NOAO Observing Proposal *Standard proposal* **Panel:** *For office use.*
Date: October 1, 2018 **Category:** Galactic - Other

Probing Short Duration Stellar Variability with Star Trail Images of Four K2 Fields

Abstract of Scientific Justification *(will be made publicly available for accepted proposals)*:
Thomas & Kahn 2018 demonstrated, using high fidelity ray-tracing simulations, that star trail images enable wide-field ground-based telescopes to resolve stellar variability down to a time scale of 10 milliseconds. We request half a night with the Dark Energy Camera on the Blanco 4-m telescope to take star trail images of four K2 fields to validate this method, characterize its performance, and detect new sources of stellar variability. The 270 square degree survey will be the first of its kind and will add a new dimension to our understanding of over 10,000 sources.

Summary of observing runs requested for this project

Run	Telescope	Instrument	No. Nights	Moon	Optimal months	Accept. months
1	CT-4m	DECam	0.5	grey	May - July	May - July
2						
3						
4						
5						
6						

Scheduling constraints and non-usable dates *(up to six lines)*.

We have no scheduling constraints.

Investigators *List the name, status, and current affiliation for all investigators. The status code of "P" should be used for all investigators with a Ph.D. or equivalent degree. For graduate students, use "T" if this proposal is a significant part of their thesis project, otherwise use "G".*

PI: David Thomas **Status:** G **Affil.:** Stanford University
Institute for Computational and Mathematical Engineering, 475 Via Ortega, Stanford, California 94305
Email: dthomas5@stanford.edu Phone: 760-525-6973 FAX: None

CoI: Steven Kahn **Status:** P **Affil.:** Stanford University
CoI: Krista Lynne Smith **Status:** P **Affil.:** Stanford University
CoI: Robert Blum **Status:** P **Affil.:** National Optical Astronomy Observatory
CoI: Zeljko Ivezic **Status:** P **Affil.:** University of Washington
CoI: Colin Burke **Status:** G **Affil.:** University of Illinois Urbana-Champaign

Scientific Justification *Be sure to include overall significance to astronomy. For standard proposals limit text to one page with figures, captions and references on no more than two additional pages.*

Probing Short Duration Stellar Variability with Star Trails

Time domain astronomy has now begun in earnest and is revolutionizing many fields, especially using large surveys capable of collecting light curves en masse (Djorgovski et al., 2012). However, almost none of these surveys is performing optical monitoring at less than a few minute timescales, omitting a variability regime that we know to be important for studying phenomena ranging from compact stellar remnants to trans-Neptunian objects: sub-second photometry. Thomas & Kahn 2018 presented a new method and demonstrated, through high fidelity ray-tracing simulations, that it is capable of collecting such light curves for thousands of objects at a time. We propose using the Dark Energy Camera (DECam) on the Blanco 4-m telescope to validate this method and to provide sub-second photometry for four strategically chosen K2 fields (shown in Figure 1).

Our method is comprised of operational and image processing components. The operational component is to take star trail images. A simulated DECam star trail image is shown in Figure 2. The authors of Howell & Jacoby 1986 realized that each trail serves as a light curve for its corresponding source and facilitates high time resolution photometry. We have trained a deep neural network to identify stellar variability in simulated star trail images from the Large Synoptic Survey Telescope (LSST). The network detection efficiency on tophat-like flares is shown in Figure 3. We are preparing the next generation of our network for DECam.

DECam's wide field of view and superb resolution make it the best instrument to validate our method with (Flaugher et al., 2015). The 2.2 degree field of view captures many sources simultaneously and allows us to survey the sky around 700 times faster than existing high time resolution instruments (Dhillon et al., 2007). The wide field is complemented by a 570 Megapixel camera and 0.26 arcsecond pixel scale which mean that a trailing source will spend approximately $17/\cos(\delta)$ milliseconds over each pixel, leading to excellent time resolution. After validating and further refining our method on DECam we hope to employ it during the commissioning of the LSST.

The proposed survey is the first of its kind and will add a new dimension to our knowledge of the four chosen K2 fields. Scanning the sky for M-dwarf flares will allow us to constrain their frequency, correlate them with cluster properties, and compare high time resolution photometry of the flare up with numerical simulations (Yang et al., 2017; Van Doorsselaere et al., 2017). Occultations from trans-Neptunian objects would allow us to detect new structures in the solar system, in particular the small Kuiper Belt Objects that are of particular theoretical interest and which produce occultations lasting for tens of milliseconds (Roques & Moncuquet, 2000; Zhang et al., 2013). Perhaps the most intriguing possibility is that we will discover new sources of variability.

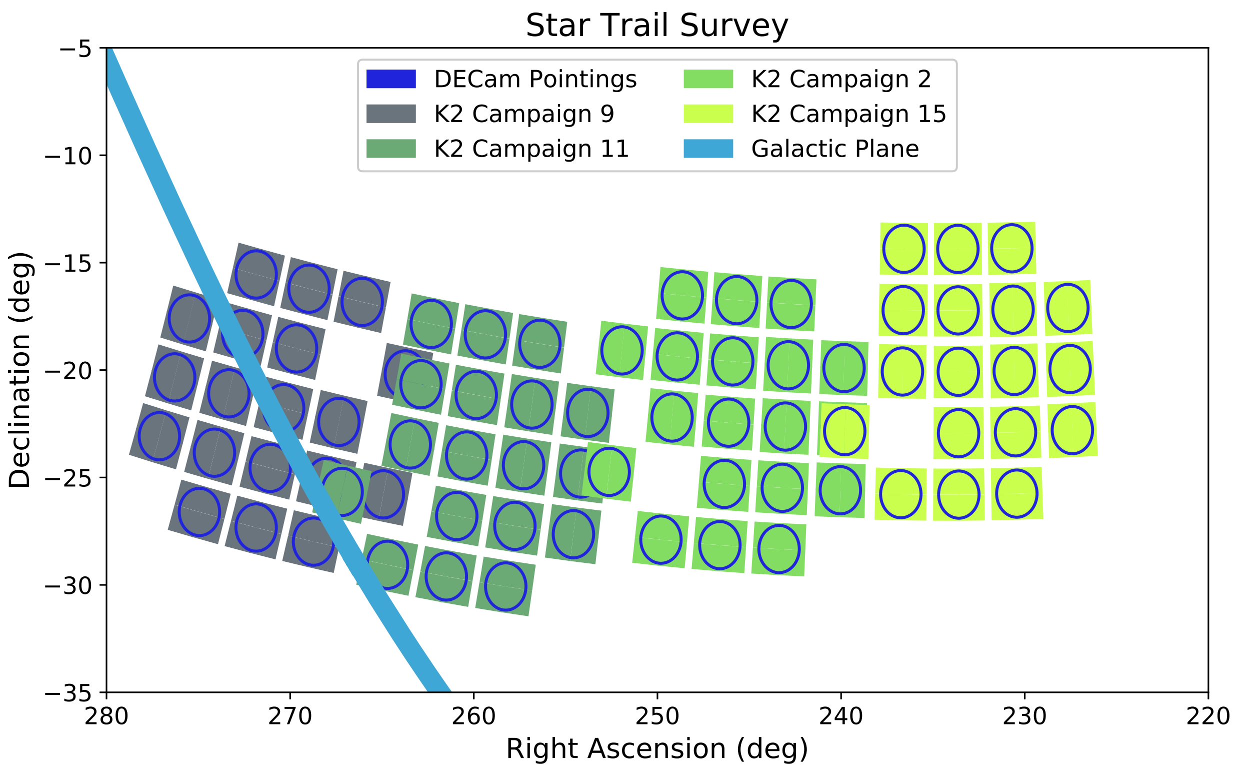

Figure 1: The proposed 270 degree star trail survey. The four K2 fields are shown in varying shades of green. Each DECam pointing will inscribe a single Kepler module of 4 CCDs. The first pass will take static exposures; the remaining two passes will take star trail exposures.

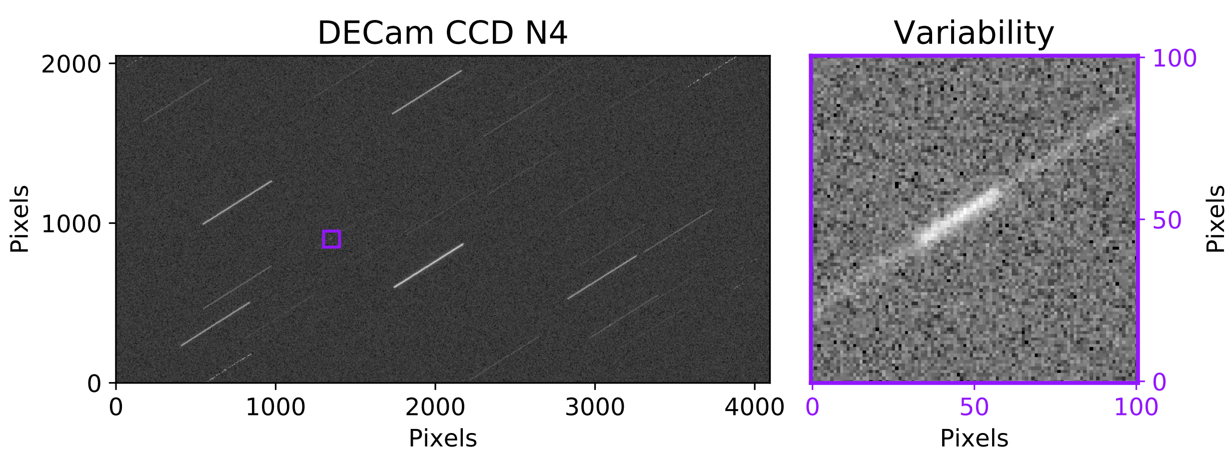

Figure 2: *Left:* A simulated DECam star trail image on the N4 CCD. The region exhibiting variability is outlined in purple. *Right:* A 100 x 100 pixel crop and zoom-in of the variable region.

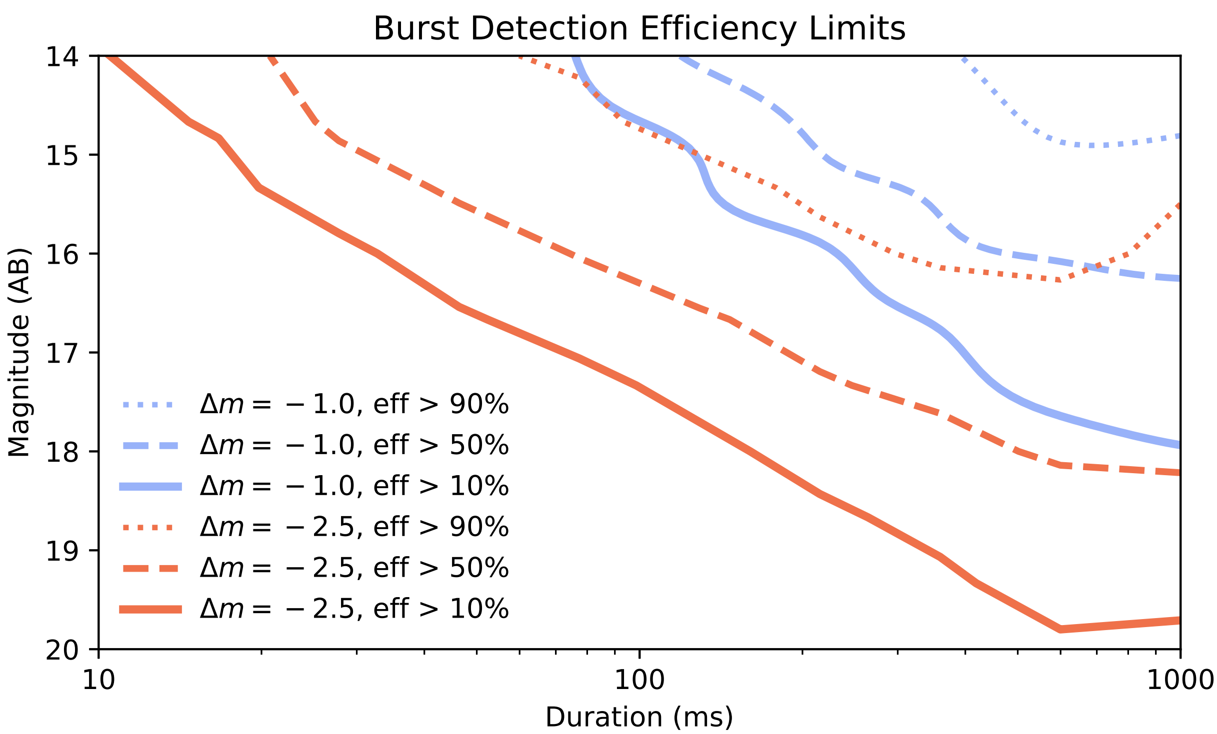

Figure 3: The contours show the probability the network will detect a burst with the given source magnitude and burst duration. The blue and red contours correspond to burst magnitude changes of -1.0 and -2.5 respectively. The dotted, dashed, and solid lines correspond to 90%, 50% and 10% detection efficiencies respectively.

Experimental Design *Describe your overall observational program. How will these observations contribute toward the accomplishment of the goals outlined in the science justification? If you've requested long-term status, justify why this is necessary for successful completion of the science. (limit text to one page)*

Observing Four Adjacent K2 Campaigns: 2,9,11,15

The Kepler K2 mission is a sequence of continuous 80-day observing campaigns of fields distributed around the ecliptic plane. Each field contains thousands of targets with well-characterized optical light curves, many with 2-minute cadence. This rich time-domain data makes these fields ideal for testing our method.

The survey we propose covers four K2 fields: 2,9,11,15. These adjacent fields extend from the galactic plane to 35 degrees above it, providing a wide range of source densities for our method. The fields in this suite also share good observing periods and can be surveyed in a single evening.

The DECam field of view almost perfectly inscribes a single Kepler Module of four CCDs. This allows us to efficiently cover the K2 fields by visiting the center locations of the modules. We tile each field 3 times in the 'r' band. The first is a static exposure for reference. The following two visits take 15 second star trail exposures. We discuss these choices further in the technical description.

Image Processing and Analysis

The image processing and analysis has three stages. First we generate simulated data and train the algorithm on it. We will use the Sherlock 2.0 high performance computing cluster at Stanford University to produce a suite of simulated DECam star trail images. CatSim will be used to seed realistic catalogs; PhoSim, which has already been used to study DECam, will be used for the image simulations. Then we will train networks to detect three variable signatures: bursts, occultations, and smooth trends on timescales of tens of milliseconds to minutes.

In the second stage we calibrate the performance of the algorithm. We will insert simulated variable star trails in the real DECam images and examine the algorithm's ability to uncover them. If we discover effects in the DECam images that are not captured in the simulations, then we can set aside a partition of the real data to use in the training, which will push the network to generalize. At the end of this stage we will have established consistent performance on simulated and real images and have measured the algorithm's performance limits on the signatures of interest.

The third stage will be scanning the real DECam data and communicating the results. The variable events we find will collectively support global statistical analysis and individually be candidates for custom, detailed follow-up analysis. We will combine the variable events with the performance limits to constrain the frequency of specific short duration phenomena in our galaxy.

Proprietary Period: 18 months

Use of Other Facilities or Resources *(1) Describe how the proposed observations complement data from non-NOAO facilities. For each of these other facilities, indicate the nature of the observations (yours or those of others), and describe the importance of the observations proposed here in the context of the entire program. (2) Do you currently have a grant that would provide resources to support the data processing, analysis, and publication of the observations proposed here?"*

The proposed survey will provide high time resolution data on 270 square degrees of sky. This will complement multiple analyses already performed on the Kepler field that overlaps it, including ,, .

If this works well, then we can scale it up to the next generation ground-based wide field telescope: the LSST. The PI already is working on commissioning projects on the Telescope and Site team. He also has access to the Sherlock 2.0 computing cluster at Stanford University. This will fulfill our needs.

Previous Use of NOAO Facilities *List allocations of telescope time on facilities available through NOAO to the PI during the last 2 years for regular proposals, and at any time in the past for survey proposals (including participation of the PI as a Co-I on previous NOAO surveys), together with the current status of the data (cite publications where appropriate). Mark with an asterisk those allocations of time related to the current proposal. Please include original proposal semesters and ID numbers when available.*

This will be the first time David Thomas observes at NOAO facilities. He is supported by a team that has ample experience with NOAO facilities including WIYN, Blanco, and the upcoming LSST.

Observing Run Details for Run 1: CT-4m/DECam

Technical Description *Describe the observations to be made during this observing run. Justify the specific telescope, the number of nights, the instrument, and the lunar phase. List objects, coordinates, and magnitudes (or surface brightness, if appropriate) in the Target Tables section below (required for queue and Gemini runs).*

The crux of our experiment is to resolve star trails and detect changes in individual trails. We use four metrics to assess how the exposure time impacts these goals: trail resolution SNR (S_{res}), trail change SNR (S_{change}), CCD fraction (C), and survey duty cycle (D). S_{res} compares the ratio of flux in the trail to the sky background, source Poisson, and readout noises. Contrary to conventional exposures, this ratio decreases with exposure time because once a trail passes over a pixel it stops providing signal to it, while the sky background continues to increase with time. S_{change} compares the immediate change of flux a source to the sky background, source Poisson, and readout noises. C is the ratio of the length of an equatorial star trail over the length of the diagonal of a 2048 x 4096 pixel DECam CCD. It provides a sense of the fraction of sources that trail off CCDs. D is the fraction of exposure time over the combined exposure-readout-slew-time and shows how efficient our survey is with its allocated time.

We use many variables from the *DECam User Guide* in our metrics code, including zero-points, filter transmissions, readout noise, sky brightness, and slew time as a function of angle. We find that 15 second exposures in the 'r' band are optimal for these metrics. These exposures give $S_{res} > 10$ for trails with source magnitudes $m < 14$. They also give $S_{change} > 5$ for $\Delta m = -0.2, m < 12.5$ or $\Delta m = -1.0, m < 15$. C is 0.19, which roughly means that greater than 80% of the trails are contained within the CCD. The average readout and slew time for our survey is 31 seconds leading to a reasonable duty cycle of $D = 0.33$.

We take three exposures of each target. The first is a 15 second static exposure and serves as a reference image which will be valuable to our testing and analysis. The final two are 15 second star trail exposures. Progressing through the four K2 fields will take around 3 hours and 8 minutes, which includes exposure, readout, and slew times. The remainder of the half-night is a safety buffer, which will allow us to address any issues that come up using the telescope in this unique manner. If we keep to the schedule and have sufficient time remaining, then we do one more pass over the fields.

There are three periods between May and July that are particularly favorable for our survey. The first half of the night from July 18 to 31; the second half of the night May 1 to 13; and the second half of the night from May 28 to June 5. All these nights have at least 3 hours where each field is at airmass < 1.5 and limited moonlight. Finally, we have confirmed that our targets are within the Blanco 4-m/DECam horizon limits.

Instrument Configuration

Filters: r	Slit: -	Fiber cable: -
Grating/grism: -	Multislit: -	Corrector: -
Order: -	λ_{start}: -	Collimator: -
Cross disperser: -	λ_{end}: -	Atmos. disp. corr.: -

RA (deg)	Dec (deg)	Filter	Tracking	Exposure Time (sec)	Comment
263.72779	-20.201175	r	on	15	K2 Campaign-9, Module-1
264.9247	-25.784213	r	on	15	K2 Campaign-9, Module-3
266.07655	-16.82745	r	on	15	K2 Campaign-9, Module-4
267.34745	-22.412586	r	on	15	K2 Campaign-9, Module-6
268.0217	-25.201351	r	on	15	K2 Campaign-9, Module-7
268.72661	-27.984544	r	on	15	K2 Campaign-9, Module-8
268.97252	-16.209388	r	on	15	K2 Campaign-9, Module-9
269.65253	-18.992061	r	on	15	K2 Campaign-9, Module-10
270.35534	-21.774739	r	on	15	K2 Campaign-9, Module-11
271.08764	-24.552602	r	on	15	K2 Campaign-9, Module-12
271.85166	-27.328437	r	on	15	K2 Campaign-9, Module-13
271.8502	-15.549016	r	on	15	K2 Campaign-9, Module-14
272.58167	-18.316964	r	on	15	K2 Campaign-9, Module-15
273.33749	-21.082731	r	on	15	K2 Campaign-9, Module-16
274.12191	-23.844644	r	on	15	K2 Campaign-9, Module-17
274.93987	-26.602962	r	on	15	K2 Campaign-9, Module-18
275.48614	-17.597012	r	on	15	K2 Campaign-9, Module-19
276.2882	-20.33974	r	on	15	K2 Campaign-9, Module-20
277.12054	-23.077546	r	on	15	K2 Campaign-9, Module-21
263.72779	-20.201175	r	off	15	K2 Campaign-9, Module-1
264.9247	-25.784213	r	off	15	K2 Campaign-9, Module-3
266.07655	-16.82745	r	off	15	K2 Campaign-9, Module-4
267.34745	-22.412586	r	off	15	K2 Campaign-9, Module-6
268.0217	-25.201351	r	off	15	K2 Campaign-9, Module-7
268.72661	-27.984544	r	off	15	K2 Campaign-9, Module-8
268.97252	-16.209388	r	off	15	K2 Campaign-9, Module-9
269.65253	-18.992061	r	off	15	K2 Campaign-9, Module-10
270.35534	-21.774739	r	off	15	K2 Campaign-9, Module-11
271.08764	-24.552602	r	off	15	K2 Campaign-9, Module-12
271.85166	-27.328437	r	off	15	K2 Campaign-9, Module-13
271.8502	-15.549016	r	off	15	K2 Campaign-9, Module-14
272.58167	-18.316964	r	off	15	K2 Campaign-9, Module-15
273.33749	-21.082731	r	off	15	K2 Campaign-9, Module-16
274.12191	-23.844644	r	off	15	K2 Campaign-9, Module-17
274.93987	-26.602962	r	off	15	K2 Campaign-9, Module-18
275.48614	-17.597012	r	off	15	K2 Campaign-9, Module-19
276.2882	-20.33974	r	off	15	K2 Campaign-9, Module-20
277.12054	-23.077546	r	off	15	K2 Campaign-9, Module-21
263.72779	-20.201175	r	off	15	K2 Campaign-9, Module-1
264.9247	-25.784213	r	off	15	K2 Campaign-9, Module-3
266.07655	-16.82745	r	off	15	K2 Campaign-9, Module-4
267.34745	-22.412586	r	off	15	K2 Campaign-9, Module-6
268.0217	-25.201351	r	off	15	K2 Campaign-9, Module-7
268.72661	-27.984544	r	off	15	K2 Campaign-9, Module-8
268.97252	-16.209388	r	off	15	K2 Campaign-9, Module-9
269.65253	-18.992061	r	off	15	K2 Campaign-9, Module-10
270.35534	-21.774739	r	off	15	K2 Campaign-9, Module-11

271.08764	-24.552602	r	off	15	K2 Campaign-9, Module-12
271.85166	-27.328437	r	off	15	K2 Campaign-9, Module-13
271.8502	-15.549016	r	off	15	K2 Campaign-9, Module-14
272.58167	-18.316964	r	off	15	K2 Campaign-9, Module-15
273.33749	-21.082731	r	off	15	K2 Campaign-9, Module-16
274.12191	-23.844644	r	off	15	K2 Campaign-9, Module-17
274.93987	-26.602962	r	off	15	K2 Campaign-9, Module-18
275.48614	-17.597012	r	off	15	K2 Campaign-9, Module-19
276.2882	-20.33974	r	off	15	K2 Campaign-9, Module-20
277.12054	-23.077546	r	off	15	K2 Campaign-9, Module-21
267.17021	-25.669376	r	on	15	K2 Campaign-11, Module-1
264.69931	-29.064482	r	on	15	K2 Campaign-11, Module-4
263.45917	-23.462254	r	on	15	K2 Campaign-11, Module-6
262.87765	-20.656998	r	on	15	K2 Campaign-11, Module-7
262.31833	-17.852577	r	on	15	K2 Campaign-11, Module-8
261.49601	-29.605946	r	on	15	K2 Campaign-11, Module-9
260.92737	-26.79314	r	on	15	K2 Campaign-11, Module-10
260.38681	-23.975597	r	on	15	K2 Campaign-11, Module-11
259.86765	-21.157819	r	on	15	K2 Campaign-11, Module-12
259.36942	-18.336932	r	on	15	K2 Campaign-11, Module-13
258.25987	-30.072995	r	on	15	K2 Campaign-11, Module-14
257.76264	-27.251584	r	on	15	K2 Campaign-11, Module-15
257.28983	-24.428065	r	on	15	K2 Campaign-11, Module-16
256.83751	-21.60315	r	on	15	K2 Campaign-11, Module-17
256.40292	-18.776225	r	on	15	K2 Campaign-11, Module-18
254.57518	-27.639373	r	on	15	K2 Campaign-11, Module-19
254.17478	-24.816517	r	on	15	K2 Campaign-11, Module-20
253.79079	-21.993558	r	on	15	K2 Campaign-11, Module-21
267.17021	-25.669376	r	off	15	K2 Campaign-11, Module-1
264.69931	-29.064482	r	off	15	K2 Campaign-11, Module-4
263.45917	-23.462254	r	off	15	K2 Campaign-11, Module-6
262.87765	-20.656998	r	off	15	K2 Campaign-11, Module-7
262.31833	-17.852577	r	off	15	K2 Campaign-11, Module-8
261.49601	-29.605946	r	off	15	K2 Campaign-11, Module-9
260.92737	-26.79314	r	off	15	K2 Campaign-11, Module-10
260.38681	-23.975597	r	off	15	K2 Campaign-11, Module-11
259.86765	-21.157819	r	off	15	K2 Campaign-11, Module-12
259.36942	-18.336932	r	off	15	K2 Campaign-11, Module-13
258.25987	-30.072995	r	off	15	K2 Campaign-11, Module-14
257.76264	-27.251584	r	off	15	K2 Campaign-11, Module-15
257.28983	-24.428065	r	off	15	K2 Campaign-11, Module-16
256.83751	-21.60315	r	off	15	K2 Campaign-11, Module-17
256.40292	-18.776225	r	off	15	K2 Campaign-11, Module-18
254.57518	-27.639373	r	off	15	K2 Campaign-11, Module-19
254.17478	-24.816517	r	off	15	K2 Campaign-11, Module-20
253.79079	-21.993558	r	off	15	K2 Campaign-11, Module-21
267.17021	-25.669376	r	off	15	K2 Campaign-11, Module-1
264.69931	-29.064482	r	off	15	K2 Campaign-11, Module-4

263.45917	-23.462254	r	off	15	K2 Campaign-11, Module-6
262.87765	-20.656998	r	off	15	K2 Campaign-11, Module-7
262.31833	-17.852577	r	off	15	K2 Campaign-11, Module-8
261.49601	-29.605946	r	off	15	K2 Campaign-11, Module-9
260.92737	-26.79314	r	off	15	K2 Campaign-11, Module-10
260.38681	-23.975597	r	off	15	K2 Campaign-11, Module-11
259.86765	-21.157819	r	off	15	K2 Campaign-11, Module-12
259.36942	-18.336932	r	off	15	K2 Campaign-11, Module-13
258.25987	-30.072995	r	off	15	K2 Campaign-11, Module-14
257.76264	-27.251584	r	off	15	K2 Campaign-11, Module-15
257.28983	-24.428065	r	off	15	K2 Campaign-11, Module-16
256.83751	-21.60315	r	off	15	K2 Campaign-11, Module-17
256.40292	-18.776225	r	off	15	K2 Campaign-11, Module-18
254.57518	-27.639373	r	off	15	K2 Campaign-11, Module-19
254.17478	-24.816517	r	off	15	K2 Campaign-11, Module-20
253.79079	-21.993558	r	off	15	K2 Campaign-11, Module-21
252.62898	-24.737815	r	on	15	K2 Campaign-2, Module-1
251.92999	-19.084268	r	on	15	K2 Campaign-2, Module-3
249.8097	-27.893175	r	on	15	K2 Campaign-2, Module-4
249.20516	-22.208053	r	on	15	K2 Campaign-2, Module-6
248.92019	-19.36398	r	on	15	K2 Campaign-2, Module-7
248.64576	-16.522263	r	on	15	K2 Campaign-2, Module-8
246.60037	-28.147494	r	on	15	K2 Campaign-2, Module-9
246.35669	-25.298709	r	on	15	K2 Campaign-2, Module-10
246.125	-22.447025	r	on	15	K2 Campaign-2, Module-11
245.90076	-19.596442	r	on	15	K2 Campaign-2, Module-12
245.68598	-16.744145	r	on	15	K2 Campaign-2, Module-13
243.37691	-28.329937	r	on	15	K2 Campaign-2, Module-14
243.20141	-25.47929	r	on	15	K2 Campaign-2, Module-15
243.03384	-22.627974	r	on	15	K2 Campaign-2, Module-16
242.8729	-19.7765	r	on	15	K2 Campaign-2, Module-17
242.71813	-16.924105	r	on	15	K2 Campaign-2, Module-18
240.03962	-25.593367	r	on	15	K2 Campaign-2, Module-19
239.93857	-22.749248	r	on	15	K2 Campaign-2, Module-20
239.84013	-19.90586	r	on	15	K2 Campaign-2, Module-21
252.62898	-24.737815	r	off	15	K2 Campaign-2, Module-1
251.92999	-19.084268	r	off	15	K2 Campaign-2, Module-3
249.8097	-27.893175	r	off	15	K2 Campaign-2, Module-4
249.20516	-22.208053	r	off	15	K2 Campaign-2, Module-6
248.92019	-19.36398	r	off	15	K2 Campaign-2, Module-7
248.64576	-16.522263	r	off	15	K2 Campaign-2, Module-8
246.60037	-28.147494	r	off	15	K2 Campaign-2, Module-9
246.35669	-25.298709	r	off	15	K2 Campaign-2, Module-10
246.125	-22.447025	r	off	15	K2 Campaign-2, Module-11
245.90076	-19.596442	r	off	15	K2 Campaign-2, Module-12
245.68598	-16.744145	r	off	15	K2 Campaign-2, Module-13
243.37691	-28.329937	r	off	15	K2 Campaign-2, Module-14
243.20141	-25.47929	r	off	15	K2 Campaign-2, Module-15

243.03384	-22.627974	r	off	15	K2 Campaign-2, Module-16
242.8729	-19.7765	r	off	15	K2 Campaign-2, Module-17
242.71813	-16.924105	r	off	15	K2 Campaign-2, Module-18
240.03962	-25.593367	r	off	15	K2 Campaign-2, Module-19
239.93857	-22.749248	r	off	15	K2 Campaign-2, Module-20
239.84013	-19.90586	r	off	15	K2 Campaign-2, Module-21
252.62898	-24.737815	r	off	15	K2 Campaign-2, Module-1
251.92999	-19.084268	r	off	15	K2 Campaign-2, Module-3
249.8097	-27.893175	r	off	15	K2 Campaign-2, Module-4
249.20516	-22.208053	r	off	15	K2 Campaign-2, Module-6
248.92019	-19.36398	r	off	15	K2 Campaign-2, Module-7
248.64576	-16.522263	r	off	15	K2 Campaign-2, Module-8
246.60037	-28.147494	r	off	15	K2 Campaign-2, Module-9
246.35669	-25.298709	r	off	15	K2 Campaign-2, Module-10
246.125	-22.447025	r	off	15	K2 Campaign-2, Module-11
245.90076	-19.596442	r	off	15	K2 Campaign-2, Module-12
245.68598	-16.744145	r	off	15	K2 Campaign-2, Module-13
243.37691	-28.329937	r	off	15	K2 Campaign-2, Module-14
243.20141	-25.47929	r	off	15	K2 Campaign-2, Module-15
243.03384	-22.627974	r	off	15	K2 Campaign-2, Module-16
242.8729	-19.7765	r	off	15	K2 Campaign-2, Module-17
242.71813	-16.924105	r	off	15	K2 Campaign-2, Module-18
240.03962	-25.593367	r	off	15	K2 Campaign-2, Module-19
239.93857	-22.749248	r	off	15	K2 Campaign-2, Module-20
239.84013	-19.90586	r	off	15	K2 Campaign-2, Module-21
239.80112	-22.842778	r	on	15	K2 Campaign-15, Module-1
236.74854	-25.77599	r	on	15	K2 Campaign-15, Module-4
236.66006	-20.065128	r	on	15	K2 Campaign-15, Module-6
236.61699	-17.208912	r	on	15	K2 Campaign-15, Module-7
236.57571	-14.355501	r	on	15	K2 Campaign-15, Module-8
233.58956	-25.795758	r	on	15	K2 Campaign-15, Module-9
233.60258	-22.938687	r	on	15	K2 Campaign-15, Module-10
233.61604	-20.079162	r	on	15	K2 Campaign-15, Module-11
233.62703	-17.220917	r	on	15	K2 Campaign-15, Module-12
233.63942	-14.361349	r	on	15	K2 Campaign-15, Module-13
230.42998	-25.750422	r	on	15	K2 Campaign-15, Module-14
230.50193	-22.89622	r	on	15	K2 Campaign-15, Module-15
230.57069	-20.041484	r	on	15	K2 Campaign-15, Module-16
230.63687	-17.186745	r	on	15	K2 Campaign-15, Module-17
230.70161	-14.331263	r	on	15	K2 Campaign-15, Module-18
227.40562	-22.794871	r	on	15	K2 Campaign-15, Module-19
227.53054	-19.951623	r	on	15	K2 Campaign-15, Module-20
227.64949	-17.108981	r	on	15	K2 Campaign-15, Module-21
239.80112	-22.842778	r	off	15	K2 Campaign-15, Module-1
236.74854	-25.77599	r	off	15	K2 Campaign-15, Module-4
236.66006	-20.065128	r	off	15	K2 Campaign-15, Module-6
236.61699	-17.208912	r	off	15	K2 Campaign-15, Module-7
236.57571	-14.355501	r	off	15	K2 Campaign-15, Module-8

233.58956	-25.795758	r	off	15	K2 Campaign-15, Module-9
233.60258	-22.938687	r	off	15	K2 Campaign-15, Module-10
233.61604	-20.079162	r	off	15	K2 Campaign-15, Module-11
233.62703	-17.220917	r	off	15	K2 Campaign-15, Module-12
233.63942	-14.361349	r	off	15	K2 Campaign-15, Module-13
230.42998	-25.750422	r	off	15	K2 Campaign-15, Module-14
230.50193	-22.89622	r	off	15	K2 Campaign-15, Module-15
230.57069	-20.041484	r	off	15	K2 Campaign-15, Module-16
230.63687	-17.186745	r	off	15	K2 Campaign-15, Module-17
230.70161	-14.331263	r	off	15	K2 Campaign-15, Module-18
227.40562	-22.794871	r	off	15	K2 Campaign-15, Module-19
227.53054	-19.951623	r	off	15	K2 Campaign-15, Module-20
227.64949	-17.108981	r	off	15	K2 Campasdign-15, Module-21
239.80112	-22.842778	r	off	15	K2 Campaign-15, Module-1
236.74854	-25.77599	r	off	15	K2 Campaign-15, Module-4
236.66006	-20.065128	r	off	15	K2 Campaign-15, Module-6
236.61699	-17.208912	r	off	15	K2 Campaign-15, Module-7
236.57571	-14.355501	r	off	15	K2 Campaign-15, Module-8
233.58956	-25.795758	r	off	15	K2 Campaign-15, Module-9
233.60258	-22.938687	r	off	15	K2 Campaign-15, Module-10
233.61604	-20.079162	r	off	15	K2 Campaign-15, Module-11
233.62703	-17.220917	r	off	15	K2 Campaign-15, Module-12
233.63942	-14.361349	r	off	15	K2 Campaign-15, Module-13
230.42998	-25.750422	r	off	15	K2 Campaign-15, Module-14
230.50193	-22.89622	r	off	15	K2 Campaign-15, Module-15
230.57069	-20.041484	r	off	15	K2 Campaign-15, Module-16
230.63687	-17.186745	r	off	15	K2 Campaign-15, Module-17
230.70161	-14.331263	r	off	15	K2 Campaign-15, Module-18
227.40562	-22.794871	r	off	15	K2 Campaign-15, Module-19
227.53054	-19.951623	r	off	15	K2 Campaign-15, Module-20
227.64949	-17.108981	r	off	15	K2 Campaign-15, Module-21

R.A. range of principal targets (hours): 3.31 hours

Dec. range of principal targets (degrees): 15.74 degrees

Special Instrument Requirements *Describe briefly any special or non-standard usage of instrumentation.*

We have discussed using the Blanco telescope and DECam in non-tracking mode with the Blanco Instrument Scientist Dr. Alistair Walker. Dr. Walker believes the taking of trailed images can be automated through the DECam instrument control system, SISPI, which sends commands to the Blanco Telescope Control System. We will work with CTIO to develop and test this capability if our proposal is successful. Working with the telescope operator to manually toggle between tracking and non-tracking will be our back up plan.

References

Dhillon, V. S., Marsh, T. R., Stevenson, M. J., et al. 2007, MNRAS, 378, 825

Djorgovski, S. G., Mahabal, A. A., Drake, A. J., et al. 2012, in IAU Symposium, Vol. 285, New Horizons in Time Domain Astronomy, ed. E. Griffin, R. Hanisch, & R. Seaman, 141–146

Flaugher, B., Diehl, H. T., Honscheid, K., et al. 2015, AJ, 150, 150

Howell, S. B., & Jacoby, G. H. 1986, 98, 802

Roques, F., & Moncuquet, M. 2000, Icarus, 147, 530

Thomas, D., & Kahn, S. M. 2018, ArXiv e-prints, arXiv:1808.06977

Van Doorsselaere, T., Shariati, H., & Debosscher, J. 2017, ApJS, 232, 26

Yang, H., Liu, J., Gao, Q., et al. 2017, ApJ, 849, 36

Zhang, Z.-W., Lehner, M. J., Wang, J.-H., et al. 2013, AJ, 146, 14