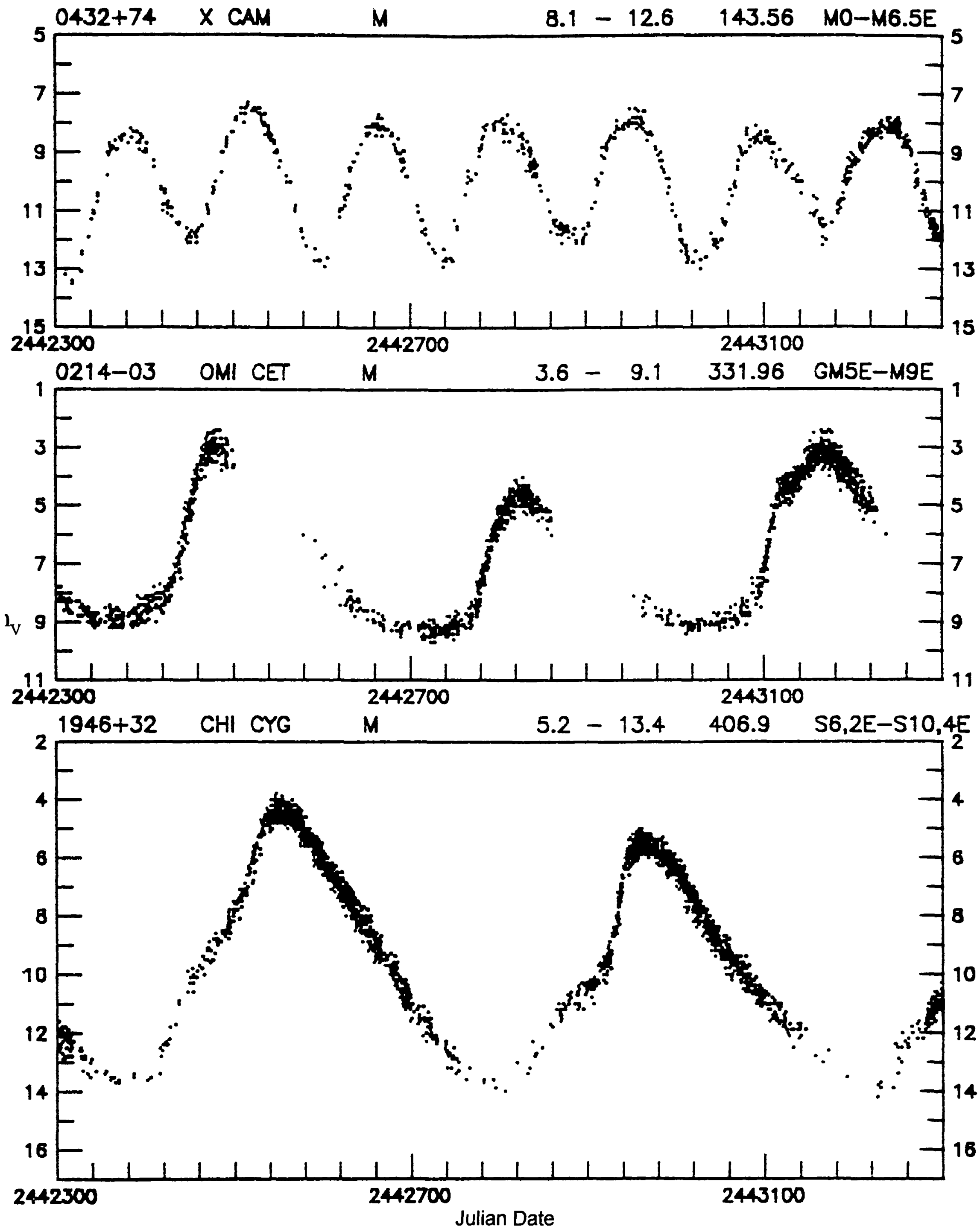
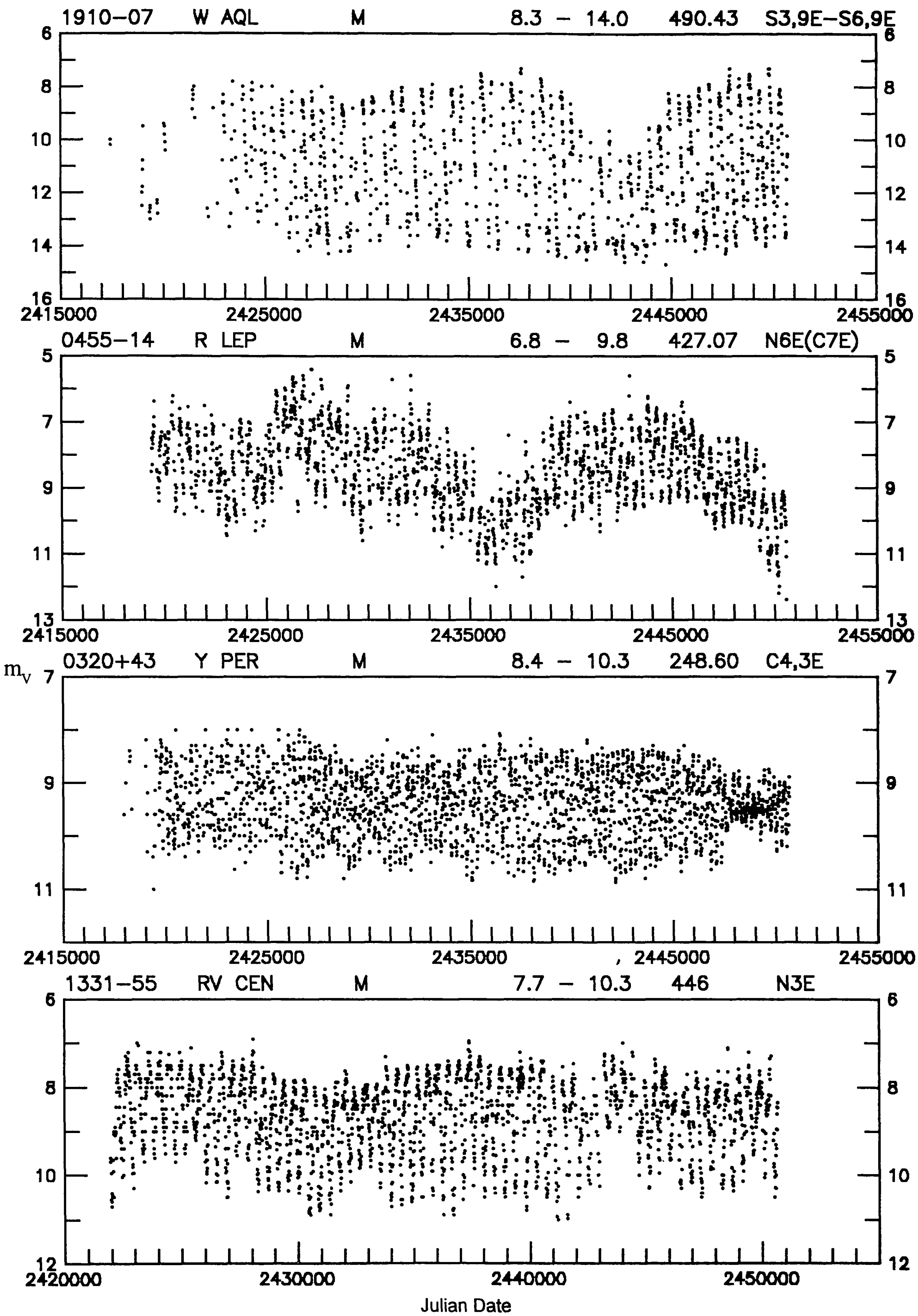


Figure 3a–c. AAVSO light curves of X Cam (a), Mira (b), and χ Cyg (c), examples of Mira stars which show the apparent correlation between the period and the shape of the light curve. X Cam (a) an example of a Mira with a period of less than 200 days, has a symmetrical light curve and small amplitude. Mira (b) is typical of variables with periods longer than 200 days, and shows a larger amplitude and steeper rising branch of the light curve. χ Cyg (c) is typical of Mira variables having a period longer than 300 days, with a large amplitude and standstills or "bumps," particularly in the rising branch of the light curve. Each point is an individual observation.



Figures 4a–d. Long-term AAVSO light curves of (from top to bottom) W Aql (a), R Lep (b), Y Per (c), and RV Cen (d), Mira stars showing a rich variety of interesting behaviors. Each point is a 10-day mean.

changes, helping us to answer questions and to increase our understanding of these stars.

3. Mira variables and the AAVSO

Because Mira variables are intrinsically bright, and because their amplitudes are large and their periods are long, they are particularly suited for visual observing. In fact, the light variations of Miras are almost always determined from visual observations compiled by the AAVSO or other variable star observer groups.

Of the 4000 stars in the AAVSO visual program, 1361 of them are Mira variables. Most of these stars (809) are M spectral class; 97 have C, N, R, or S type spectra; and the rest are of unknown spectral class. The AAVSO has the longest in time, and the largest, database of visual observations in the world. Compiled AAVSO observations on hundreds of Mira variables extend back 80 years or more and thus provide a unique database by which to analyze these stars. In fact, correlation of light curve parameters using 75 years of dates and magnitudes from the AAVSO International Database has been studied recently by H. Boughaleb as a basis for a doctoral thesis (Boughaleb 1994), and by Mennessier, Boughaleb, and Mattei (1997).

Recently, we at AAVSO have started to carry out trend analyses on long period variables of mostly Mira type in the AAVSO observing program. So far we have studied 51 carbon long period variables using 90 years of AAVSO data, and we reported our findings in the Carbon Star Phenomenon meeting in Antalya, Turkey, in May 1996 (Mattei and Foster 1997). We studied the period, amplitude, fall time (time from maximum light to minimum), rise time (time from minimum to maximum), and magnitude at maximum and minimum of these 51 long period variables. We find that the fluctuations of carbon long period variables strongly exhibit detectable long term trends. The period is more stable than other parameters, with longer-period stars more likely to show period fluctuations than shorter-period stars. Fall and rise times have a strong tendency to evolve oppositely to each other, i.e., mirror evolution, keeping the period fairly constant. Maximum and minimum magnitudes often show parallel evolution, keeping the amplitude fairly constant in these stars. About half of these stars are getting fainter, especially at maximum, and are showing a secular dimming of magnitude at maximum. We find that a good number of individual stars show a rich variety of interesting behaviors, as can be seen in the long-term light curves of W Aql, R Lep, Y Per, and RV Cen (Figures 4a, b, c, d). We are studying these stars individually and will be reporting on them at a later date.

We express our sincere gratitude and thanks to the thousands of variable star observers around the world who have been observing Mira variables over decades, thereby providing valuable data to help researchers find answers to many of the questions about these stars.

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