Unresolved Binary Stars Cause an Observed Mass Dependent Age Gradient in Upper Scorpius

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On arXiv soon!

Introduction

The Upper Scorpius (Upper Sco) subregion of the Sco-Cen OB association is an important site for the study of star formation, but the age of the region must be accurately measured to fully leverage the power of the large (> 10^4 stars), coeval population. Older work (e.g., Preibisch et al. 2002, Slesnick et al. 2008) has found an age of 5 Myr for Upper Sco using K and M stars, while more recent work (Pecaut et al. 2012, Pecaut + Mamajek 2016) has found an age of 10 Myr using A and F stars. Other studies of Upper Sco have also observed mass-dependent age gradients (e.g., Rizzuto et al. 2015). Multiplicity may provide an explanation for the age gradient and thus the discrepant ages of Upper Sco, because binaries appear cooler and more luminous, and thus younger than their single-star counterparts, and binary population statistics are mass-dependent.

Methods

We performed a low-resolution (R ~ 2800) red-optical ($5600\text{Å} < \lambda < 6900\text{Å}$) spectroscopic synthetic survey of a simulated large (20,000 systems) stellar population with an age of 10 ($\pm$2) Myr, mimicking a blind spectroscopic survey that contains some undetected binaries. We incorporated the mass-dependence of various binary properties, including the multiplicity fraction and the mass-ratio and separation distributions. We retained any simulated binaries with separation $< 1.5''$, simulating a seeing-limited survey. We created synthetic unresolved spectra (Figure 1) and fitted them with other synthetic spectra using a modified Gibbs sampler, then inferred an age using MIST models (Dotter 2016), the measured T_{eff}, and a measured composite system luminosity.

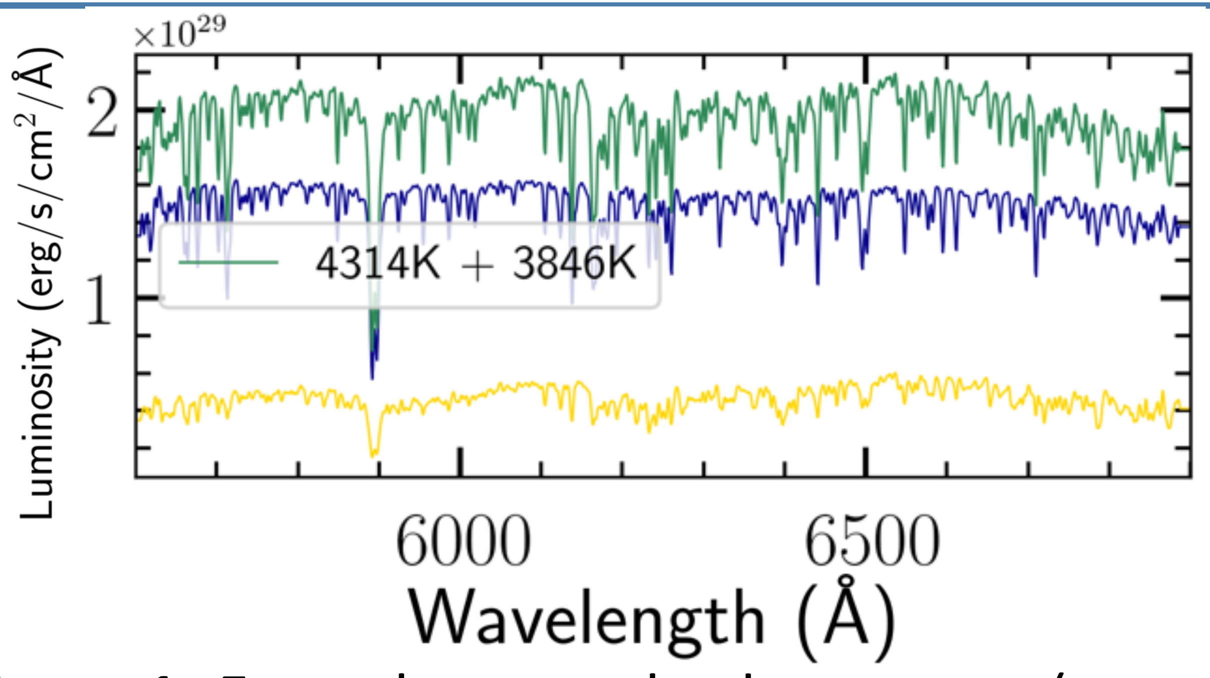

Figure 1: Example unresolved spectrum (green) and components for an K4 primary (blue) with a mass ratio of 0.7. The secondary features (yellow) contaminate the composite spectrum.

Results

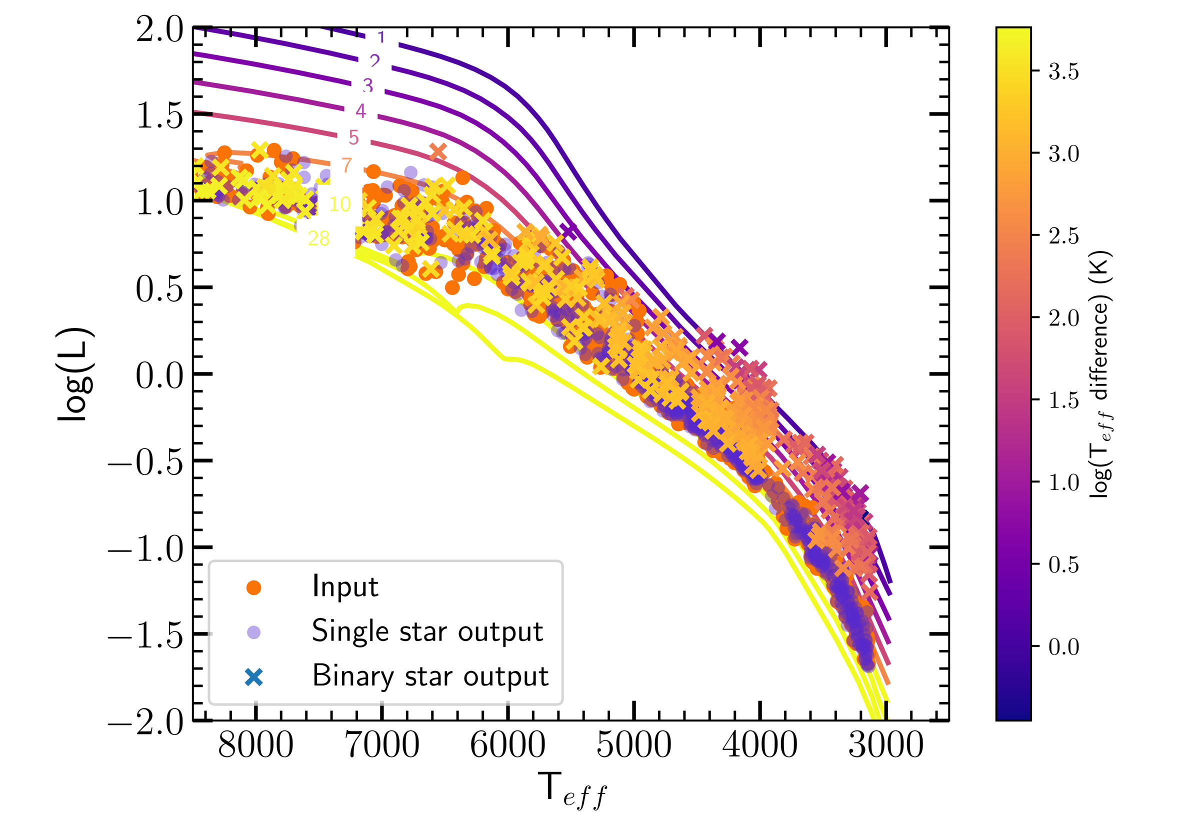

Figure 2: HR diagram of single (dots) and unresolved binary (crosses) stars. The low-temperature binaries appear younger than the high-temperature binaries, causing an apparent age gradient

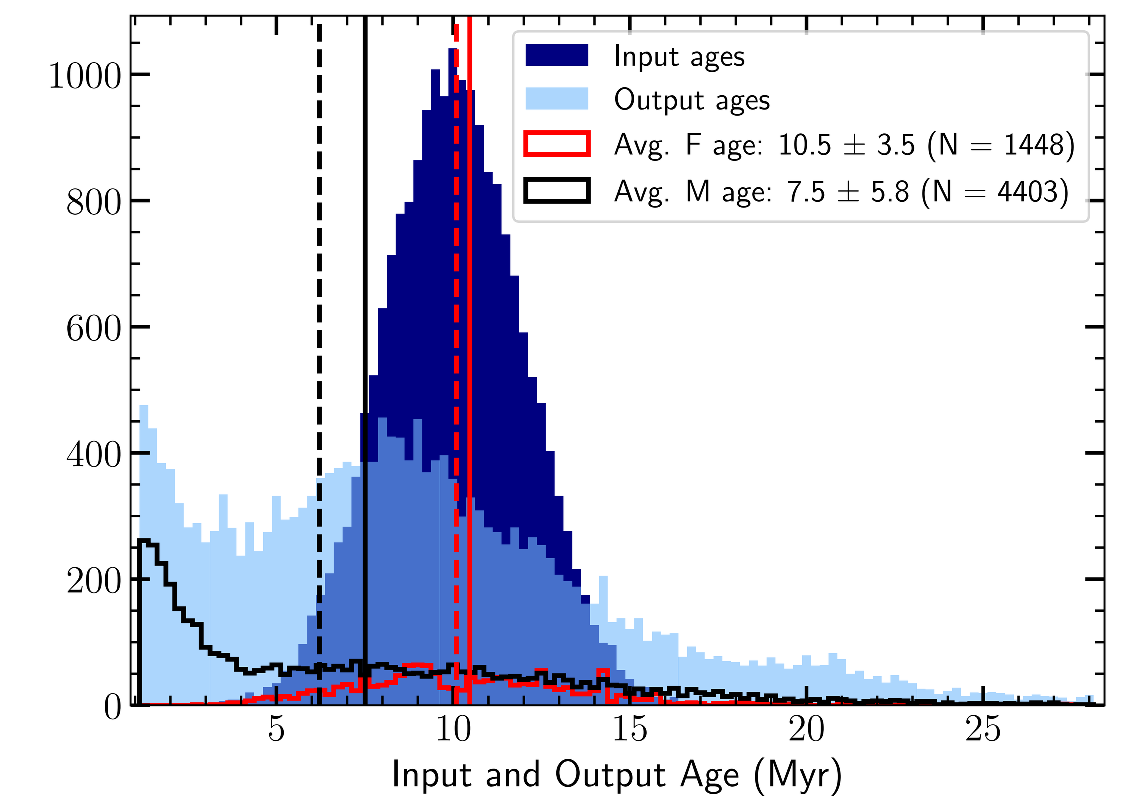

Figure 3: Input (dark blue) and output (light blue) age histogram with output M (black) and F (red) stars highlighted. The M stars appear 3 Myr younger than the F stars.

- Analyzed simulation using both an exact distance and introducing a ± 20 pc distance error, to mimic the distance errors endemic to population studies pre-*Gaia*.
- Undetected binaries preferentially bias low-mass stars to appear younger (Figure 2)
- Average recovered F star age is 10.5 (RMS = 3.5) Myr, while average recovered M star age is 7.5 (RMS = 5.8) Myr (Figure 3)
- Bias is caused by changes in the mass-luminosity relation and mass-dependent mass ratio and separation distributions.

Conclusions

The presence of unresolved binaries causes an observed mass dependent age gradient because of a combination of the shape of the mass-luminosity relation, and mass-dependent mass ratio and separation distributions. This effect combines with other phenomena, like star spots, to influence age measurements of Upper Sco and other young star-forming regions. Our results support a 10 Myr age for Upper Sco, and demonstrate the need to carefully correct for multiplicity when interpreting HR diagrams.

References

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