Solar-like oscillations in semiregular variables

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Abstract. Power spectra of the light curves of semiregular variables, based on visual magnitude estimates spanning many decades, show clear evidence for stochastic excitation. This supports the suggestion by Christensen-Dalsgaard et al. (2001) that oscillations in these stars are solar-like, i.e., stochastically excited by convection, with mode lifetimes ranging from years to decades.

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Oscillating red giants with high luminosity – the long period variables – are conventionally divided into Miras and semiregulars. Both can be monitored visually, thanks to the extreme temperature sensitivity of the TiO absorption bands that dominate the visible spectrum. For some stars, visual magnitude estimates by amateur astronomers span many decades.

Mira variables have large amplitudes and are very regular, reflecting the nature of the driving process, which is self-excitation via opacity variations. Semiregulars (SRs), on the other hand, have lower amplitudes, less regularity and often show two or three periods (Kiss et al., 1999; Wood et al., 1999). In these stars, it seems plausible that there is a substantial contribution from convection to the excitation and damping. Indeed, Christensen-Dalsgaard et al. (2001) have suggested that the amplitude variability seen in SRs is consistent with the pulsations being solar-like, i.e., stochastically excited by convection. The subject of Mira-like versus solar-like excitation has also been discussed in the context of K giants by Dziembowski et al. (2001).

Figures 1 and 2 show power spectra of visual observations for some of the best-studied long period variables. The first star, R Leo, is a typical Mira (period 310 d) and shows a narrow peak in the power spectrum. This indicates that the pulsation is stable in both period and phase.

The other stars are SRs, and all show strong evidence for stochastic excitation. The power from each oscillation mode is split into a series of peaks under a narrow envelope. This structure is typical of a stochastically excited oscillator and is strikingly similar to close-up views of individual peaks in the power spectrum of the Sun (Toutain & Fröhlich, 1992). We can estimate the mode lifetime from the width of the envelope. This seems to range from a few decades (L2 Pup) down to only a few years (e.g., X Her). For most doubly-periodic stars, the mode lifetime is similar for both periods.
Figure 1. Power spectra of visual observations of a Mira and four semiregulars. In each case, the inset shows the spectral window.
Figure 2. Same as Fig. 1, for four more semiregulars, plus one red giant from MACHO observations of the LMC (bottom panel; note change of horizontal scale).
RR CrB appears to show two closely spaced modes (periods 54 and 60 d), which at first sight seem hard to understand as consecutive low-order radial modes. However, observations of semiregulars both locally (Kiss et al., 1999) and in the LMC (Wood et al., 1999) also show some stars with period ratios close to 1.1, and models by Wood et al. (1999) indicate plausible identifications with low-order modes.

V Boo is an unusual star, with a Mira-like mode (258 d) whose amplitude has decreased steadily over the past 90 years, plus a shorter-period mode (137 d) that has remained relatively constant in amplitude (Szatmáry et al., 1996; Bedding et al., 1998; Kiss et al., 1999). As expected, the power spectrum at the long period is very strong (the peak is way off scale, at 0.1 mag$^2$), while the spectrum around the short period shows a low broad hump. However, there is also a narrow peak just left of centre in the latter. This peak does not coincide with the harmonic of the longer period, and apparently indicates a coherent long-lived component to an otherwise stochastically excited oscillation.

g Her (= 30 Her) has two pulsation modes with solar-like envelopes (90 and 60 d), but also a much longer period (890 d) that is coherent (the peak is off the top of the graph, at 0.033 mag$^2$). The latter is a typical example of a long secondary period, often seen in SRs and probably due to binarity (Wood et al., 1999; Huber et al., these Proceedings).

Finally, the bottom panel of Fig. 2 shows the power spectrum of a red giant in the LMC, based on seven years of data from the MACHO database. We see evidence for perhaps as many as five equally-spaced modes, all with similar envelopes. There is clearly much to be learned from data such as these.

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