Scientific/Technical/Management

1 Introduction

Age is key, and nearly impossible to get for field stars. Stellar rotation periods are are the most promising tool for constraining the ages of field stars.

kepler makes this possible, get rotation. with K2, new opportunity to do this for range of stellar ages, possibly more than doubling the sample of stars available. K2 also presents unique challenges in data systematics, and shorter baseline means some periods not available... thus we need to use new tools to measure rotation

we propose to measure rotation periods for all light curves from k2. this will produce a value-added dataset for the K2 mission, and extend the science yield from Kepler.

(fill 1st page w/ intro, incl. bold statements of highest level goals)

2   Scientific Motivation

in new era of both precision exoplanet studies and large surveys of the Milky Way, our ability to better understand stars and their basic properties is key to these larger projects (star formation history of MWY, ages of planet hosts, environment of young-earth like systems, etc).

2.1   Rotation Periods from *Kepler* and K2

rotation periods previously were very scarce, had to do with doppler broadening, very rarely could do with photometry.

now with *Kepler* we have seen a true revolution, going from hundreds of stars with measured periods from a wide variety of instruments and approaches, to tens of thousands of stars with homogeneous data and analysis. this opens door to understanding a fundamental property of stars

2.2   Age-Dating Field Stars with Rotation

Skumanich (1972) Barnes (2007) the promise of gyrochronology is key, has ability to get ages with accuracy that rivals any other method (10%). with Kepler/K2 is a mass production job, but with K2 new challenges in the data are lurking
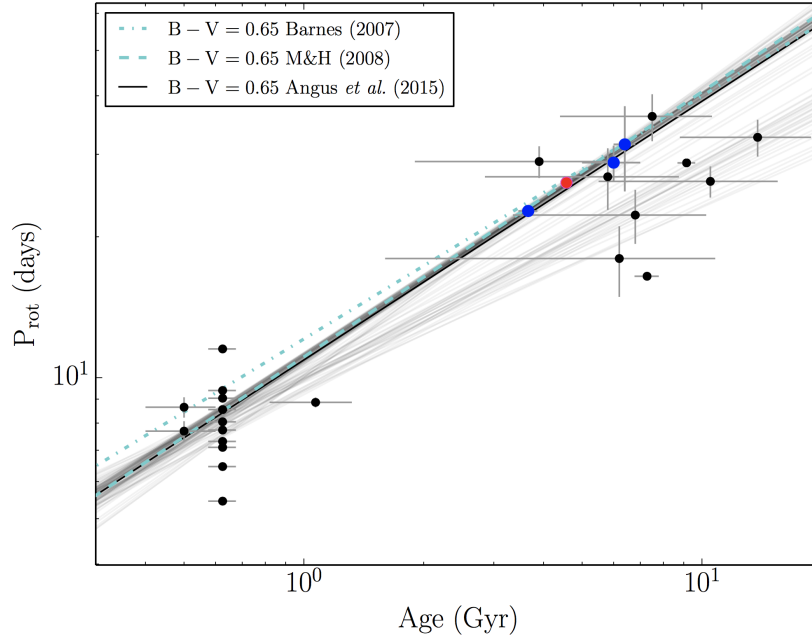

Figure 1: figure 6 from Angus et al. (2015), showing new gyrochronology relation calibrated using *Kepler* asteroseismic targets

2.3 A Mysterious Period Bimodality

Then this weird thing appeared, which is an open mystery - a bimodal period distribution - whoa (McQuillan et al., 2013). this was then extended to higher masses by Davenport (2017). Explanations are either a break from single spin-down law (possibly from different initial periods, or some new physics maybe due to chemical abundances) or represents an age bimodality of local stars.

Since this effect is seen only within 300pc so far (and only within Kepler data) due to sample properties, cannot be sure what spatial or compositional dependence this has, need a sample that spans a wider spatial area and more ages of stars
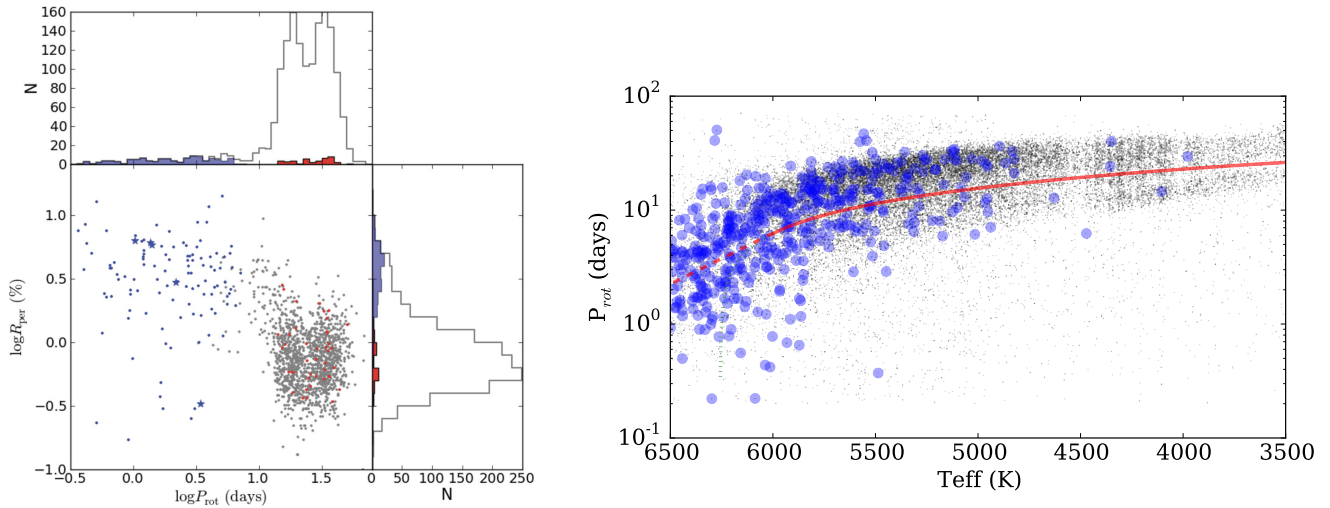

Figure 2: Left: figure 9 from McQuillan et al. (2013), showing discovery of bimodality in rotation periods from *Kepler* M dwarfs. Right: figure 3 from Davenport (2017), showing bimodality in rotation periods from *Kepler* extends from cool M dwarfs through hotter solar-type stars.

3 Proposed Research

3.1 Measuring Rotation from K2 Using the Systematics-Insensitive Periodogram

we propose the first systematic study of stellar rotation periods from the K2 data.

this will include ~XXXXX stars from Campaigns 0-16. This includes data for multiple stellar clusters that were taken as part of the Guest Observer program.

data will be reduced using SOME FLAVOR of K2 pipeline.

the Angus et al. (2016b) rotation period pipeline will then be applied to every light curve. we will generate and save every periodogram for potential follow-up analysis of differential rotation and multi-period systems

spurious signals from transits and flares will be filtered out (some smoothing or high-freq removed in the SIP?)

for stars with good period recovery, fourier fits will identify eclipsing binaries and pulsating systems (or something like this)
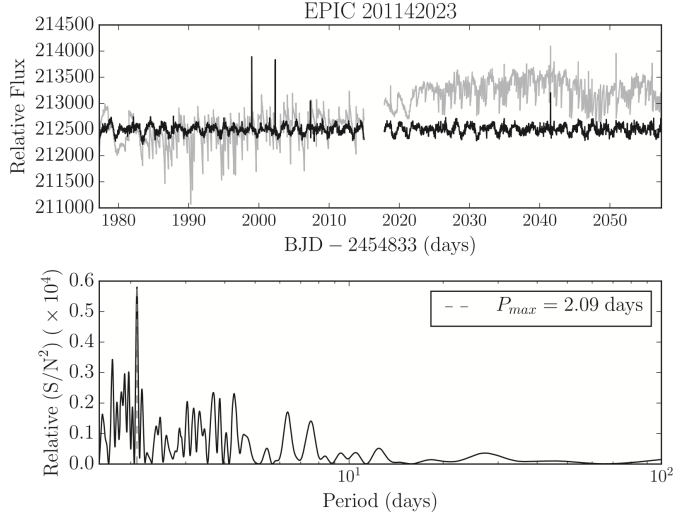

Figure 3: figure 6 from Angus et al. (2016b), showing the processing of the light curve and resulting SIPeriodogram. more simple methods give erroneous periods for this object of either 3 days via ACF, or 59 days via normal Lomb-Scargle methods.

3.2 Exploring the Period Bimodality

by combining our sample with the distances provided in the forthcoming Gaia DR2 catalog, we will be able to extend the methodology of Davenport (2017) to filter our subgiants and binary stars for our entire sample.

we then can make 3d exploration of period distribution, to see if the bimodality exists for all field stars near the sun.

the big goal here is to decide which explanation is correct!

3.3 Mapping Ages in each Field

our catalog of rotation periods from K2, combined with existing catalogs from Kepler, we will have the largest set of rotation periods ever to use for population analysis. using new technique being developed by Ruth (Chronometer) we will have improved age estimate for every star based on single rotation values. then we combine this to get age distribution within each K2 field.

Demonstration figure?

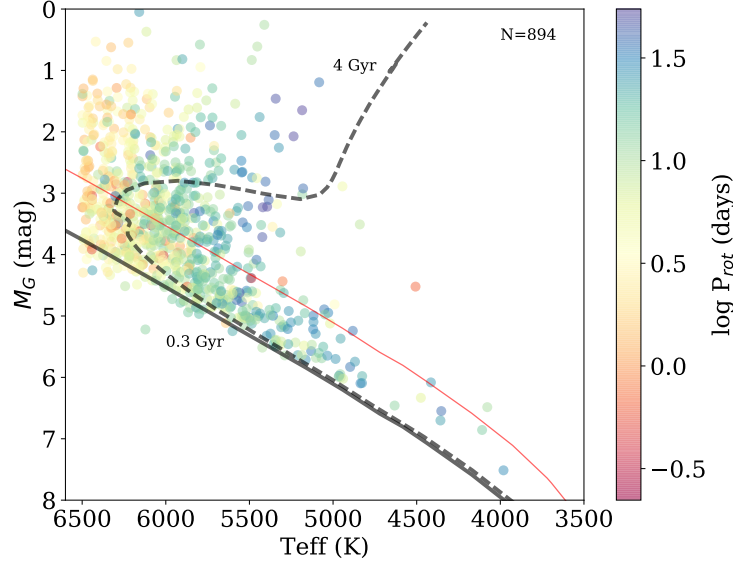discussion of improved gyrochronology calibration?

Figure 4: figure 2 from Davenport (2017), showing temperature from KIC versus absolute magnitude from Gaia

this is partially an extension of the period bimodality work (if it's an age effect), but to create a detailed map of the ages of these field stars at a range of galactic latitudes in the 17 pencil-beams available from K2. combining with the periods from Kepler, will be even better. ultimately we'd like to compare to the age distributions in simulations of these fields from TRILEGAL, and from other age indicators (asteroseismology, flare ages, etc)

4   Team Qualifications

PI Davenport has used *Kepler* to conduct the largest survey to-date of stellar activity from flares, as well as multiple investigations of starspots and their evolution with time using *Kepler* data. From these studies, Davenport has developed an age model for flare activity that will be directly comparable to the ages and starspot amplitudes derived from this study. He has also recently discovered the rotation period bimodality first noted with *Kepler* M dwarfs by McQuillan et al. (2013) extends to G and K dwarf stars (Davenport, 2017). Davenport previously collaborated on NASA ADP grant NNX09AC77G to characterize NIR variability using the 2MASS Calibration Scan Point Source Working Database (Davenport et al., 2012, 2015). He has mentored numerous students on projects using *Kepler* data, resulting in student-led publications such as the flare activity of a unique M dwarf binary system GJ 1245AB (Lurie et al., 2015), and exploring the poorly understood origins of wide binary stars through stellar rotation (R. Clarke in prep). He will manage the overall project, and lead the investigation and publication of the period bimodality exploration.

Co-I Angus is an expert in the extraction of periodic signals from *Kepler* data using

Gaussian Processes (Angus et al., 2016a) and other cutting-edge statistical techniques. She is the author of tools for generating Systematics-Insensitive Periodograms for both *Kepler* and K2 data (Angus et al., 2016b), as well as new gyrochronology calibrations using *Kepler* asteroseismic targets (Angus et al., 2015). She will lead the effort to measure and publish rotation periods for all K2 sources, and lead the graduate student in measuring ages for field stars.

other Co-Is?

5   Relevance to NASA Programs

history of MWY, age of planet systems, TESS

6   Plan of Work

Year 1: process all rotation period data
Year 2: write papers

References

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