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Period Changes in Miras

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Abstract. A brief rationale for the use of a period test statistic based on the periodogram is given. Results of its application to 380 Mira datasets are summarised.

1. Introduction

The AAVSO has a large database of Mira star information. Amongst other items, the times of light maximum and light minimum for many pulsation cycles are available for a few hundred Miras. The time differences between successive maxima (or successive minima) serve as estimates of the period of a star; such data for R Sco are plotted in Fig. 1. A question which is of interest is whether there is any evidence that the mean pulsation period is changing.

A standard method used to study changes in the pulsation periods of stars is inspection of $O-C$ ("observed – calculated") plots. Lombard & Koen (1993) pointed out that such diagrams should be standardised with respect to the appropriate noise level of the data if they are to be properly interpreted.

However, determination of the noise level is not as simple as one may at first imagine: if the mean is indeed variable, this will bias estimates of the properties of the noise. A second problem is that the curvature in an $O-C$ diagram reflects the sense of the period change. This implies that the effects of period changes of opposite sense will counteract each other in the $O-C$ diagram, leading to loss of sensitivity.

A simple, but realistic simulation can be used to demonstrate these points. The top panel of Fig. 2a shows simulated data, with a covariance (i.e. noise) structure typical of that seen in Miras. The lower two panels show the result of modulating the mean period by adding a sinusoid with an amplitude of 2 units. The corresponding $O-C$s, all plotted on the same scale, appear in Fig. 2b. Comparison of the bottom two panels of the $O-C$s is particularly instructive: despite the fact that the amplitude of period modulation is the same in the two cases, the maximum $O-C$ excursion is *smaller* in the bottom panel. This is a result of the more rapid period change visible in the bottom panel of Fig. 2a.

It is also interesting to consider the significance levels of the standardised $O-C$ test in the two cases where there is a change in mean period. As a result of

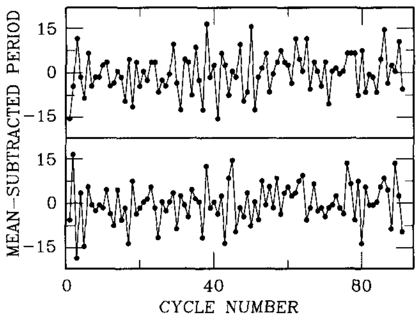

Figure 1. The time intervals between successive times of light maximum (top panel) and successive minima (bottom panel) for R Sco. Mean periods of 223.45 and 223.53 d respectively have been subtracted from the two datasets.

the presence of the trends in $\overline{P}$, the noise level of the data is overestimated, leading to an underestimate of the significance of the $O - C$ excursions: significance levels of 0.11 and 0.30, instead of 0.01 and 0.04, are found.

Lombard (1998) suggested a periodogram-based alternative to the $O - C$ method, in which both the problems mentioned above are dealt with. The efficacy of the method rests on the clear separation in the frequency domain between slow changes in the mean period on the one hand, and rapid variability due to noise on the other. The high frequency part of the periodogram thus carries information about the covariance structure of the random part of the data, while the low frequencies provide information about slow evolution of the mean period. Furthermore, the periodogram is insensitive to the sense of any period change: changes of opposite sense are cumulative, rather than competitive. This is clearly visible in Fig. 3, where the periodograms of the three datasets of Fig. 2a are shown. The large increase of low frequency power with the more rapid variation of the mean power is particularly noteworthy.

2. Results

Koen & Lombard (2001) described how the full data (times between light maxima, and those between light minima) can be combined and tested using Lombard's (1998) tests. The method has been modified slightly and applied to 380 Mira datasets from AAVSO (1990) which are sufficient large. Details can be found in Koen & Lombard (2004): here we only present a list (Table 1) of stars for which the test gave highly significant results. Fig. 4 summarises the significance levels found for all the stars.

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Table 1. A list of stars for which the period change statistic was significant at the 1% level or better.

1	R Aql	14	W Dra	27	T Cap	40	W Eri
2	R Aur	15	Z Aur	28	U Ara	41	RS Aql
3	R Cnc	16	TY Cyg	29	Z Cas	42	R Cam
4	R Hya	17	U Per	30	W Tau	43	V Cap
5	RS Lyr	18	V Cas	31	Z Vel	44	Z Sco
6	RU And	19	S Lac	32	ST Cyg	45	U CMi
7	RW Car	20	S UMi	33	U UMi	46	RT Cen
8	S Her	21	T Ser	34	X Aur	47	RS Sco
9	S Ori	22	R Lep	35	T Ari	48	U Her
10	S Scl	23	R UMa	36	Y Mon	49	TW Cyg
11	S Sex	24	T Cep	37	S Vir	50	SV Dra
12	T CMi	25	RU Lyr	38	ST And	51	R Cyg
13	T Hya	26	U Dra	39	T Hor	52	W Peg

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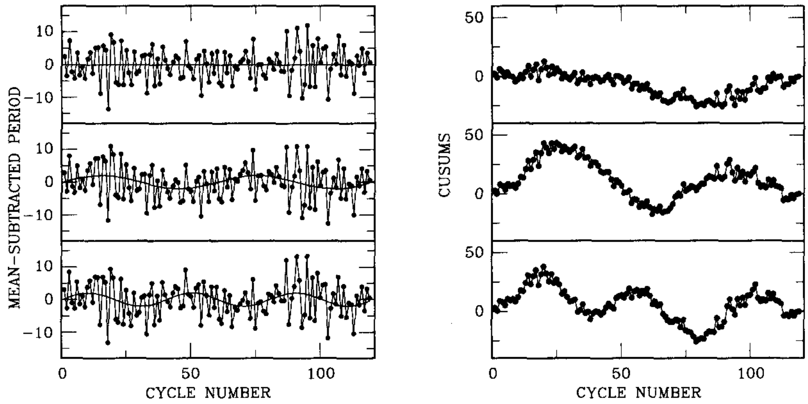

Figure 2. (a – left): Simulated Mira period data with a constant (top), slowly changing (middle) and rapidly changing mean period. (b – right): $O - C$ diagrams for the three simulated datasets in (a).

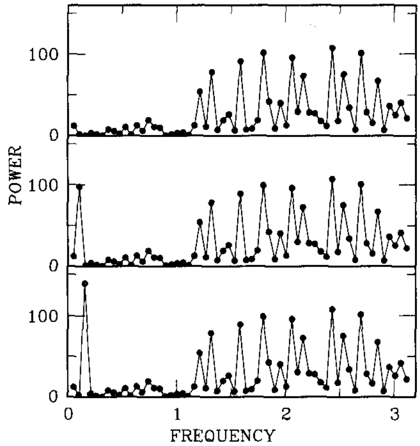

Figure 3. Periodograms of the three datasets in Fig. 2a.

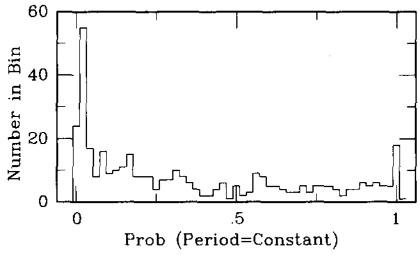

Figure 4. The distribution of the 380 test significance levels.

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