Asteroseismology of the Brightest K2 Stars

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Science Justification: Models describing the interior structure and atmospheres of stars are of fundamental importance across many areas of astrophysics, from the characterization of exoplanets to physical processes governing stellar interiors, stellar populations and galaxy dynamics. As our knowledge of stellar physics progresses, models must be anchored to empirically determined measurements to reliably predict properties of stars for which direct observations are difficult to obtain.

The most powerful tests of stellar models come from the brightest stars, for which complementary observational techniques such as astrometry, asteroseismology, and interferometry can be combined. We propose long-cadence observations of the brightest K2 stars in Campaign 9. The key science goals are to use detections of oscillations in red giants to calibrate asteroseismic scaling relations, and to use pulsations in bright stars to provide insights into poorly understood physical processes such as convective core overshooting.

Target selection: We selected our targets from all stars on silicon that are brighter than $Kp <$ 7 mag. M giants were excluded as their periods are too long to be resolved during the K2 Campaign. We are left with 36 stars of various mass and evolutionary state, ranging from 12 red giants, several blue supergiants, rotational variables, two classical Cepheids, and several binary systems. Long cadence (LC) observations will be sufficient for these targets.

We supplement this list with six solar-like main sequence stars with $Kp < 8$ mag. They are anticipated to show oscillations with periods of the order of minutes, so short cadence (SC) data will be required. We also request SC observations of the Herbig Ae star HD 163296. Zwintz et al. (2014) reported that oscillation frequencies in pre-main-sequence stars are closely linked to their age, although doubt has been cast on this result (e.g. Ripepi et al. 2015). Being bright and well-studied, HD 163296 can shed light on this problem. As these stars commonly oscillate with periods of the order of minutes, SC observations are necessary.

Observing methodology: Capturing the entire flux of bright stars is either extremely pixel expensive or impossible owing to the extended bleed columns, calling for novel methods to perform photometry on these stars.

We propose that, wherever necessary, our bright targets are observed with a 40-pixel diameter circular mask, equivalent to ~20 12th magnitude stars per target. Photometry will be performed using a weighted sum of the unsaturated pixels in the halo around the star, with the weights optimized to minimize the pointing drift signal and noise level. This halo photometry method has been successfully applied to bright stars in the Pleiades and Hyades, observed during K2 Campaign 4 (White et al. in prep). The example of γ Tau (Kp=3.5) is shown in Fig. 1. The left panel shows the K2 image of γ Tau, the centre panel shows the weights applied, and the right panel shows the resulting power spectrum. Red giant oscillations are detected with a frequency of maximum oscillation power of $\nu_{\max} = 61 \pm 3\,\mu$Hz and large frequency separation of $\Delta\nu = 5.6 \pm 0.1\,\mu$Hz.

An alternative method using the calibration smear data to recover LC light curves of bright stars has been demonstrated by Pope et al. (2016). While this method requires no additional pixels, the halo photometry method is preferred as the short integration times of the smear data leads to significantly greater noise (equivalent to a star $\sim$ 6 mag fainter), and there is significant potential for source contamination in this crowded field.

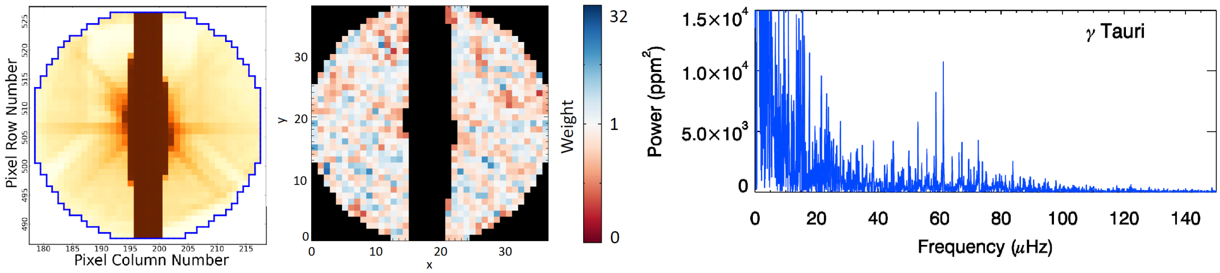

Figure 1: *Left:* K2 image of γ Tau. Pixels included in our analysis are bounded by the blue square. Colour indicates the median flux level in each pixel, with brown pixels being saturated. *Centre:* Weights applied to each pixel to produce the final light curve. *Right:* Power spectrum of γ Tau, showing red giant oscillations.

SC smear data is only recorded for columns where there are active pixels in SC. SC smear could be cheaply obtained for each of our LC targets by placing an active SC pixel in columns around the targets.

Perceived impact: Our proposal will address two key science goals:

- **Scaling Relations for Red Giants**: Radii, masses, and hence ages of red giants are often estimated from two asteroseismic parameters, $\nu_{\max}$ and $\Delta\nu$, which have been proposed to scale with the surface gravity and density respectively. Although these scaling relations have some theoretical justification (Belkacem et al. 2011), they require empirical validation across different evolutionary stages, particularly for red giants, for which deviations have been noted (e.g. White et al. 2011, Miglio et al. 2012). We will measure and compare interferometric and seismic radii in order to calibrate the scaling relations for red giants. Such a task is particularly important for ensuring that asteroseismic stellar parameters are robust for galactic archaeology studies, one of the key science goals of K2 observing campaigns (PI:Stello).
- **Interior Models of Stars**: Pulsating stars are key to understanding the structure of stars. Processes such as core overshooting and internal differential rotation are poorly understood, but asteroseismic modelling of these stars can provide the much needed observational input to refine models (e.g. Aerts et al. 2011) and understand the driving mechanisms for pulsations. For such bright targets, asteroseismology can be readily combined with complementary constraints, namely high-resolution spectroscopy and interferometry, which are necessary to remove model degeneracies (e.g. Cunha et al. 2007).

Justification of DDT: Campaign 9 is a dedicated micro-lensing campaign. The only opportunity to propose other targets is through DDT.

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