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Color me Correlated: Using Color Amplitudes as a Diagnostic of White Dwarf Pulsation Parameters

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White dwarf stars are the endpoint of evolution of 97% of all stars. As such, they contain clues to prior stages of evolution, such as mass loss and the red giant phase. A subclass of white dwarfs are observed to pulsate, and through asteroseismology we can use the pulsations to constrain details of their interior structure. In order for this to be successful, we need an independent way of determining the spherical harmonic parameters, ℓ and m, of each pulsation mode.

The observed amplitudes of pulsating white dwarfs depend not only on their pulsation indices, ℓ and m, but also on the amount of limb darkening. Since limb darkening is a function of wavelength, the amplitude ratio of a mode observed in different filters can place constraints on the ℓ value of the mode (see [1,2] for examples). If nonlinearities in the form of harmonics are also present, then constraints can be placed on both ℓ and m.

We employ this technique using lightcurves in different colors and, for a given mode, compare the amplitudes of the first through third harmonics with theoretically calculated amplitudes. Small amounts of noise in the observed lightcurves can result in incorrect parameters. However, by taking lightcurves in different filters simultaneously and obtaining lightcurves whose errors are correlated, the effects of noise are greatly reduced.

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1. Method for Determining ℓ and m

In order to determine the ℓ and m pulsation parameters, we generate nonlinear theoretical light curves (see [3]) in three different filters (u', g', r') at a set of $T_{\rm eff}$ and $\log g$ values and a range of ℓ and m values with ℓ going from 0 to 2 and m going from 0 to ℓ. From these light curves, the amplitudes of the first three harmonics are calculated and stored with the associated ℓ and m values. The next step is to consider an observed light curve, which in our case is also synthetic with known ℓ and m values, and decompose it into its first three harmonics as well. Then ratios are formed for each harmonic between different filters and each ratio is compared with the corresponding ratios for each ℓ and m combination stored. The ℓ and m combination whose ratios most closely match the observed ratios is deemed the correct set of ℓ and m values.

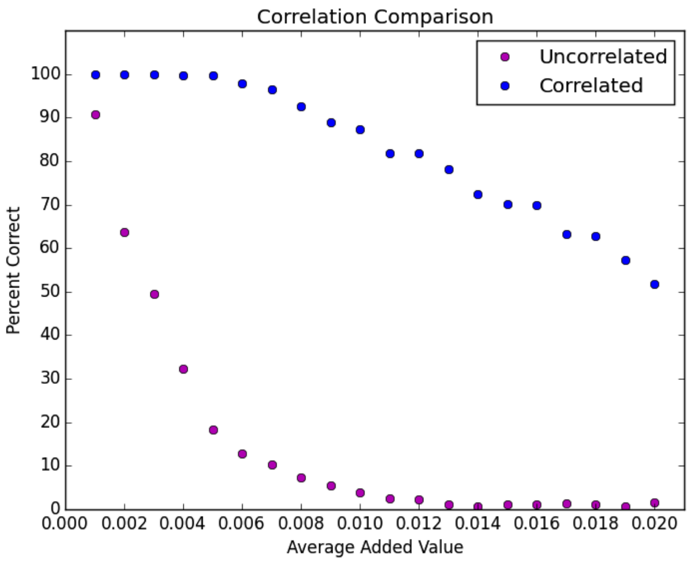

Figure 1: Percent of trials where the parameters were correctly recovered out of 500 trials. As more error is added, recovering the parameters becomes more difficult, but if the errors in the different filters are correlated, then the pulsation parameters can recovered much more reliably.

After finding a method for determining the ℓ and m pulsation parameters for perfect synthetic light curves, we decided to add Gaussian noise to our observed light curves and determine the point at which the method is no longer adequate. The first trials of this showed that the method was very sensitive to the amount of noise added, getting the parameters right 50% of the time when the relative noise added to the light curves was about 0.003. For this case, our method would often be impractical because light curves cannot easily be obtained with such a low noise level. Next, we considered adding correlated noise to each of the three light curves, where the noise added to one light curve is the same as that added to the other two. With this type of noise, the method was more robust, getting the parameters right 50% of the time at a relative noise level of 0.021.

2. Conclusions

The assumption of correlated noise is based on simultaneous observations in the different filters, and such observations present their own set of challenges. Nevertheless, these observations offer some clear advantages in terms of their noise properties for mode identification.

References

[1] Robinson, E. L., Mailloux, T. M., Zhang, E., et al., 1995, ApJ, 438, 908

[2] Brassard, P., Fontaine, G., Wesemael, F. 1995, ApJS, 96, 545

[3] Montgomery, M. H. 2005, ApJ, 633, 1142

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