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Detecting oscillatory modulation in quasar light curves using combination kernel Gaussian Processes with Celerite

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ABSTRACT

Aim: We propose a new application for Gaussian Processes combination kernels for detecting DRW light curves with sinusoidal modulation. Combination kernels in GP models have been successfully employed to study the variability of spotted, rotating stars (Angus+2017). A model can be expressed in that framework as a combination of Gaussian kernels, i.e. functions describing covariance between pairs of points as a mode of their separation in a chosen metric. For light curves the time difference between pairs of observations can be the most useful metric. Thus the kernel f(delta x) us a function of time difference delta(t) . Gaussian Processes can successfully recover the DRW signal, represented by the Real Term kernel in Celerite, fDRW. We can combine that kernel with oscillatory term fSHO. Thus a combination kernel consists of two kernels with relative amplitudes A and B , fCOMB = A fDRW + B fSHO . A scientific application would be to search for binary SMBH where the orbital motion modulates the DRW signal from accretion disks (amplitude A similar to B) , or distinguish between a signal from a Quasar (dominant amplitude A) or an RR Lyrae / EB (dominant amplitude B).

1 MOTIVATION

There are various ways of model selection. Given observational dataset, and a hypothesis that a certain model describes the parent distribution of the observables, one would explore the parameter space by calculating for each set of parameters the metric describing the 'goodness of fit' between the data and the model. One such metric is chi-squared, but one might choose any other cost function that would be optimized to find the best set of parameters for the model. This means that to distinguish between eg. a DRW model and an oscillatory model one would optimize for the best parameters of DRW model, and then do likewise for the harmonic oscillation model. Such procedure requires two 'passes' through the dataset (Butler&Bloom2011, Sesar+2007) . For the last decade Gaussian Processes have become more well known as an alternative approach to classical 'least sqares fitting', by employing a class of functions that are characterized by covariance between pairs of points in the dataset (Williams GP Book, Celerite paper DFM+2017). A quick classifier would be directly relevant in context of big astronomical surveys, such as LSST, SDSS, PTF, PS1, etc.

2 METHODS

We first test the method by simulating a DRW light curve (parametrized by asymptotic amplitude SF_{∞}, and characteristic timescale τ) , and then adding a sinusoidal modulation (parametrized by amplitude A, period P). With $\tau = 100$ days, and regular sampling every dt = 5 days , we explore regimes from $A << SF_{\infty}$, to $A\ SF_{\infty}$, and from $P << \tau$, to $P >> \tau$:

$A \in 0.01, 0.1, 0.25, 0.5, 0.75 SF_{\infty} X P \in 0.25, 1, 4\tau$

We then test the combination kernel GP on SDSS S82 light curves of spectroscopically selected QSO from Schneider+2007 to measure completeness.

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