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Statistical analysis of periodograms standardized by 3D hydrodynamical simulated time series of stellar surfaces

When the noise affecting time series is colored (i.e. frequency dependent) with unknown statistics, a difficulty for the detection of periodic signals is to control the true significance level of the test outcome.

Recent hydrodynamic simulations, performed in 3 dimensions, are able to generate reliable time series of convection, which is a stochastic colored noise for exoplanet detection. The objective of this work is to investigate whether these 3D simulated stellar noise training data sets could improve the detection.

Assuming the reliability of these synthetic time series, we propose to use them to standardize the periodogram of the data under test. We analyze the statistics and the performances of different detection tests applied to these new periodograms.

In the case of regular sampling, we show that the proposed standardization leads to powerful tests whose false alarm and detection rates can be accurately (analytically) controlled. New adaptive tests, from the literature in Statistics (e.g. Higher-Cristiscm and Berk Jones tests), never used in the exoplanet community, are shown to be particularly interesting to detect RV signatures that deviate from pure sinusoidal oscillations. In the case of irregular sampling, we demonstrate that combining the proposed periodograms standardization with bootstrap techniques also allow to derive consistent FA rate estimates. Consequently, if reliable time series of the colored noise are available, they can constitute a useful tool to derive detection tests that are both powerful and reliable.

Authors: Dr SULIS, Sophia (Austrian Academy of Science, Space Research Institute); Dr MARY, David (Université Côte d'Azur, Observatoire de la Côte d'Azur, CNRS); Dr BIGOT, Lionel (Université Côte d'Azur, Observatoire de la Côte d'Azur, CNRS)

Presenter: Dr SULIS, Sophia (Austrian Academy of Science, Space Research Institute)

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