

EVOLVING MIRA PERIODS

Albert A. Zijlstra

UMIST, Department of Physics, P.O. Box 88,
Manchester M60 1QD, UK.
a.zijlstra@umist.ac.uk

T.R. Bedding

University of Sydney, School of Physics, Sydney
NSW 2006, Australia.
bedding@Physics.usyd.edu.au

1 Mira periods

There is good reason to expect that Mira variables will show stable periods. The period is linked to the fundamental parameters of the star via the pulsation equation

$$\log P = 1.5 \log R - 0.5 \log M + \log Q \quad (1)$$

where Q depends on the pulsation mode. On short time scales, M is constant. The radius R is related to the luminosity L , as determined by the shape of the AGB in the HR diagram. Fast variations in P have therefore been explained as due to thermal-pulses.

2 Variable Periods

A number of Mira variables are sufficiently bright to have been monitored by amateur astronomers. The BAAVSS archive goes back more than a century. Other sources of data are the AAVSO, AFOESV, VSOLJ and RASNZ. We have been analyzing stars in these archives for period variability. Three types of period changes, in excess of normal (5%) period jitter, are found.

2.1 Continuous changes

The first type is a continuous declining period, over a time scale of the order of one century. An example is R Hya, for which Figure 1 shows all available amateur data. The period decreased between 1850 and 1950 but stabilized after 1950. The amplitude declined simultaneously with the period.

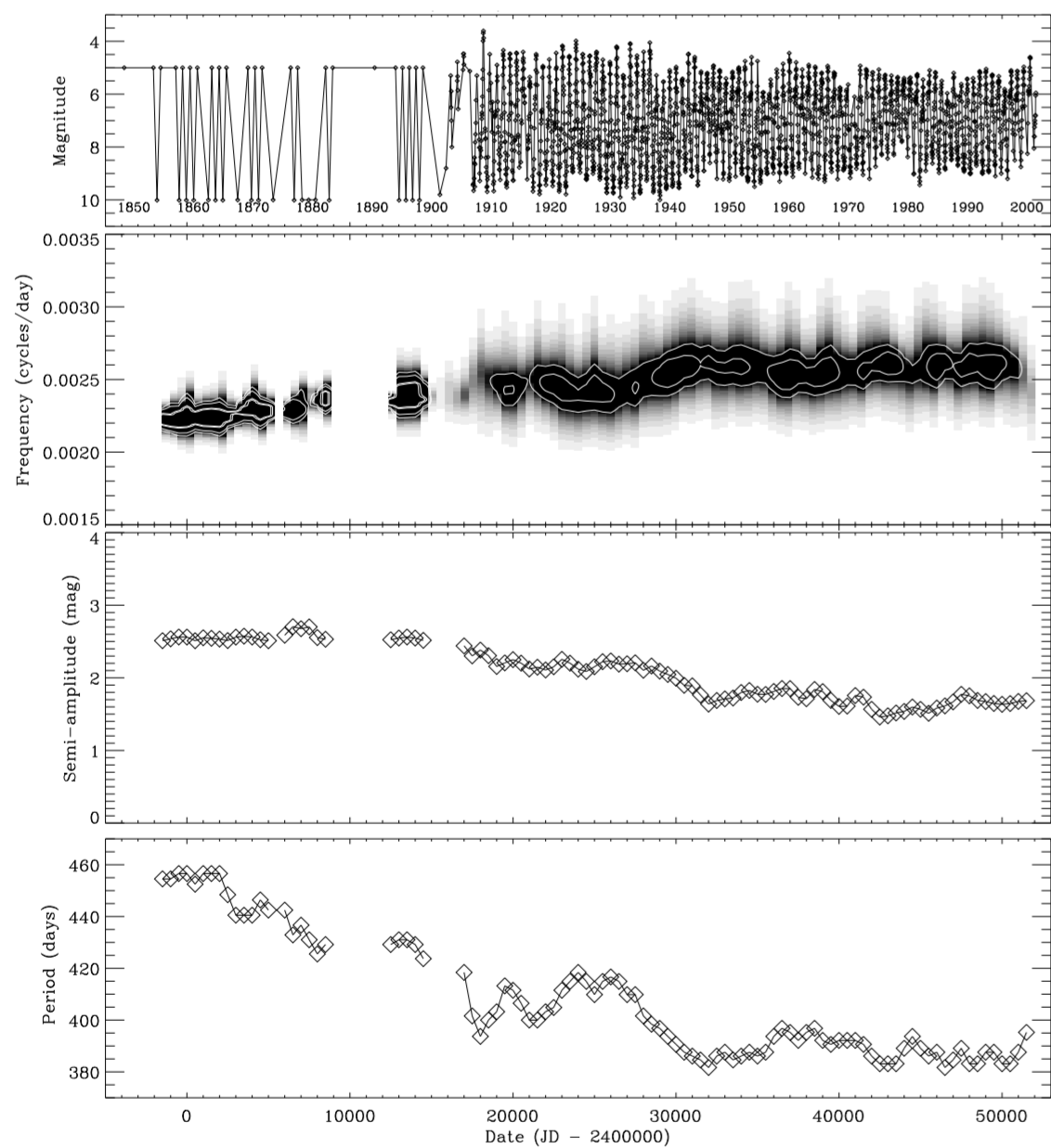


Figure 1: Period analysis for R Hya. Top panel: light curve; second panel: wavelet analysis showing significance of the period; third panel: semi-amplitude of the dominant period; bottom panel: period evolution

Historical data indicates that the period was about 495 days before AD 1750, and declined linearly between 1750 and 1950. The same type of variability is shown by R Aql and RU Vul (Fig. 2).

2.2 Sudden changes

Miras in this small group show a sudden change in period, after a long lasting stable period. T UMi in Fig. 2 shows an example. BH Cru may also be of this type, but its period behaviour before 1968 is not known.

2.3 Meandering periods

These are Miras where the periods fluctuate by typically 10%, on a time scale of the order of 50 yr. We do not have sufficient time coverage to determine whether the fluctuations are periodic. In Fig. 2, W Hya and S Ori give examples of this behaviour. It appears fairly common among the longest-period stars.

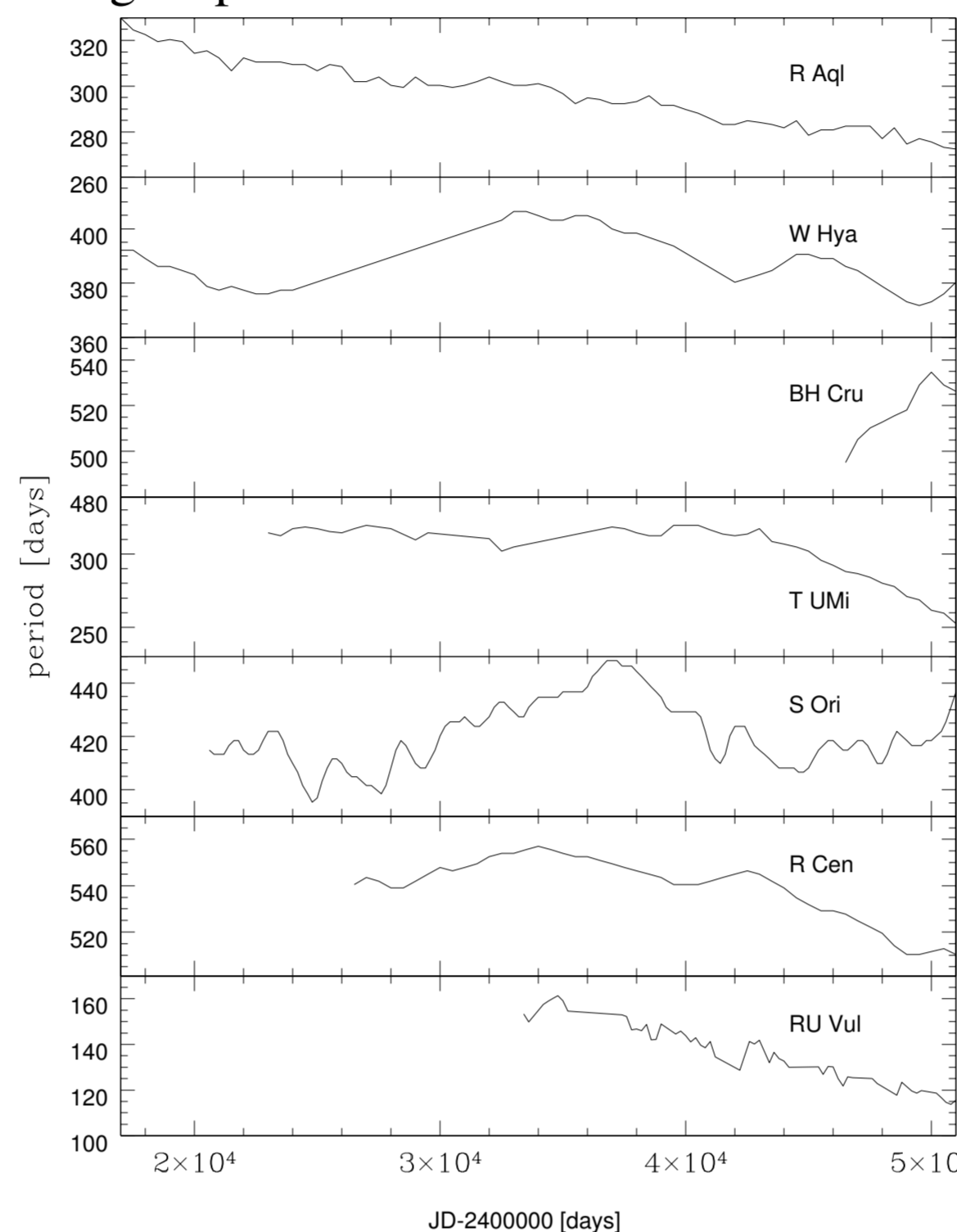


Figure 2: Period evolution of Miras. The x-axis covers one century starting in AD 1905. R Aql and RU Vul are examples of continuous changes; T UMi and possibly BH Cru show sudden changes and W Hya, S Ori and R Cen show meandering periods.

2.4 Properties

- The stars with **continuous changes** show period change of about 25%, over 200 yr. Stars with **sudden changes** show the same total change, but ten times faster. The **meandering stars** show half the total change, but have about the same fractional change per cycle as the continuous changing stars.

- Both declining and increasing periods occur.
- The meandering Miras all show long periods.
- The stars include both oxygen and carbon stars.
- The observed stars with period variations are a small fraction of all known Miras. At $P < 400$ days, a few per cent vary their periods (Fig. 3); for $P > 450$ days, the fraction increases. However, fewer Miras with $V_{\max} > 6$ have been monitored for sufficiently long to detect changes. Among the brightest Miras with $P > 450$ days, **up to half show period variability**.

2.5 Models

On-going thermal pulses are expected to lead to very fast period variations (Wood & Zarro, 1981). Alternatively, Van Horn et al. (2003) find fuel-supply-driven luminosity oscillations with time scales $\sim 10^3$ yr during the hydrogen-burning phase. These also predict period fluctuations, but occurring more often than thermal pulses. Both models can fit especially the continuous and sudden changes. The meandering Miras vary too fast for this second model. An envelope instability, e.g. responding to the amplitude of the pulsation, could be considered (Zijlstra et al., 1996; Ya'Ari & Tuchman, 1996).

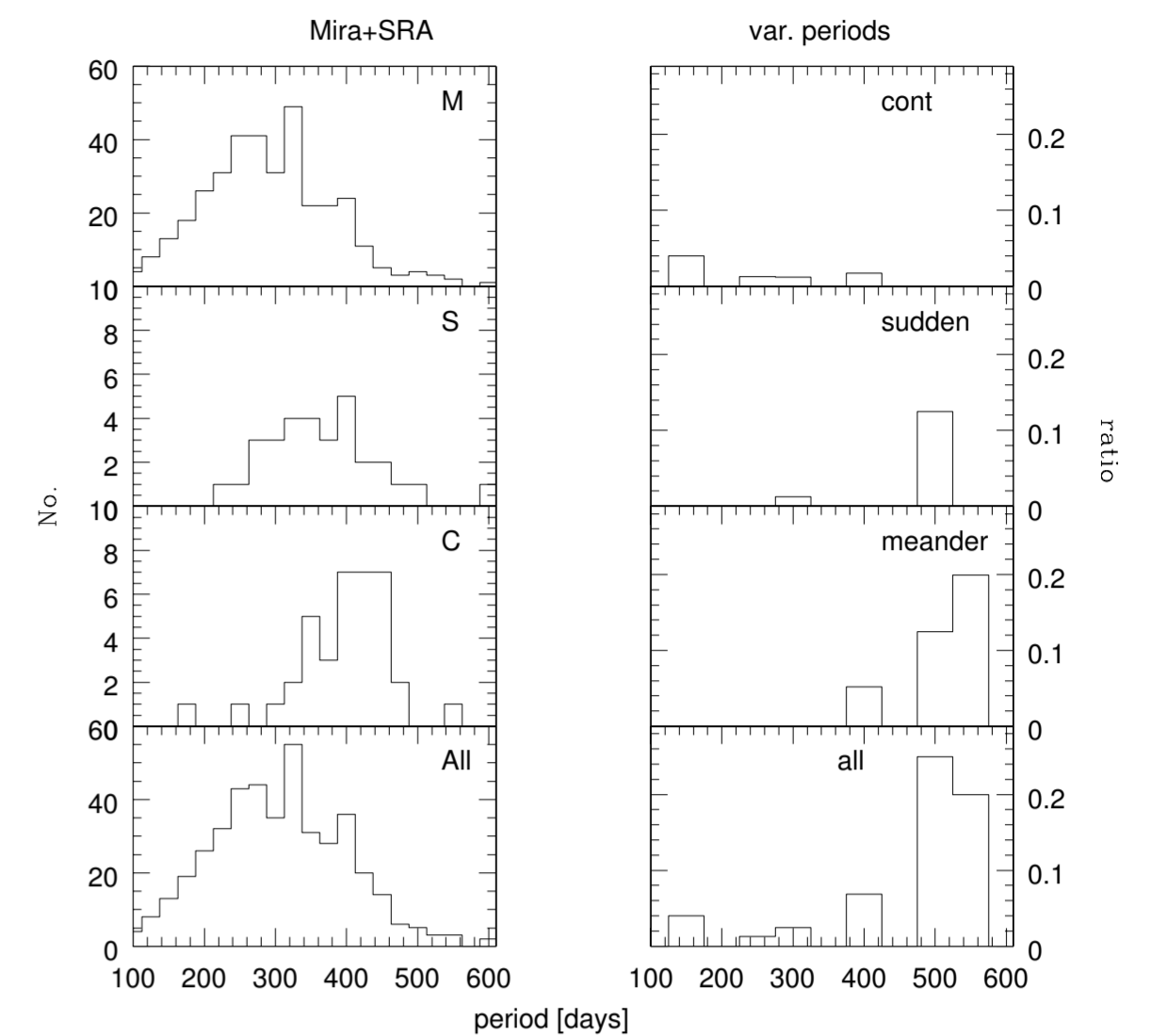


Figure 3: Left: No. of all stars with $V_{\max} < 10$, as function of period. Oxygen, S-type and carbon stars are shown separately. Right: fraction of stars with variable periods, versus period

3 SC and CS stars

BH Cru recently evolved from an SC to a CS star. SC stars have C/O close to 1, but show metal oxides (e.g. ZrO, YO). CS stars instead show C_2 bands. The change in BH Cru has been attributed to carbon dredge-up following a thermal pulse. The change coincided with a large increase in period. In the thermal pulse scenario, this occurs immediately after the onset of the pulse. However, carbon dredge-up after a pulse only occurs once the period is again decreasing, and the spectral evolution is not predicted.

A decreasing temperature may have caused the spectral changes. Fig. 4 shows its effect on the equilibrium chemistry of the photosphere. BH Cru has $T_{\text{eff}} = 3000$ K and C/O = 1.02. The period change suggest a 150 K decrease in T . This would have given an increase in the C_2 abundance of a factor 5, and a decrease in ZrO, without requiring dredge-up.

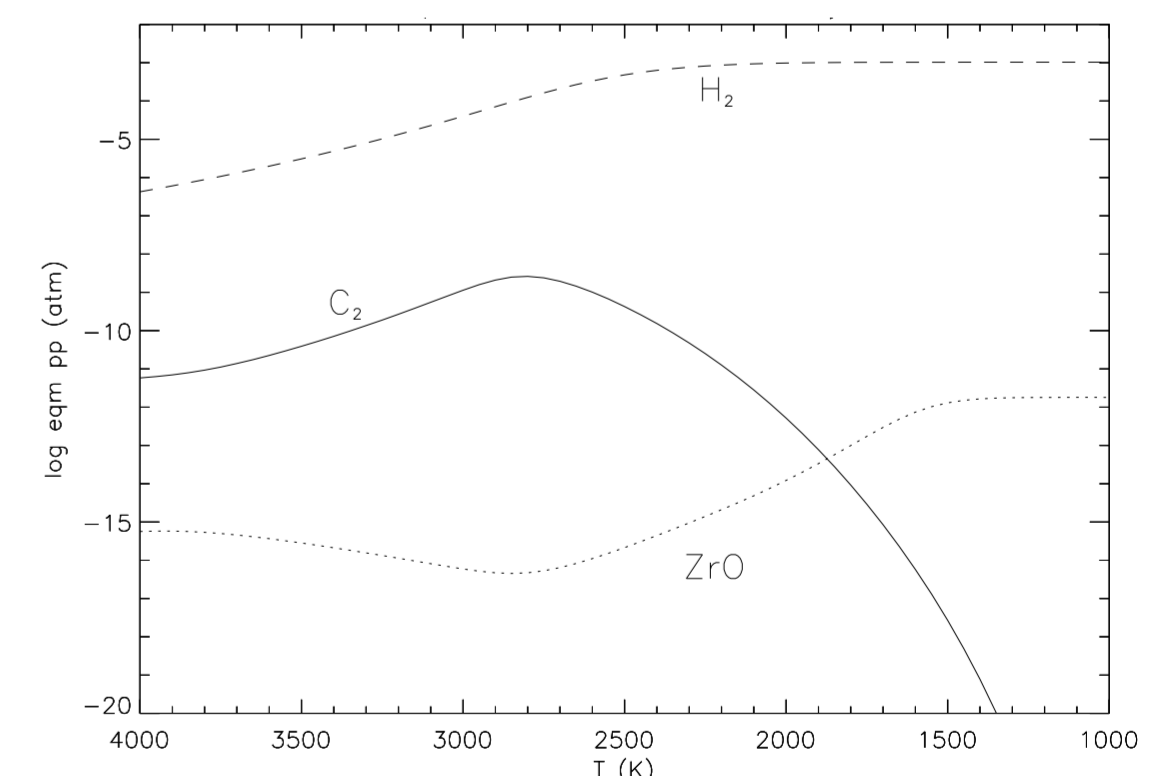


Figure 4: Photospheric C_2 and ZrO abundance as function of temperature. The increasing period of BH Cru indicates an increasing radius (eq. (1)) and a decreasing temperature. The abundances are for C/O=1.5, but the same behaviour is found for C/O closer to 1.

References

- Van Horn, H. M., Thomas, J. H., Frank, A., & Blackman, E. G. 2003, ApJ, 585, 983
Wood P. R., Zarro D. M., 1981, ApJ, 247, 247
Ya'Ari A., Tuchman Y., 1996, ApJ, 456, 350+
Zijlstra A.A., Bedding T.R., Mattei J.A., 2002, MNRAS, 334, 498