K2 Campaign 9: Monitoring Massive Young Stars in the Lagoon Nebula

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The mechanisms of variability in young stars are intimately tied to their structure and environment. Decades of photometric monitoring have shown that T Tauri stars are highly variable, and that this variability is connected with starspot modulation, circumstellar extinction, and unsteady accretion. Yet only recently have space telescopes provided the high cadence, high precision, long baseline photometric monitoring necessary for discerning and categorizing light curve patterns. This exquisite data has come largely from two projects: the Coordinated Synoptic Investigation of NGC 2264 using the *CoRoT* telescope (CSI 2264; Cody et al. 2014), and K2's Campaign 2 observations of the Upper Scorpius and ρ Ophiuchus regions. These efforts have shown that young, low-mass stars display at least eight different types of light curve morphologies, one example of which is shown in Fig. 1.

A key question that has emerged is how the observed light curve fluctuations are tied to physical mechanisms and circumstellar dust properties, as a function of stellar mass and age. The CSI 2264 and K2 C2 efforts that we are involved in focus mainly on 3-10 Myr old stars of K/M spectral types. Yet sparse ground-based monitoring of the higher mass Herbig stars (e.g., Herbst & Shevchenko 1999) has shown that nearly all earlier type accreting stars are variable as well. **K2 has the chance to provide optical monitoring data on the relatively unexplored area of high mass star variability during its Campaign 9, which will include the ~1 Myr old high-mass star cluster NGC 6530 (i.e., Lagoon Nebula and its ~60 B stars).**

With K2, we have an unprecedented chance to explore several distinct scientific areas. First, we will measure the prevalence of different light curve morphologies among high mass stars and correlate these with circumstellar properties such as infrared excess and accretion indicators. In addition, we will derive rotation periods for several hundred stars to assess angular momentum evolution as a function of mass and age. There are six known pre-main-sequence δ Scuti stars in the Lagoon, for which K2 short cadence observations will greatly refine their pulsation properties (Zwintz et al. 2006). Finally, we will identify and characterize any eclipsing binary and young planetary transit candidates present in the sample.

This work is complemented by a large collection of ground-based photometry (X-ray through mid-IR) and spectroscopy, as well as planned new observations. Over 100 of our targets have already been observed as part of the GAIA-ESO spectroscopic survey. We have the backing of *Spitzer*; PI Cody's proposal to conduct mid-infrared monitoring of the Lagoon region simultaneous with K2 Campaign 9 was recently approved (see Figure 2). In addition, we are working with collaborators to obtain simultaneous multi-color photometry from the Vista Survey

Telescope Omegacam (1x1 degree field of view), and co-I Alencar has proposed for simultaneous spectroscopic monitoring with the VLT Flames instrument.

To identify suitable targets for K2 observation we have mined the literature for young star candidates in NGC 6530, focusing on the optically revealed X-ray and infrared samples provided by *Chandra* and *Spitzer*. In particular, we are submitting the set of MYStIX (Massive Young Star-forming complex Study in Infrared and X-Ray; Kuhn et al. 2013) sources with *V* brighter than 17. We have filled out the sample with further targets from Damiani et al. (2004), Sung et al. (2000), Rauw et al. (2002), Prisinzano et al. (2005, 2007), Kumar et al. (2010), Kalari et al. (2015), along with A and B stars from van den Ancker et al. (1997). In total, there are 326 targets with Kepler magnitudes ranging from 8.1 to 16.9 (spectral types B to K). 120 have evidence for circumstellar disks and/or accretion. In the event that not all the proposed stars can be observed, we suggest removing the faintest objects from the list. Imposing a cut of *Kp* > 16 removes 74 targets. There are also three stars with *Kp* brighter than 9 we do not consider high priority if pixels need to be conserved.

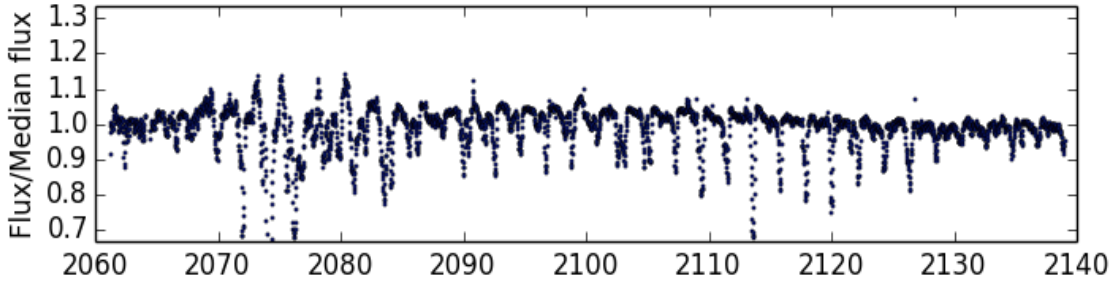

Fig 1. *An 80-day young star light curve from our K2 Campaign 2 pipeline (Cody et al. in prep), showing transient dipping behavior indicative of occultations by coherent inner disk dust features. The connection between these structures, planet formation, and the stellar mass dependence will be elucidated by further monitoring observations.*

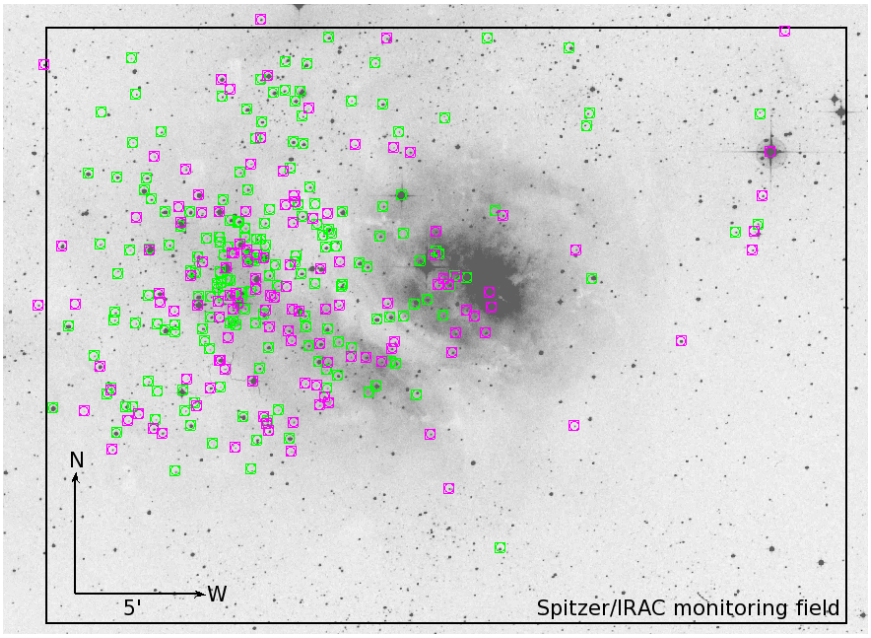

Fig 2. *Optically visible (V<17) pre-main-sequence targets in the Lagoon Nebula region. These stars have been approved for simultaneous mid-infrared monitoring at 3.6 and 4.5 μm with the Spitzer Space Telescope IRAC camera, and are proposed here as K2 targets. Magenta squares are candidate disk-bearing and/or accreting stars, whereas green squares represent X-ray emitters with no published evidence of circumstellar material.*