Rapidly Rotating Pre-Main-Sequence M Dwarfs with Highly Structured Light Curves

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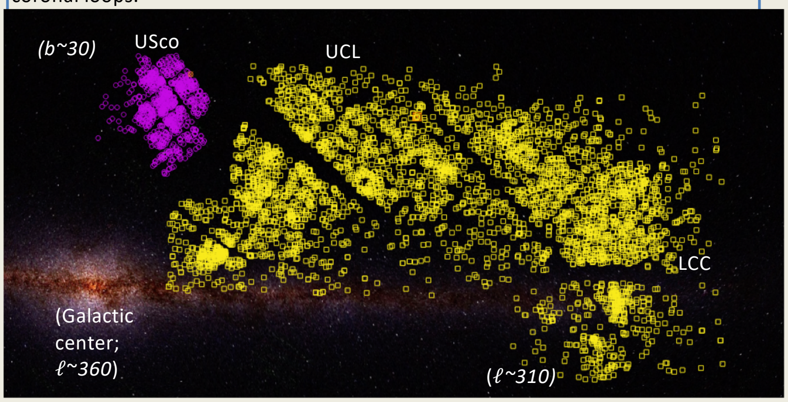
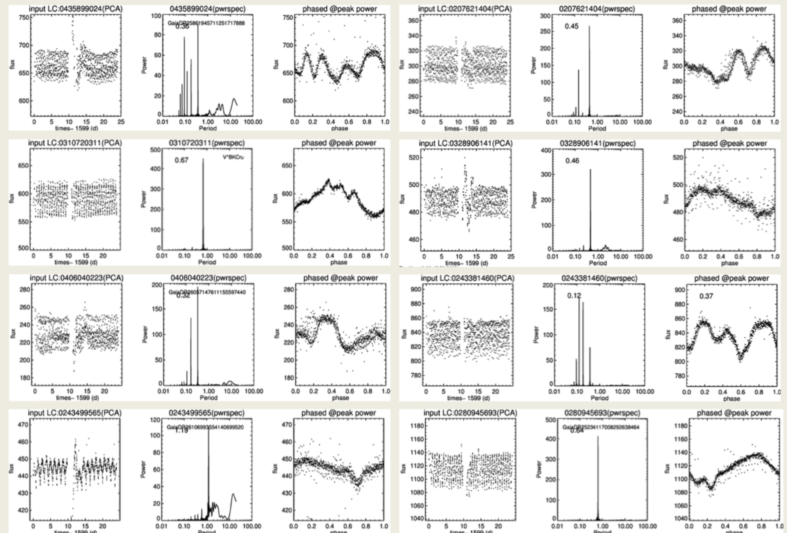
Abstract

This poster will present new results from our TESS study of stars in the ~15 Myr old Upper Centarus-Lupus (UCL)/Lower Centaurus-Crux (LCC) association. In recent years, we have been using K2's high precision photometry to probe stellar variability and stellar rotation to lower masses and lower amplitudes than has ever been done before. In both K2 and TESS data, we find a new type of periodic photometric variability among rapidly rotating (<0.6d) young (<50 Myr) M stars without IR excesses. The variations are too sharp and narrow to be due to spots, and too broad to be planets. We think this is likely due to matter entrained in coronal loops.



↑ **2MASS HiPS map with periodic association member stars overlaid**. The Scorpius-Centaurus OB Association is nearby (~100-150 pc, age ~10-20 Myr) and covers a huge swath of sky from our perspective (~80 degrees from northeastern-most magenta to southwestern-most yellow). There are at least three subgroups commonly regarded as being part of the Sco-Cen Association: Upper Scorpius (USco; upper left of figure), Upper Centaurus-Lupus (UCL; center of figure), and Lower Centaurus-Crux (LCC; lower right of figure). Magenta: Stars from USco with periods from K2 data; boundaries between the chips are apparent. Yellow: Stars from UCL/LCC with periods from TESS data; missing "stripes" in distribution come from TESS selection effects. Initial member sample drawn from Gaia DR2 analyses in the literature.

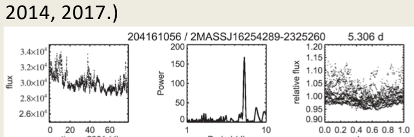


↑ Most of the cluster stars that we have studied with K2 or TESS have sinusoidal periods, as expected for starspot modulation. However, some have sharp, angular structures (see light curve explainer below). These stars' phased light curves have sharp, angular dips too sharp to be spots and too big to be planets; we think they are matter entrained in coronal loops. Because these light curves are observed to change shape subtly after a flare (and because there are more instances of these light curves in younger clusters), **we suspect that flares (and by extension X-rays) are important to whatever is going on in these stars**. The light curves shown here are a subset of the 100+ we have found in UCL/LCC – the panels for each are light curve, power spectrum, and phased light curve. There may be some color anomalies found in the UCL/LCC population – they are redder in R_p-[4.6] and/or bluer in B_p-R_p (Stauffer et al. 2021) than other similar UCL/LCC stars.

Brief Light Curve Explainer

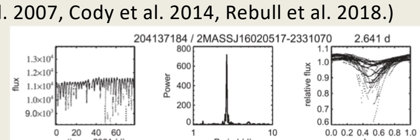
- From K2 (and CoRoT) data, we have identified several patterns in light curves and associated power spectra (see, e.g., Cody et al. 2014, Rebull et al. 2016ab). A subset of these are relevant here.
- **Bursters** trundle along and spike up occasionally, some even having a quasi-periodic bursting behavior. These spikes are blue (as seen in multi-color observations), and all of the stars displaying these patterns have large IR excesses, e.g., disks. We interpret these as surges of accretion from the disk to the star. (See, e.g., Cody et al. 2014, 2017.)

Burster →



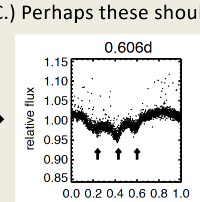
- **Dippers** trundle along and dip down occasionally, often periodically and at the same phase every cycle. The dips can vary in depth and are red (as seen in multi-color observations). All of the stars with this pattern have large IR excesses, e.g., disks. We interpret these as dust occulting the line of sight, either from texture in the inner disk or the accretion column rotating into and out of view. (See, e.g., Bouvier et al. 2007, Cody et al. 2014, Rebull et al. 2018.)

Dipper →



- "**Scallop shell**" was the name Stauffer et al. (2017) assigned to another class of objects found in K2 data; others have called them "highly structured" or "composed of many Fourier components" (Guenther et al. 2020; Zhan et al. 2019; both using TESS data). These stars have light curves with sharp, angular dips – too sharp to be starspots and too big to be planets. They often are stable over the K2 or TESS campaign, but may change shape subtly after a flare, from which (among other evidence) we conclude they are likely related to mass entrained in coronal loops (Stauffer et al. 2017, 2018, 2021). **All are M stars. All rotate quickly** (<0.65 d). **None have any detectable IR excesses**. **All are young**; we find more in younger clusters. (Numbers of these: 5 [1%] in Pleiades, 28 [3%] USco, 6 [4%] Taurus, and now 100+ [3%] UCL/LCC.) Perhaps these should be called "Stauffer stars"?

Something else! →



- Stauffer et al. (2017) also identified "**flux dip**" & "**transient flux dip**" stars, where there is just one narrow dip that often changes over time. These are also young but disk-free M stars, rotating quickly (persistent flux dips <2d and often <0.65d; transient flux dips >1d). These may be disintegrating knots of dust orbiting close to the star.