Stellar Rotation in UCL/LCC with TESS

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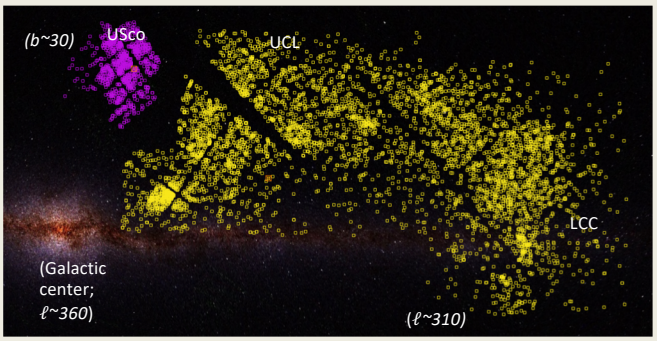
Abstract

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. Younger stars are generally more rapidly rotating and have larger star spots than older stars of similar masses. K2's large field of view was able to monitor a significant fraction of many nearby clusters and associations; some of the nearest associations can only be monitored by TESS, which observes ~85% of the sky. We present rotation rates from a TESS study of stars in the ~15 Myr old Upper Centarus-Lupus (UCL)/Lower Centaurus-Crux (LCC) association.

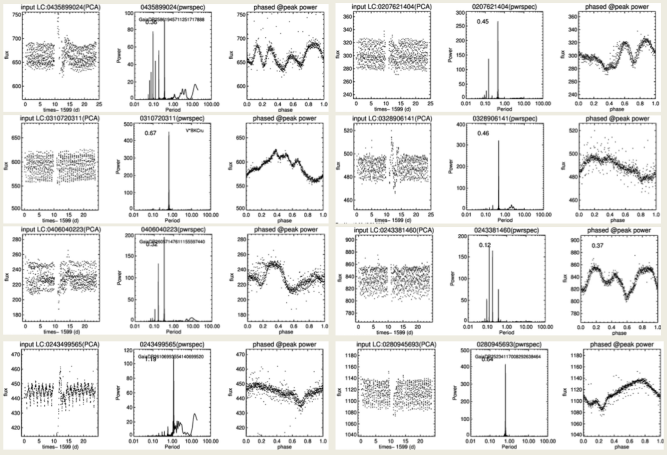


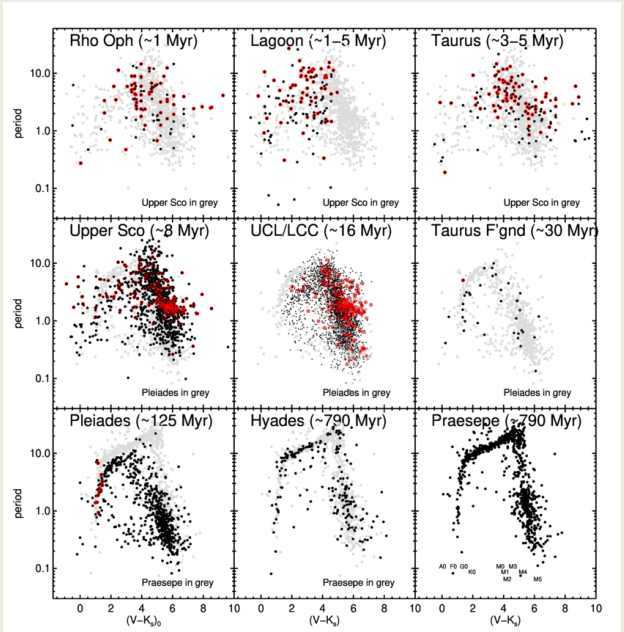
↑ **2MASS HiPS map with periodic association member stars overlaid**. The Scorpius-Centaurus OB Association is nearby (~100-150 pc, age ~10-20 Myr) and covers a huge swath of sky from our perspective (~80 degrees from northeastern-most magenta to southwestern-most yellow). There are at least three subgroups 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 membership analyses in the literature.

↓ **The diversity of light curves** – all the same types of light curve shapes and power spectrum properties – **that we have found in K2 data are also found in TESS data**. Most of the stars have sinusoidal periods, as expected for starspot modulation. Source confusion is a larger concern, given TESS' larger pixels, and multi-period systems need to be vetted as being likely binaries vs. simple source confusion.

Here, we highlight some of the scallop shell/flux dip stars that we identified in UCL/LCC. (Panels are: light curve, power spectrum, phased light curve.) These stars, whose brethren we first identified in Pleiades and USco, have sharp, angular structures in their phased light curves that are too narrow for spots and too broad for planets; we believe they are likely caused by matter entrained in coronal loops rotating with the star. There are more of these stars at younger ages.

For more detail, see Stauffer et al. (2017, 2018, 2021); also see Guenther et al. (2020) and Zhan et al. (2019).





↑ **Space-based stellar rotation rates as a function of color** (proxy for mass). Shown is a sequence of clusters of increasing age from left to right and top to bottom. Each cluster has another, older cluster plotted underneath in grey to guide the eye in comparisons across clusters. An additional red circle indicates IR excess, e.g., a circumstellar disk. (IR excesses in Pleiades are all debris disks.) Points are smaller in UCL/LCC to be more easily distinguished (~4000 stars in UCL/LCC, vs. ~1000 in USco and ~800 in Praesepe).

- For youngest stars, disk locking matters. When the disk is gone, the stars spin up from contraction onto the MS, then they spin down due to wind braking.
- The basic form of the relationship is in place by ~8 Myr (USco); there is a slowly rising slow sequence for M>0.5 Msun, and a steep drop to shorter periods for M<0.5 Msun.
- 'Slow sequence' at higher mass end becomes well-defined and narrow by 125 Myr (Pleiades). Preliminary results suggest it is more clearly defined in UCL/LCC than USco, but still far more diffuse than Pleiades.
- The 'slow sequence' extends to lower masses at later ages.
- Among USco-UCL/LCC-Pleiades, the M star slope is roughly the same across all three clusters, but is shifted to reflect that older stars are physically smaller, and thus have spun up over time.
- The M star relation steepens with age – Praesepe and Hyades M star relationship is much steeper than Pleiades. The lowest masses have the longest spindown timescales.
- The "pileup" of disked stars at ~2d is obvious here in M stars in USco and UCL/LCC, but it is also present in Taurus. This is a signature of disk locking in these young clusters.

References for data: Rho Oph: Rebull et al. (2018); Lagoon: Rebull et al. (in prep); Taurus: Rebull et al. (2020); USco: Rebull et al. (2018); UCL/LCC: Rebull et al. (in prep); Taurus Foreground: Rebull et al. (2020); Pleiades: Rebull et al. (2016ab); Hyades: Rebull et al. (in prep); Praesepe: Rebull et al. (2017).