Ultra-precise analysis of the light curves of CoRoT and *Kepler* δ Scuti stars

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Abstract. It is well known that the residuals of the multifrequency analysis of δ Scuti stars are correlated, giving rise to challenging features such as a plateau (HD 50844, HD 50870, HD 49434, ...) of non-resolved frequencies with amplitude higher than the expected noise level. Several hypotheses have been advanced to explain these features: effective convection, rotation, non-linear interactions, etc. We have recently demonstrated that in some cases the underlying function describing the light variations of δ Scuti stars has not the property of being analytic. The strong consequence of this result is that the Fourier expansion on which the harmonic analysis is based could be not justified.
In order to know the extension of this phenomenon among δ Scuti stars, we have used photometric data from CoRoT seismofield and a set of *Kepler* stars. The results show that this inconsistency in the application of harmonic analysis is almost ubiquitous to the δ Scuti pulsating stars.

1 Context

To perform seismological studies of the stars it is essential to detect pulsational frequencies in their photometric or radial velocity time series. A periodogram ([1]) is a well defined and easy to calculate estimator of the spectral density of a time series. Therefore, it is widespread in the asteroseismology literature. However, it is not always guaranteed that a periodogram is an unbiased estimator of the spectral density, i.e. the discrete Fourier transform converges to the real frequency content of the time series. Indeed, it is only guaranteed that a function has a convergent Fourier expansion when the function is analytic.

In [2] we proposed a method to study the analyticity of the underlying function of light curves through the "connectivities" in order to test whether the periodogram is an unbiased estimator of the spectral density. Connectivities are calculated by fitting an analytic model to the time series. In [2] we used an L2 metric to estimate the best fitting model, here instead we make use of an L1 optimization since this proved to be superior when the data has a non-Gaussian distribution ([3]).

We have applied this test to a set of 10 light curves from CoRoT and *Kepler* observations (5 each). *Kepler* light curves were selected from the list of δ Scuti stars characterized in [4] and CoRoT light curves were selected from the seismo targets in the literature taking into account the classification during the preparatory phase of the mission ([5]).

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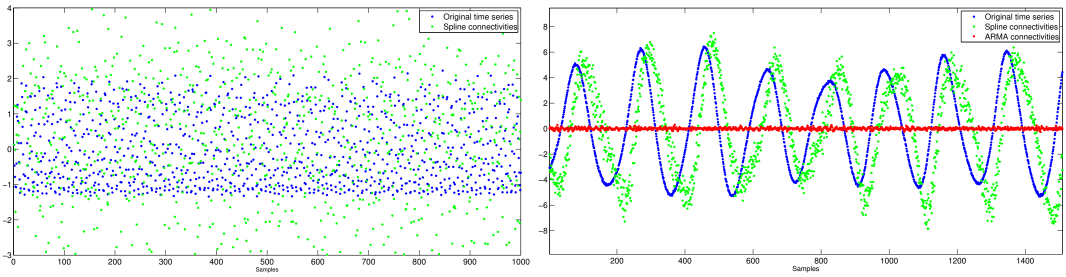

Figure 1. Analyticity test for KIC 09408694 (left panel) and KIC 010273384 (right panel). Light curves are shown in blue, connectivities calculated by a spline fitting (analytic) in green and by an ARMA model (non-analytic) in red. Correlation indicates a non-analytic underlying function.

2 Analyticity test and results

We have found that 8 of the 10 δ Scuti stars analyzed show light curves with a non-analytic underlying function. Figure 1 shows the result of the analyticity test for the light curves of two *Kepler* stars: one which has an analytic underlying function (KIC 9408694) and one which does not (KIC 10273384). Notice that splines connectivities are correlated with the light curve of KIC 10273384[1] while for KIC 9408694 there is no apparent correlation and the Pearson correlation coefficient is -3.9×10^{-5}. Correlation with the original time series indicates that the underlying function is non-analytic according to the test (for more details, see [2]).

Our results suggest that the non-analyticity of the underlying function is an almost ubiquitous phenomenon in the photometric time series of δ Scuti stars as observed by the space satellites CoRoT and *Kepler*. In consequence it is not guaranteed that the periodogram is an unbiased estimator of the frequency content of δ Scuti stars.

A massive study of *Kepler* and CoRoT stars is in progress to shed more light on the origin of the non-analyticity of the underlying function.

References

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[1] ARMA connectivities are shown here to demonstrate that a non-analytic approximation can fit the data.