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Instabilities in Long Period Variables.

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Abstract.
The light curves analysis of stars on the Asymptotic Giant Branch (AGB) with relatively long periods (greater than 450 days), allow us to see that the evolution of their period over the time is not constant: it is subject to instabilities. Using a wavelet analysis we derive three main trends occurring in these stars: sudden change, meandering behavior or continuous change. The variations may be the consequences of physical processes like thermal pulses, convection... etc, and lead to a particular distribution of the mass loss. This paper presents the results obtained from the study of Mira-type stars and Semiregulars.

Key words. Stars: Miras – Semiregulars – period – light curves – Wavelet analysis

1. Introduction

Physical processes such as thermal pulses, convection or even magnetism, are likely to play a role in the evolution of AGB stars. They would affect not only on their pulsation but also the mass loss produced.
Using the data from the American Association of Variable Stars Observers (AAVSO) and the Association Francaise des Observateurs d'Etoiles Variables (AFOEV); combined with a wavelet analysis tool (developed by Foster 1996), we investigated the particular behaviors of Mira-type stars and Semiregulars with a pulsation period greater than 450 days. We used this threshold because these objects are more likely to present perturbation in the evolution of their period.

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2. Classification of the LPVs Miras

There are not large numbers of Miras with such long periods: we counted about 50. As for the majority of Miras, they are likely O-rich. But we have to take into account the quality of the light curves: we avoided those with too large gaps between the data points, with many incoherent points ... etc. Finally, only 23 stars remained with enough data to analyse. To make a direct comparison possible, we used the same method as Templeton, Mattei and Willson (2005) to determine the period evolution: we used a linear fitting routing on $d(lnP)/dt$ (slope over average period). The values found for the stars of our sample are in the order of $|10^{-3}|$ to $|10^{-5}|$ yr^{-1} against values inferior to $|10^{-3}|$ yr^{-1} for the majority of the stable Miras with lower period. The very long period Mira variables seem significantly unstable. The graphics relative to the period variations show at least three different main trends (also defined by Zijlstra and Bedding, 2002). The classification can be based on four "prototype stars"each of those presenting a different behavior. We can also notice that there is no obvious link between the type of period change and the chemical composition of the stars.

– R Cen (Fig.1) underwent a sudden change in the period evolution: from 1919 to 1935 the period decreased from 550 to 543 days and after a brief episode of increase to 553 days until 1949, we see a spectacular drop to 512 days by 2001 (- 41d). This fall may be due to the occurrence of a thermal pulse. Only this star was reported to have such a behavior.

– V Del (Fig.2) is an example showing a continuous change in its period. This can be either a period decrease (like V Del) but other stars show a continuous increase. This mira with an observed period of 533.51d, presents a drop of ~22 days over 88 years. We can also notice that this change is not straight but presents fluctuations.Three stars in total present such changes.

– V Cam (Fig.3-Left) is representative of the majority of the stars of our sample (19 over 23). The period presents small changes that are close to a sinusoidal trend. There is no obvious sign of a general drop or increase in the long run.

– The RU Tau (Fig.3-Right) type could be described as belonging to the previous group. Indeed, it presents the same meandering behavior, the difference is in the the few number of oscillations and their quasi-regularity.

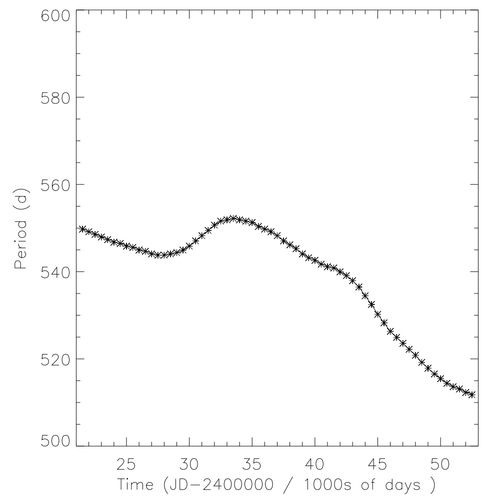

Fig. 1. Sudden change in the Mira variable R Cen.

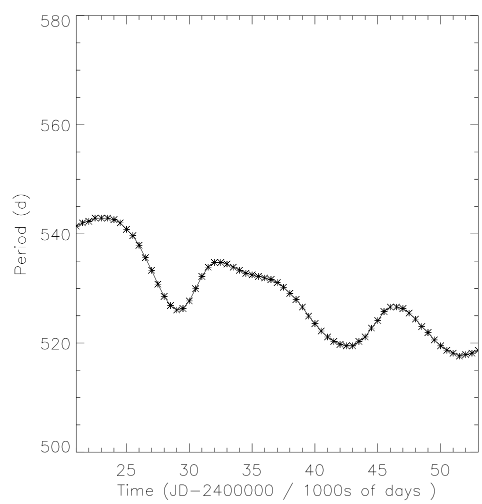

Fig. 2. Continuous decrease of the period of the Mira V Del.

3. Classification of the the Semiregulars LPVs

The Semiregulars are red giants or supergiants pulsating stars divided into different classes: SRa, SRb, SRc, SRd (supergiant) according their regularity. The number of objects that comply with our selection criterion is not high: we only found 26 stars. Once the wavelet analysis is applied, only 11 remain (among them 7 O-rich and 4 C-rich). The problem in dealing with Semiregulars is the presence of close modes, namely the first and second overtones, which create frequency overlapping and aliasing effects. Using linear fitting to

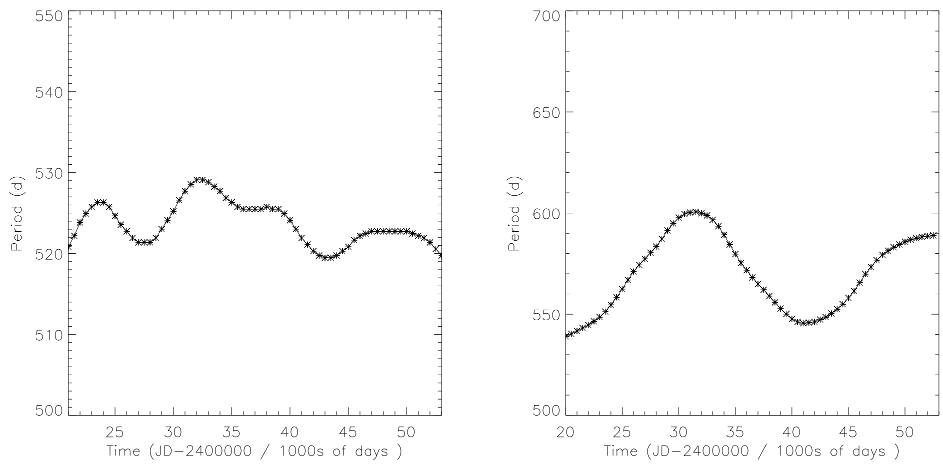

Fig. 3. Left Panel:V Cam (Mira) shows a quasi-sinusoidal evolution of its period, with more or less regularity. Right Panel: RU Tau (Mira) can be considered as meandering star, but the number of oscillations is low.

quantify the period change over the time, we observe that the very long period Semiregulars were unstable with $d(lnP)/dt$ (change rate) comprises between $|10^{-3}|$ and $|10^{-5}|$ yr^{-1} which is in the same order for the unstable miras. Two main trends can be derived: continuous and meandering changes.
We can notice that the nature of the changes is independent of the type of irregularity of the stars (SRa,SRb...etc).

- ST Psc (Fig.4-Left) presents a nearly straight increase gaining 90 days in 33 years. On the contrary, S Aur and S Per show a slight decrease that could be associated to a meandering behavior. Four stars, in total present that trend.
- T Cnc (Fig.4-Right) is an example of proper meandering variation mirroring the Mira-type variable V Cam. Six objects have this behavior.

4. Nature and consequences of the instabilities

The origin of the different trends may be associated in part to the occurrence of thermal pulses; that would be true mainly for sudden changes. Convection or even a cyclic magnetic activity may be invoked for the meandering behavior.
The presence of Tc^{99} is a good indicator of the occurrence of a dredge-up, hence for the occurrence of a thermal pulse (Lebzelter et al.,2003). Indeed in some Mira stars like R Cen (Hawkins et al, 2001), RU Aur and RU Her (Lebzelter and Hron 2003), Technetium 99 has been found. For the Semiregulars, only SW Gem and TW Peg have been studied and found without the element by Lebzelter and Hron (2003). We can see that few of the LPVs of our sample have been investigated yet. But we can also notice that from a statistical point of view, it seems highly unlikely that TPs are responsible for all the instabilities seen in those stars.
The different behaviors observed can also play a role in the distribution of the mass loss. This distribution would therefore be different depending upon whether the star experiences a sudden change (we would have an unique shell) or a meandering change (presence of multiple closely spaced rings).

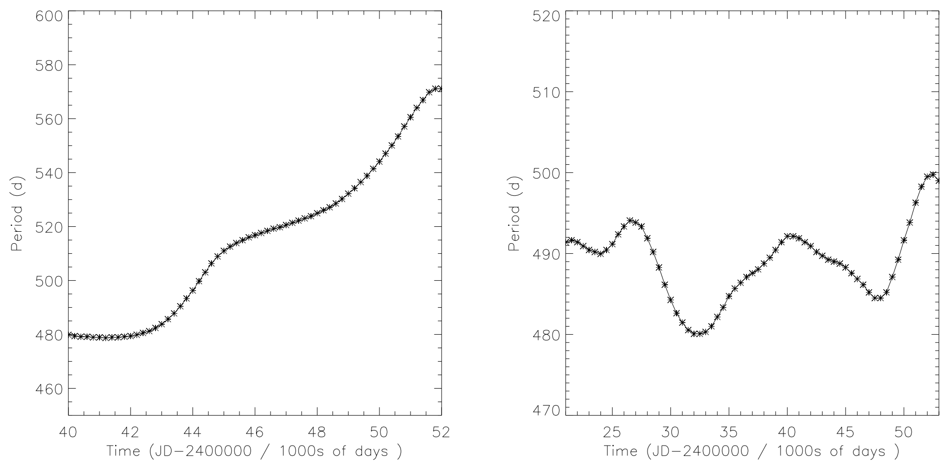

Fig. 4. Left:Continuous increase in the Semiregular ST Psc. Right: Meandering trend in the Sr T Cnc.

5. Conclusion and perspectives

The study of the period evolution of Miras and Semiregulars with a period greater than 450 days shows that the periods are unstable on the timebase sampled. The period changes have been derived by a wavelet analysis and different behaviours are found. We discriminate between continuous, sudden and meandering period changes. The reason for such behaviors is not obvious. The action of thermal pulses can be put forward but no extensive research on e.g. the presence of Tc^{99} in these stars has been carried yet. The doubt remains for example on the origin of the very small variations in the meandering stars: TPs cannot be responsible for all the forms of instabilities. So, we mustn't forget the possible implication of other processes like convection or magnetism.
To confirm or disprove all these hypothesis more observations are needed: high resolution spectroscopy to detect Tc^{99}, IR and optical observations for the detection of shells around the star and spectropolarimetry to unveil the possible role played by the magnetic field.

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