From periods to cycles: new methods applied to solar, stellar and "in silico" data

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Many of the astronomical datasets, such as photometry of young active stars or surface activity tracers on the Sun show rather cyclic than exactly periodic behaviour. However it is widespread practice that these datasets are studied using spectral analysis methods that intrinsically make an assumption of a long term stable period. One of those methods is a well known Lomb-Scargle periodogram. Less known, but alternative to spectral analysis methods are methods of phase dispersion minimization (PDM). In our study, we have generalized one of these methods referred to as D^2 statistic [1] so that it relaxes the condition of a stable period. The modification to the statistic, by assuming that the period can slightly vary over time around a certain mean value, was introduced by employing a selection function in time and phase [2, 3]. We will refer to this mean oscillation period as the cycle length. The PDM methods are easily generalizable to multidimensional time series such as the data sets being produced by fully three-dimensional (3D) numerical models. Recently we have used one of such datasets namely solar-like semi-global 3D magnetoconvection simulation [4], denoted as PENCIL-Millennium, which exhibits solar-like cycles with irregular behavior. By applying the D^2 multidimensional statistic we detected four cycles in different regions of the simulation space. The shortest cycle being extremely incoherent, was previously impossible to detect with any other period estimation tool [3]. Besides estimating lengths of magnetic activity cycles, D^2 method is useful in estimating the rotational periods of the active stars. Due to surface differential rotation, possible azimuthal and latitudinal dynamo waves, the light-curves of these stars exhibit rather quasi-periodic behaviour. This leads to the power spectra with multitude of spectral lines grouped into different bands. By making small assumptions on the possible physical causes behind this, we can estimate the mean rotational period of the star (an analogue of the Carrington period for the Sun). This mean rotational period serves as a good input parameter when building continuous models for the light-curve of the star. One of the flexible models amongst the others is the so called Carrier Fit model, which we have used for extracting the epochs of the minima of the young solar analogue LQ Hya. The results showed good agreement with the previous studies [5].

[1] J. Pelt. Statistical Methods in Astronomy, 1983, 201, 37-42.
[2] J. Pelt. European Southern Observatory Conference and Workshop Proceedings, 1993, 47.
[3] N. Olspert, M. J. Käpylä, J. Pelt. Workshop on Solar & Stellar Astronomy Big Data, 2016.
[4] M. J. Käpylä, P. J. Käpylä, N. Olspert, et al. Astronomy & Astrophysics, 2016, 589, A56.
[5] N. Olspert, M. J. Käpylä, J. Pelt, et al. Astronomy & Astrophysics, 2015, 577, A120.