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SETTING STELLAR CHRONOMETERS: THE PTF(+) OPEN CLUSTER SURVEY

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While we have known for 45 years that a solar-type star's rotation rate and magnetic activity depend on its age (Skumanich 1972), many details still elude us. We cannot yet fully describe the evolution of rotation or activity for stars of a given mass, nor can we use rotation or activity measurements to estimate accurately the ages of isolated field stars. Fortunately, recent technological advances have transformed our ability to observe open clusters, the best laboratories for testing age-dependent stellar properties. We are currently surveying low-mass stars in six open clusters ranging in age from 35 Myr to 3.5 Gyr; here, I focus on our results for the Hyades and Praesepe. These data will allow us to improve our understanding of the age-rotation-activity relation for $\lesssim$1 $M_\odot$ stars.

Our survey targets are members of Alpha Persei, the Pleiades, M37, Praesepe, the Hyades, NGC 752, and Ruprecht 147. For our rotation period (P_{rot}) measurements, we relied initially on data from the Palomar Transient Factory (PTF), a time-domain experiment using the robotic 48-inch telescope at Palomar Observatory, CA, real-time data-reduction and transient-detection pipelines, and a dedicated follow-up telescope. (For examples of our complementary work on magnetic activity in these clusters, see Núñez & Agüeros (2016), Núñez et al. (2017), and A. Núñez's contribution to these proceedings.)

The Hyades and Praesepe, both $\approx$650-Myr-old, are a crucial bridge between young open clusters (e.g., the Pleiades, at $\approx$125 Myr) and older ($\geq$2 Gyr) field dwarfs. Our work on these linchpin clusters began with Agüeros et al. (2011), where we presented new P_{rot} for 40 late-K to mid-M Praesepe members measured with PTF. In Douglas et al. (2014), we extended our analysis to the Hyades, combining new P_{rot} with those in the literature to determine that Praesepe and the Hyades follow identical rotation-activity relations, and that the mass-period relation for the combined clusters transitions from a single-valued sequence to a wide spread in P_{rot} at $\approx$0.6 $M_\odot$.

In Douglas et al. (2016), however, after adding new P_{rot} from our *K2* observations and removing all confirmed and candidate binaries from the Hyades mass-period plane, we found that nearly all $\gtrsim$0.3 $M_\odot$ stars are slowly rotating. We also found that models of rotational evolution predict faster rotation than is observed at 650 Myr for stars $\lesssim$0.9 $M_\odot$. The dearth of $\gtrsim$0.3 $M_\odot$ single rapid rotators indicates that magnetic braking is more efficient than was thought, and that age-rotation studies must account for binarity.

In Douglas et al. (in prep), we analyze new *K2* light curves for Praesepe, and measure $\approx$700 P_{rot}. We find that >50% of the rapidly rotating stars with $\gtrsim$0.3 $M_\odot$ are possible binaries. The remaining $\gtrsim$0.3 $M_\odot$ rapid rotators are not confirmed single stars, as they have not been searched for companions. We therefore require deeper binary searches to confirm whether binaries in the Hyades and Praesepe have different P_{rot} distributions.

We have also published P_{rot} for the Pleiades (Covey et al. 2016) and are working on PTF and/or recent *K2* data for our other survey targets. These data will constrain angular-momentum evolution in low-mass stars and, together with our work on magnetic activity in these clusters, help us develop a robust age-rotation-activity relation.

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