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MULTI-PERIODIC OSCILLATORY EVENT IN A STELLAR SUPERFLARE: SPECTRAL ANALYSIS AND INTERPRETATION

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We report the detection of multiple quasi-periodic pulsations (QPPs) observed during the flaring activity of a young, active solar-type star observed by NASA's Kepler Mission. The QQP signal was analyzed with a data-driven non-parametric method, Singular Spectrum Analysis (SSA), which has never been utilized previously for analyzing solar or stellar QPPs in flares. The present analysis reveals that the apparent anharmonic shape of the QPPs in this superflare results from a superposition of two intrinsic modes whose amplitude and time modulation are suggestive of specific physical processes that are also found in operation during solar flares.

Keywords: Stars: Flare – Stars: Solar-type – Stars: Activity

1. INTRODUCTION

The superflare occurred on KIC 8414845, a young, active solar-type star observed by NASA's Kepler Mission. Its light curve (Fig. 1, left panel) was found in short-cadence observations from 2012 Dec 7 to 2013 Jan 11. The QQP signal of the flare was obtained after detrending the curve. In order to disentangle the flare trend and reduce the risk of introducing artificial signals that may be misinterpreted as QPPs, we applied an analytical physics-inspired model of the flare profile [1]. Fig. 1 (middle panel) shows the model superposed to the detrended light curve of the flare. The specific physical explanation for the generation of QPPs is still under debate although a variety of mechanisms have been proposed in the literature. The most viable ones can generally be divided into two groups: those where the flare emission is modulated by magnetohydrodynamic (MHD)

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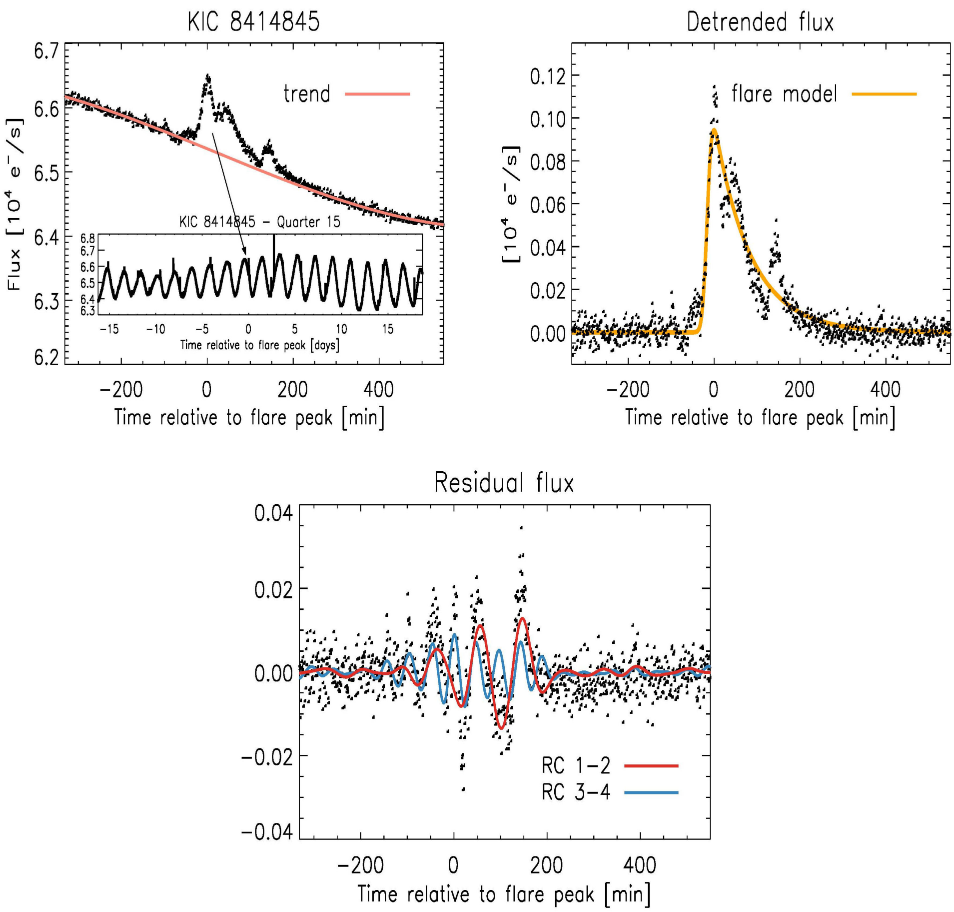

Fig. 1. *Left panel:* Light curve showing the flare on KIC 8414845. *Middle panel:* Flare model by [1] superposed to the detrended light curve of the flare. *Right panel:* Two couples of reconstructed components (RCs 1-2 and 3-4) reproduce major portions of the variability in the residual light curve of the flare.

oscillations and those based on some regime of repetitive magnetic reconnection (see review of [2]). A main issue with QPPs is the ability to distinguish the observed variability with the one associated to stochastic processes that manifest themselves as colored noise [3]. To this aim, we applied a specific technique, the Singular Spectrum Analysis (SSA; [4]) to identify dominant modes that are often missed by other spectral methods and establish their significance against colored noise. SSA is a non-parametric data-driven method that relies on the eigendecomposition of the correlation matrix estimated after embedding the signal into its delayed coordinates and has been already applied in the astrophysical context to analyze solar coronal data ([5] [6] [7]). The reconstructed time series of the two main significant modes obtained through SSA are shown in Fig. 1 (right panel) and recover major portions of the variability in the original time series. SSA is thus proven to represent a powerful tool to investigate quasi-periodic processes in stellar superflares, providing knowledge that can be important for revealing physical processes operating during these energetic events. Investigation of other multiple QPP events in the context of both solar and stellar flares is currently under way through SSA with the aim of yielding further insight into the mechanisms underlying their production.

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