Hα Variability in Low-Mass Stars and Brown Dwarfs

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Motivation

- Low mass stars are some of the most abundant objects in the universe
- Angular momentum problem for these objects:
  - Low-mass objects do not slow as efficiently as higher mass objects: braking mechanism?
  - Result: several mechanisms during early life of a star(Herbst et al. 2007)
- Understand initial conditions of objects' evolution
- **In the K-M (<0.82M☉) spectral type range we explore:**
  - **Variability**
  - **Age**
  - **Accretion disks**

Methods

Observations

- Data taken with the WIYN 0.9m at KPNO in Hα (6650Å) and continuum Hα "off" (6660Å) over 8 nights.
  - Hα is a tracer for stellar activity (accretion, flares, chromospheric activity) (Sicilia-Aguilar et al. 2004)
- Observing regions in Taurus and Praesepe 2-4 times per night, 180 seconds long exposures
- Additional data from 2019 with WIYN 0.9m.

Analysis

- Custom Reduction Pipeline
- Mass estimates for objects
- Multi-aperture differential photometry
- Lomb-Scargle(LS) periodogram analysis

Praesepe	Taurus
600-800Myr Activity dominated by stellar flares, star spots. 23 objects	1-3Myr Actively accreting. 12 objects, 10 likely accretion disks.

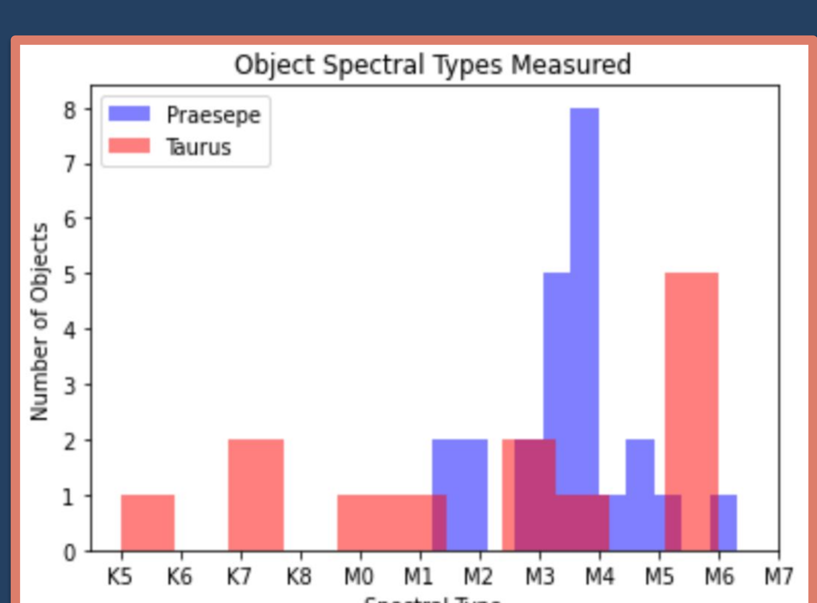

Figure 1: All objects observed in Taurus (red) and Praesepe (blue) sorted by spectral type. We use spectral type as an estimate for mass based primarily on temperature and region age for Taurus (Herczeg & Hillenbrand 2014, Baraffe et al. 2015) and Praesepe(Pecaut & Mamajek 2013).

Results

Periodicity for an M dwarf in Taurus

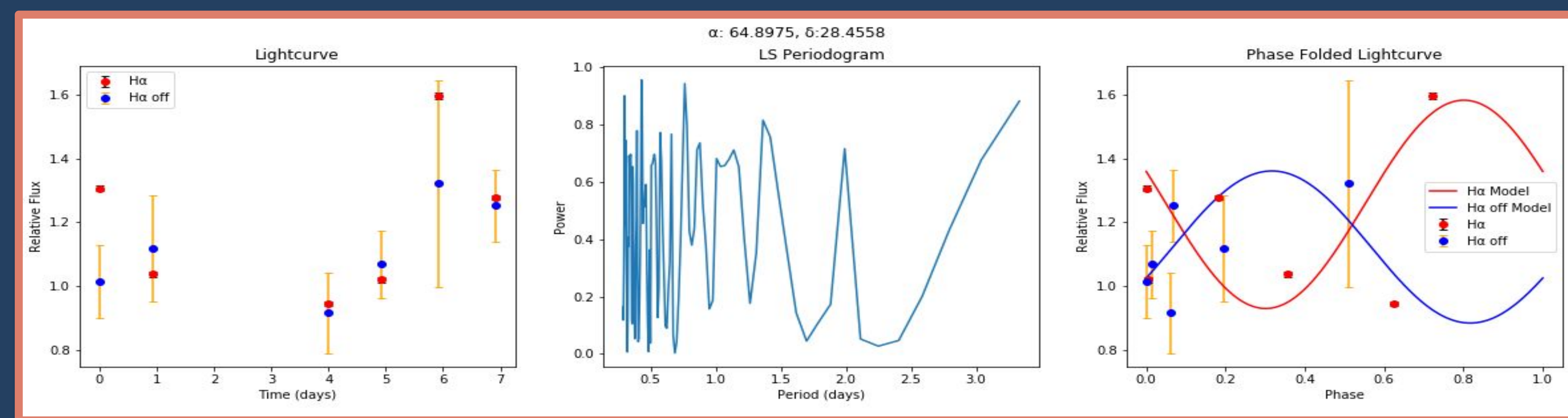

Figure 2: Above is just a sample of one target in Taurus with the lightcurve, LS periodogram, and phased lightcurve appearing in that order. Hα and continuum flux measurements are denoted by the red and blue circles respectively. Determining periodicity for lower mass M type objects have proven to be inconsistent.

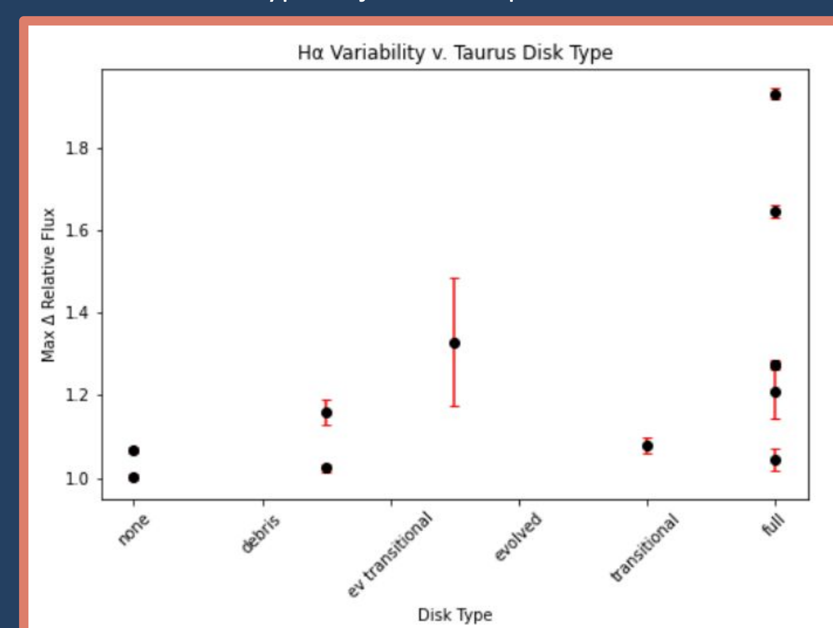

Figure 3: Maximum relative flux per Taurus object versus the accretion disk type; 10 objects in Taurus are known to host accretion disks (Esplin 2014), ranging from debris to full disk (1 to 5), where debris is defined as the remains of dust around the object and a full disk is optically thick in the infrared wavelengths.

Periodicity in Praesepe

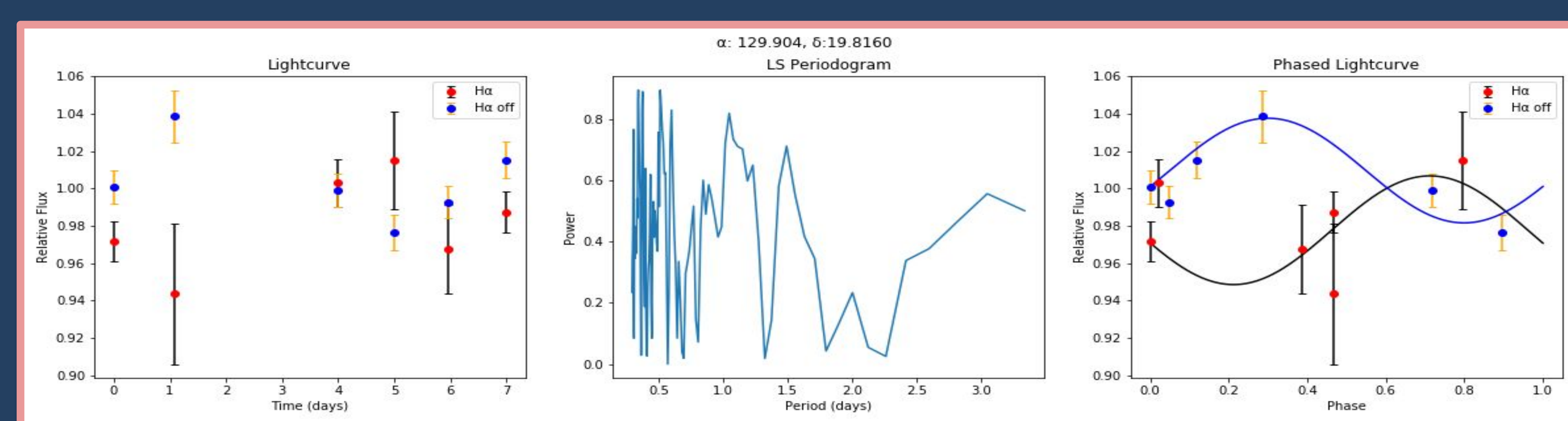

Figure 4: A figure similar to Figure 2 for an object in Praesepe, formatted identically. This figure shows the light curves of a K7.8 type star (M~0.65M☉) which follows the trend we have seen where periodicity is more difficult to determine for lower mass objects in both Taurus and Praesepe.

A Comparison

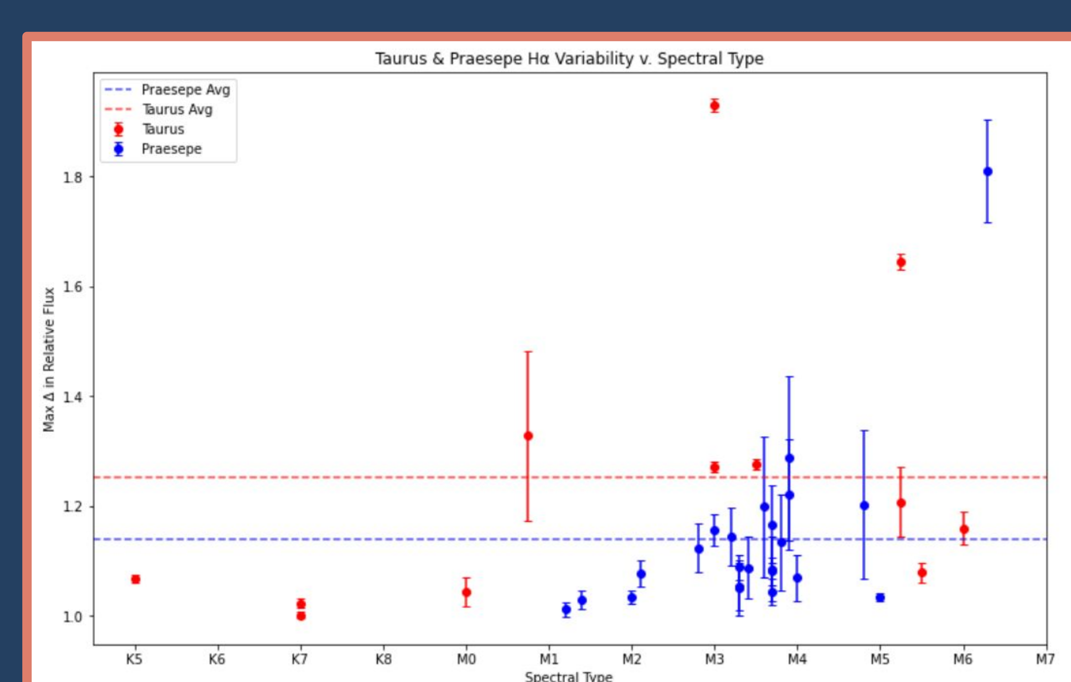

Figure 5: Maximum relative flux per object for all Taurus(red) and Praesepe(blue) objects versus spectral type (Esplin 2014 & Kraus 2007). The maximum flux is the maximum each object reached over the 8 nights, and error on these measurements is the error calculated via differential photometry methods. The dashed lines indicate the average maximum flux for objects in the corresponding region. While we are limited by the small sample size of Taurus objects in particular, there is an upwards trend in flux as mass decreases.

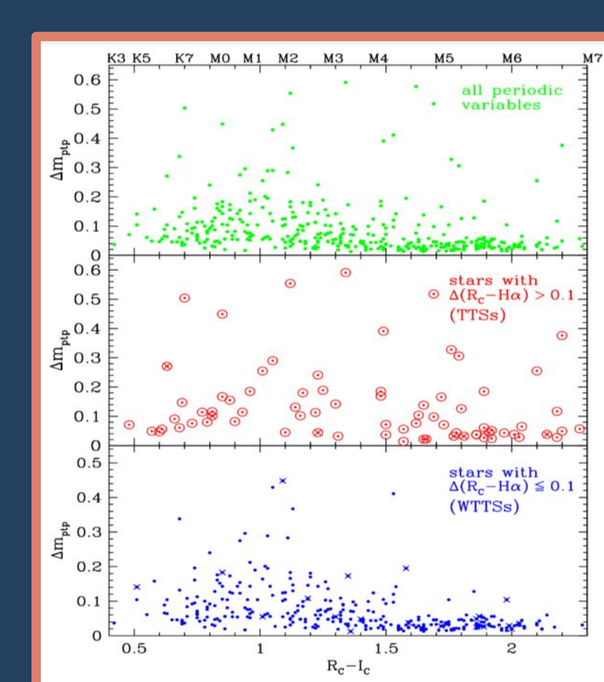

Figure 6: Peak to peak change in flux versus spectral type for periodic variable objects from Lamm et al. 2004 (Herbst et al. 2007). Objects in red are those with higher Hα emissions, and blue are those with lower Hα emissions. This plot demonstrates a larger spread of fluxes for objects with greater Hα emissions, in addition to larger spread in lower masses. This provides loose comparison to trends in our data;

Discussion

- Unable to confirm periodicity for many objects because our observational time baseline is shorter than the duration of any periodic signals
- Some weather effect consistently biased Hα off flux measurements on the second night for both fields
- Preliminary periodograms: although we have been able to generate some models, we believe that to less uncertainty more data gathering is required

Praesepe

- Average maximum flux 0.14
- 86% objects have flux change less than 0.2

Taurus

- Average maximum flux 0.25
- 50% objects have flux change less than 0.2
- Objects with full accretion disks display wider spread in maximum flux

Conclusions

For objects in Taurus and Praesepe, where the sample is limited to a spectral type range of K5 - M6 and M0 - M6 respectively, we determine there is a possible minor correlation between age and variability, given the trend towards higher flux for objects in the younger Taurus region., There is a **trend toward higher flux in lower mass objects in both Praesepe and Taurus**. We also see that **objects with younger, fuller disks tend to have a wider spread in maximum Hα variability** than those whose disks have begun to dissipate.

For the future we would like to explore the relationship between period and mass, compile photometric data analysis from other groups, create deep stacks in each filter, and look at relationships with different colors. Beyond that we would use K2 data to support our conclusions.

Acknowledgements & References

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References

1. Herbst et al. (2007)
2. Sicilia-Aguilar et al. (2004)
3. Herczeg & Hillenbrand (2014)
4. Baraffe et al.(2015)
5. Pecaut & Mamajek (2013)
6. Esplin (2014)
7. Kraus (2007)