STELLAR ROTATION WITHIN THE BETA PICTORIS MOVING GROUP USING TESS LIGHTCURVES

C. Edwards[1], L.M. Rebull[2], J. Benter[3], S. Jones[4], E. Pfahler[5]
E. Hurliman[3], H. Shine[3], L. Wilkinson[3], J. Meliani[4], E. Otis[4], C. Lund[5], S. Tennent[5], R. Werthmann[5], S. Seymour[5], K. Benter[6]
[1]Chicago Public Schools, [2]Caltech, [3]Tri-Valley High School, [4]FCS Innovation Academy, [5]Falmouth High school, [6]Le Roy High School

Abstract

The Beta Pictoris Moving Group (BPMG) is a nearby (~50 pc) association of young (~20 Myr) stars at a critical stage of stellar evolution, when circumstellar disks are dissipating and, as a result, the distribution of angular momentum in the system is actively changing. This project aimed to investigate the relationship between infrared excess, stellar rotation, and other youth indicators in BPMG members to better understand disk dispersal timescales and angular momentum evolution in young stars.
By comparing period (P) and V-K (as a proxy for mass) for BPMG with other clusters such as the Pleiades, we can explore how the rotation rate evolves as a function of mass and age.

Background

Generally, conservation of angular momentum during star formation means that young stars often rotate quickly, with some (large?) fraction subject to disk-driven regulation; older low-mass stars are subject to wind braking and rotate more slowly. However, the details of how rotation rates change as a function of both mass and age remain uncertain, with open questions driven by gaps and other texture in the distributions. Advances in space-based photometric monitoring (e.g., K2, TESS) have enabled a surge in time-series data, allowing for increasingly precise measurements of rotation periods in young clusters (e.g., Rebull et al. 2016, 2017, 2018, 2020, 2022, 2026 and references therein), which have revealed intriguing structure based on unprecedented numbers of stars with which we can study the intertwined relationships among mass, age, rotation rate, and disks/accretion. In the BPMG, circumstellar disks are dispersing and stars are unlocking/just unlocked from their disks, particularly in the K and M regime. This makes the BPMG a particularly interesting laboratory in which to study stellar rotation rates to attempt to bridge gaps in our understanding.

Limitations

The BPMG is close, so its members are generally bright enough for TESS, which is a small telescope (10.5 cm). But TESS's pixels are 21", so spatial resolution is a limiting factor. Periods for BPMG members that are closer than ~21" to each other (or to contaminating sources) are difficult or impossible to untangle. We dealt with such source confusion on a case-by-case basis, and in some cases could assign periods with some confidence, but in other cases, it was impossible.

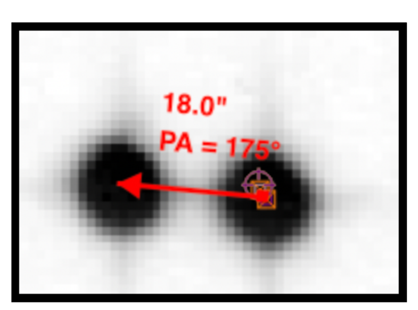

Figure 1. Example of source confusion between 2 comparably bright sources 18" apart; BPMG member on the right.

Sample SEDs and Phased Light Curves

HD 168210 | HD 39060 / β Pictoris | GJ 3261A and GJ 3261B

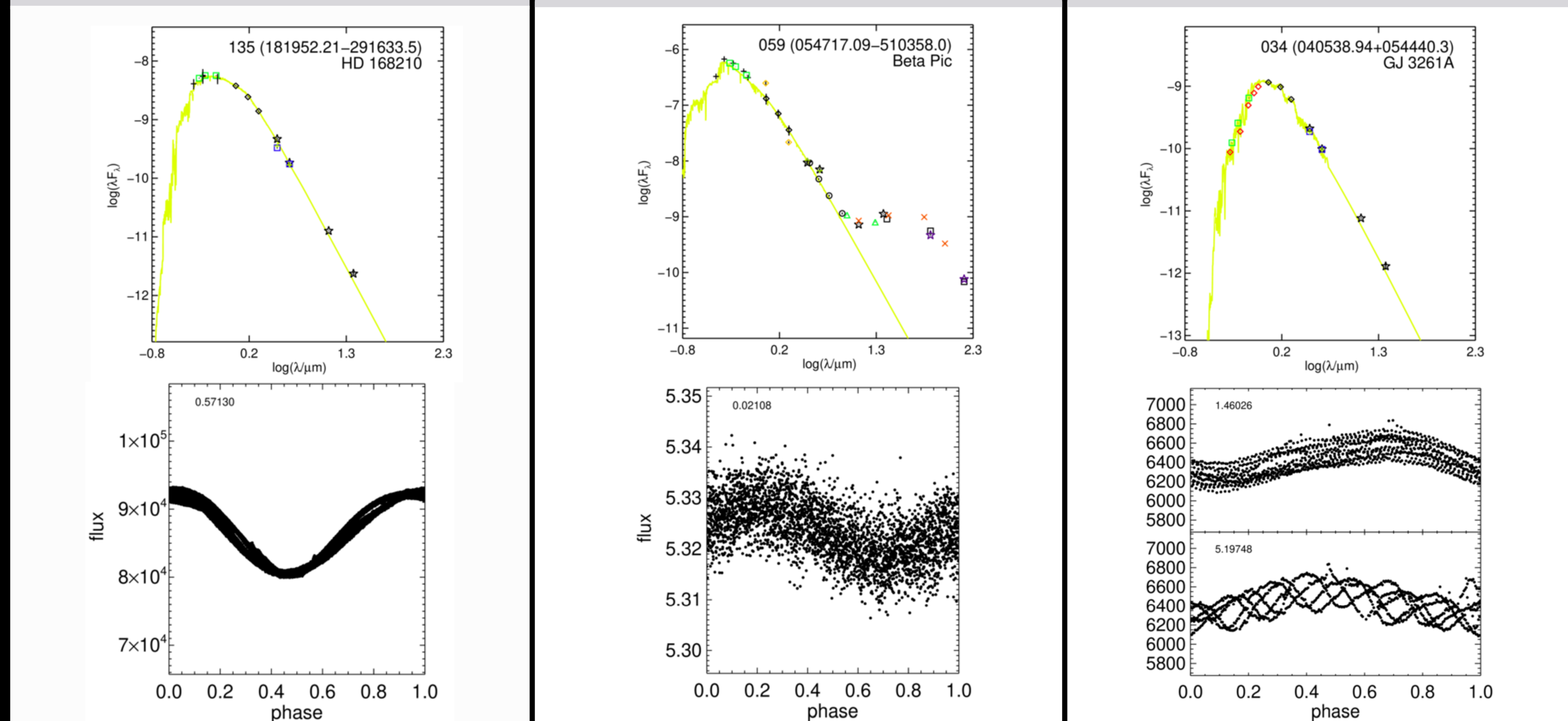

Figure 2. Spectral energy distributions (SEDs) and phased TESS light curves (LCs) for 3 different BPMG members. From left to right, star with no IR excess (no disk), Beta Pic itself (with a disk, and evidence of accretion activity in the LC), known binary (with more than one period apparent in the LC). (SED symbols indicate survey of origin; chartreuse line is a reddened stellar model fit to the optical/NIR.)

Period vs. V-K for Disk-Free M stars

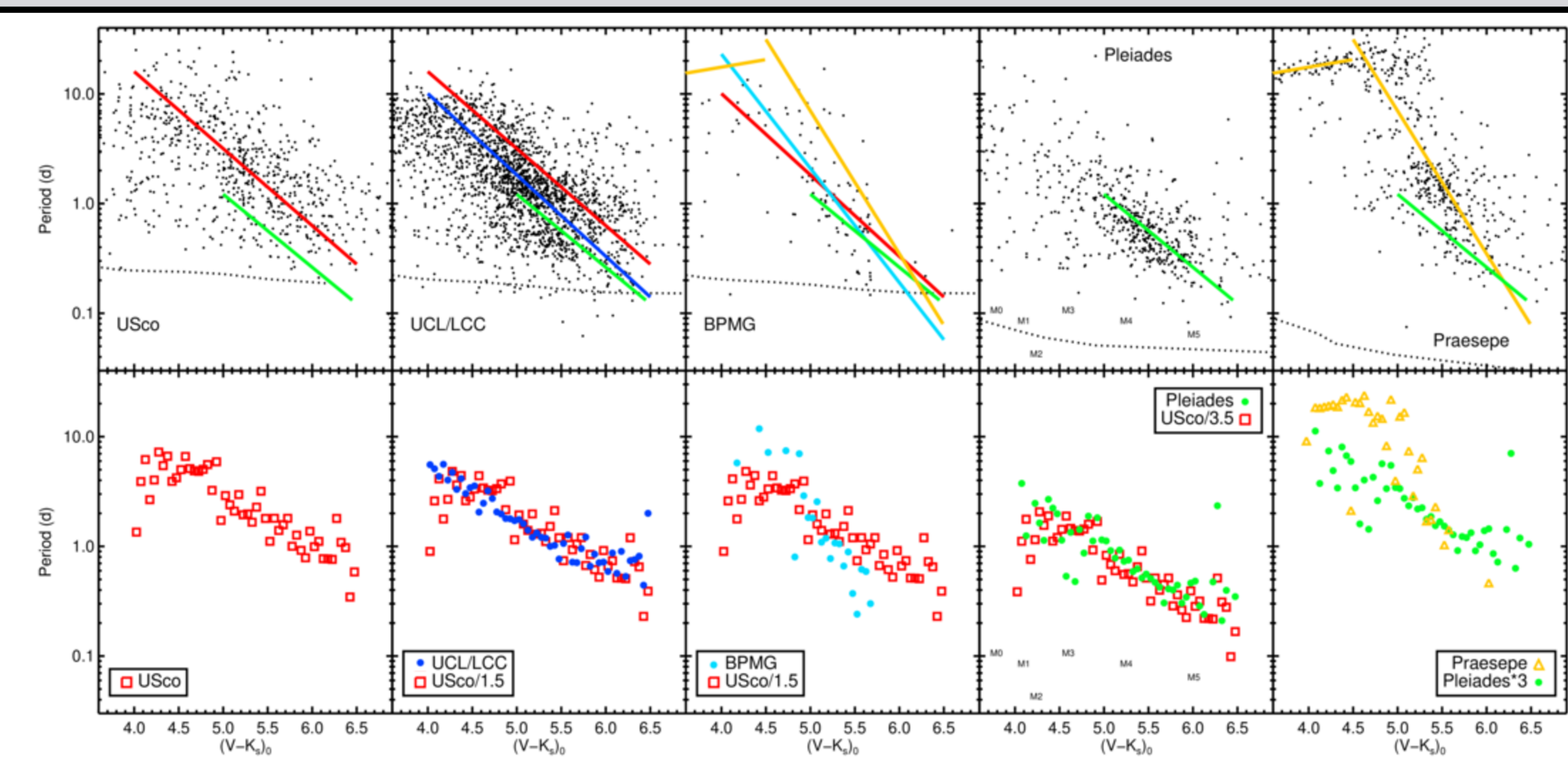

Figure 3. Rotation should be affected by disks; stars free of their disks should be free to spin up as they contract onto the main sequence (MS). As discussed in Rebull et al. (2022) and references therein, the disk-free M stars in USco, UCL/LCC, and Pleiades seem to maintain the same slope in the P vs. V-K plot on the way to the MS, whereas the Pleiades to Praesepe evolution is different. This figure shows how the BPMG stars fit into this sequence. Interestingly, the slope found for the BPMG M stars is not, at first glance, the same as that for USco, UCL/LCC, and Pleiades. However, there are some important caveats to consider. (1) There are far fewer stars available from BPMG defining this relationship (~100 BPMG vs ~600 USco, ~2000 UCL/LCC). (2) Confusion may still be a factor. Earlier versions of this plot showed a steeper (more like Praesepe), but removing clearly confused stars, the slope was more like UCL/LCC. It could very well be that we still have confusion issues with older background stars. Further work is needed. We had hoped that we could explore the ~2d pileup of rotation rates seen in UCL/LCC here in BPMG (where the stars have had more time to spin up after having "let go" of their disks), but there are just not enough stars to explore this.

BPMG in context

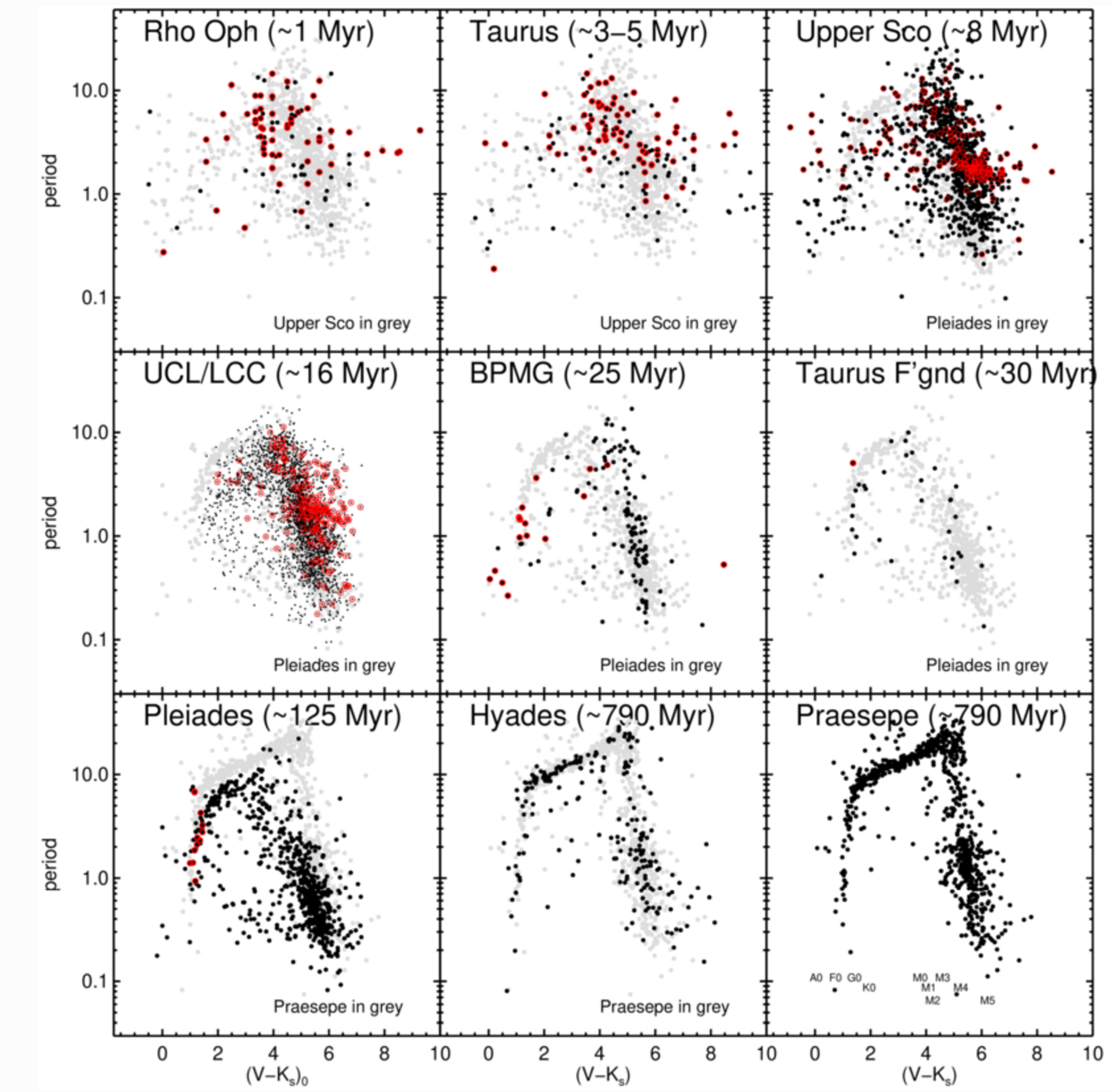

Figure 4 Period (days) vs. (V - Ks)o for BPMG in context with 8 other clusters (UCL/LCC and BPMG from TESS, the rest from K2). Stars with IR excesses (e.g., disks) are shown with a red circle. Each cluster has the next youngest most populous cluster underplotted in grey. The BPMG stars have been corrected for source confusion, though unresolved binaries remain. The basic overall structure seen in the Pleiades and UCL/LCC are evident. The limited number of stars hinders exploration of detailed substructure.

Conclusions

The distribution of BPMG rotation rates aligns well with expectations, closely resembling the overall pattern found in both UCL/LCC and Pleiades. However, the distribution specifically of M stars suggests that we may still be affected by confusion and we need to revisit these issues.

Data Information

We analyzed 193 BPMG members in Luhman (2024), identifying periods from 173 stars and unconfused periods for 141. We reported 91 entirely new periods (never before measured in the literature) for 91 stars; we confirmed or improved literature values for 97 additional stars (for example, sometimes the literature period is >100d, and we are reporting <30d period). There are 18 with IR excesses at any band. We assembled SEDs from 2MASS, WISE (AllWISE, CatWISE, unWISE), Gaia, DENIS, Akari, Spitzer (SEIP), Herschel, Pan-STARRS, SDSS, VVV, IRAS, and MSX. We obtained light curves from TESS, K2, NEOWISE, ZTF, and ASAS-SN; we used HLSPs from CDIPS, ELEANOR, QLP, SPOC, T16, TASOC, TGLC, EVEREST, K2SC, K2SFF, & K2VARCAT. We used the IRSA Time Series Tool to do Lomb-Scargle analysis on all of the light curves. This work used the archives at IRSA, MAST, and ADS. This work was conducted as part of the NASA/IPAC Teacher Archive Research Program (NITARP), which receives funding from the NASA ADP program.