Ultra-precise photometry in crowded fields: A self-calibration approach

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We delivered the first systematic search for periodic transiting exoplanets in K2. This search was based on aperture photometry: It depended on having (relatively) isolated stars at the Kepler imaging resolution. The K2 Campaign 9 (K2C9) imaging will contain many more stars than pixels; the targets will be the extreme opposite of "isolated". There are many approaches to crowded- field photometry, with the dominant techniques involving either point-source modeling (the field is a mixture of PSFs) or image differencing. Both of these techniques require exquisite flat-field knowledge, if the aim is to deliver high-precision flux differences over time.

Preliminary work performed in preparation for the K2 mission suggested that sub-pixel (intra-pixel) variations in the detector sensitivity - combined with spacecraft orientation drifts - might be affecting Kepler photometric measurements at relevant levels. We have shown that we can in principle (with K2-like data) infer the sub-pixel flat-field and the astronomical scene, conditioned on a PSF, provided that there are multiple stars in the field, and that their centers move significantly relative to the focal-plane pixel grid.

The K2C9 data will be near-optimal for this kind of self-calibration: The crowded bulge field will non-trivially illuminate a large number of pixels simultaneously, and the pixel drift of the spacecraft pointing will cause that illumination to change, providing a data lever to infer the scene (the stars), the PSF, and the sub-pixel flat-field. These data will permit a full generative model of the K2C9 observations and deliver extremely precise light curves for discovery of small microlensing events and other transients.

If there is any flexibility in the spacecraft attitude management policy, we can recommend pointing maneuvers or spacecraft attitude management changes that could be used to improve the fidelity of, and information available to, any self-calibration.