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TFAW: signal detection, reconstruction and de-noising for time-domain surveys using wavelets.

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Abstract

There have been many efforts to correct systematic effects in astronomical light curves to improve the detection and characterization of planetary transits and astrophysical variability. Algorithms like the Trend Filtering Algorithm (TFA) use simultaneously-observed stars to measure and remove these systematic effects. We present TFAW, a modified version of TFA which reduces the high-and-low-frequency noise in variable-star light curves without changing their intrinsic characteristics. We modified TFA's signal detection by adding a Stationary Wavelet Transform filter that allows to do a preliminary noise and outlier removal to increase the signal-to-noise ratio of any variable signal within the data. An additional wavelet-based filter is added to TFA's iterative signal reconstruction to characterize the noise- and trend-free signal and the underlying noise contribution at each iteration. This adaptive noise estimation reduces correlated and uncorrelated noise while preserving signals typical of astrophysical changes. We carried out a series of tests over simulated sinusoidal and transit-like signals to assess the effectiveness of the method, and applied TFAW to real light curves from the TFRM and K2 datasets. TFAW is a generic algorithm applicable to any kind of ground- or space-based time-domain survey and stellar variability type. TFAW improves the signal detection rate by increasing the signal detection efficiency (SDE) up to a factor $\sim$2.5$\times$ for low S/R light curves. The simulated transit detection rate improves by a factor $\sim$2-5$\times$ in the low-S/R regime compared to TFA. The standard deviations of simulated and real TFAW light curves are $\sim$40% better compared to TFA. TFAW yields better MCMC posterior distributions and returns lower uncertainties, less biased transit parameters and narrower credibility intervals for simulated transits. We applied TFAW to multiperiodic light curves to show its capabilities to separate the different signal contributions. (See poster).