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Significance of periodogram peaks

Maria Süveges[1], Leanne Guy,[1] Shay Zucker,[2] and the Gaia CU7 team[1]

[1]Dept. of Astronomy, University of Geneva, Switzerland
[2] Dept. of Geosciences, Faculty of Exact Sciences, Tel Aviv University, Israel

Abstract. Three versions of significance measures or False Alarm Probabilities (FAPs) for periodogram peaks are presented and compared for sinusoidal and box-like signals, with specific application on large-scale surveys in mind.

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The detection of tiny periodic signals in noisy and irregularly sampled time series of large-scale surveys is a challenging task due to sparse time sampling which is neither regular nor fully irregular, oversampling in frequency space and the ensuing strong dependency among periodogram values at different frequencies. We compare three recent propositions for the computation of the FAP from the literature. The F^M method (Paltani 2004; Schwarzenberg-Czerny 2012) is based on an equivalent independent frequency set. Baluev (2008) draws on the extreme-value theory of stochastic processes. The GEV method (Süveges 2014) uses univariate extreme-value theory.

The F^M method can be applied to any periodogram type for which the marginal distribution is known; the Baluev method, only to those with some specific margins; the GEV method, to any periodogram. All assume uncorrelated errors in the time series. The Baluev method does not need the estimation of any parameters and its CPU requirements are negligible. The other two methods must estimate some parameters from simulations. The needs of the GEV method however can be reduced in two ways (Süveges 2014; Süveges et al. 2015) and so it requires less CPU than the F^M method.

Süveges et al. (2015) describe the performance of the three methods on sinusoids. For transit-like signals analysed with the box least squares method, we show that the GEV method approximates the true distribution of the periodogram peak better than the F^M method, similarly to the results on sinusoids. At a desired confidence level α, the fraction of false signal detections on noise (Type I error) by the GEV method is close to α, whereas the F^M method results in too many false positives. Consequently, the F^M method detects a larger fraction of shallow-transit signals than the GEV method. However, among the detections, the fraction of those with a *correctly recovered* period is smaller than for the GEV method. When time series with no periodicity (pure noise) are also present among the data, this fraction decreases further, more so for the F^M method than for the GEV method, due to the general permissiveness of the former.

In summary, both the Baluev and the GEV methods are better suited to the needs of large-scale surveys than the F^M method, due to to their more favourable rate of correct frequency identifications among all detections and to their lower CPU needs.

References

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